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Water Quality Assessment of River Osun, Osogbo, Nigeria Using HEC-RAS Model

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ABSTRACT

Water is life and every human activity revolves round its availability. Inadequate hydrological data on River Osun has discouraged researchers from modelling water quality across the river. This study modelled water quality across the river using Hydrologic Engineering Centre River Analysis System (HEC-RAS) software. Forty (40) water samples were collected from upstream (7^0 45' 26", 4^0 37' 22") (Kajola, Owode), midstream (7^0 44' 17", 4^0 33' 20") (Oke-Jetu, Isale-Osun), and downstream (7^0 45' 06", 4^0 32' 41") (Gbodofon, Ebunoluwa) sampling stations on River Osun from May 2015 to January 2016. Physical [Temperature and Total Dissolve Solid (TDS)], Chemical [Carbonaceous Oxygen Demand, Dissolved Oxygen, Nitrate-Nitrogen, Nitrite-Nitrogen, and Orthophosphate] and Biological (BOD) tests were carried out on the water samples using standard procedure (APHA, 2005). These parameters were input into HEC-RAS software to simulate water quality on River Osun. Three hundred (300) developed questionnaires on the prevalence of water borne diseases in Osogbo were distributed to households and health workers. Pearson correlation Coefficients (PCC) was used to analyse the data at 5% significance level. Temperature and TDS for rainy and dry season varied from (24.9 - 28.9)^{0}C and (29.0 -339)^{0}C; (90 -110) mg/l; (41.9 - 64.3) mg/l, respectively. The temporal variation of DO, NO_3-N, NO_2-N and PO_4^{3-} for rainy and dry seasons parameters varied from (5.2 - 7.6) mg/l and (3.21 - 6.10) mg/l; (0.00 -7.41) mg/l and (9.0 - 19.3); (0.207 - 0.622) and (0.715 - 1.145) mg/l; (3.64 - 5.91) mg/l and (4.04 - 6.21) mg/l, respectively. The BOD values ranged from (0.4 -2 .0) mg/l and (1.93 - 2.96) mg/l, respectively for the rainy and dry seasons. Significance correlation ($p< 0.05$, 16 df) does occur between the pair of resident with water borne diseases and stations at upstream and midstream of the river in water samples with high pollution sources, there is low correlation ($p<0.05$ 16 and 14 df) between the pair of other stations across the river and residents with water borne diseases. The DO, CBOD, NO_3-N, NO_2-N, and PO_4^{3-} output from HEC-RAS for rainy and dry seasons varied from (5.6 -7.4) mg/l and (3.391-5.828) mg/l; (14.81 -15.69) mg/l and (15.87-15.93) mg/l; (0.235 - 5.43827) mg/l and (13.24 -19.1) mg/l; (0.806484 - 1.22) and (0.2085 - 0.4041) mg/l; (3.76-5.16) mg/l and (4.12 - 4.88) mg/l , respectively across the river. The result can be useful to trace the pollution sources and develop water resources management towards achieving Vision 20:2020.

1. Introduction

Water is of fundamental importance to life, that is plant and animal particularly man. It is very vital in maintaining life process and growth. Water pollution by effluent has become a question of considerable public and scientific concern in light of evidence of their extreme toxicity to human health and to biological ecosystems (Olaniyan, 2014). Worldwide water bodies are primary means for disposal of wastes, especially the effluent from industrial, municipal sewages and agricultural practice that are near them. This water can alter the physical, chemical and biological nature of receiving water body (Olaniyan, 2012). Coliform bacterial and commonly used as bacteria indicator of water pollution Sometime notable pathogen found in surface water which has caused human health problems include;

Salmonella, Parasitic warms (helminthes) and Novo virus.

Bacteria and fungi are very critical to the breakdown of the toxic component of the effluent. It has been observed that dissolved oxygen in water is required during the decaying of the organic matter, which may lead to depletion of oxygen in the water body and cause harmful substance to accumulate (Olaniyan *et al*., 2015).

Organic pollutant includes; Detergent, Disinfection by products found in chemically disinfected drinking water such as chloroform, food processing wastes, which can include oxygen demanding substance, fat and grease, insecticides and herbicides a large range of organo-halides. Other chemical compounds includes: petroleum hydrocarbons including fuel and lubricants (motor oil), volatile organic compounds such as industrial solvent from improper storage, tree and bush debris from logging operation, chlorinated solvent, Poly

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Chlorinated Biphenyl (PCB), various chemical compounds found in personal hygiene and domestic products.

Inorganic matter in effluent are formulated using various chemical containing nitrogen, phosphorus and potassium. These element especially phosphorus stimulates the growth of microscopic plant while nitrogen promotes over growth of aquatic vegetation which degrades water quality. Potassium promotes productivity of aquatic animals such as fish (Kolawole, Ajibola and Osuolale, 2008). Inorganic pollutant includes;

i. Acidity caused industrial discharged {e.g. supplied from power plants. Chemical wastes as industrial by-productions)
ii. Fertilizers containing migrants i.e. nitrate and phosphate which are found in storm water run-off from agriculture, commercial and residual use.
iii. Heavy metal from motor vehicles (via urban storm water run-off and the acidic mine drainage).

River Osun is one of the major rivers in Nigeria well known for economic activities such as irrigation, fishing, and mining of sand and gravel from the bed. It is one of the tourist centre approved by UNESCO where people come to for annual festival and drop money, animals and other wastes. In addition, there are quite number of industries located in Osogbo the State capital of Osun, Nigeria. Rapid developments in the study area had caused dramatic increase in the rate of waste generation and effluent from residential houses and hotels around the river. However, the water quality is deteriorating day by day due to anthropogenic input of dissolved nutrient, organic matter and industrial effluent, which is built up on its bank. Therefore, it is of vital importance to monitor and simulate the water quality parameters to ascertain whether the water still suitable for various use

3.0 Material and Methods

3.1 Brief Description of the Study Areas

River Osun bears it origin from Igede Ekiti, through Ilesha forest and enters Osogbo at west. It has a number of tributaries that join it in Osogbo which include; River Ajibu, Okoko, Ogbagba, Asaba and Elekunkun. The geology of river Osun catchments area comprises predominantly pre-Cambrian rocks; the so called basement complex from the fairly clayed loam of the surrounding district is derived. The River is 19.562 Km long on latitude 7^0 45"0°N and longitude 4°37"30°E as shown in Figure 1.

Land sat images of 2010 were acquired from Africa Regional Centre for Space Science and Technology (ARCSSTE), Obafemi Awolowo University Ile Ife, Osun State, Nigeria to produce land use map. The existing map of Osun was geo-referenced and then digitalized. The satellite image classified and referenced data (existing classification data on the area) was used for land cover classification.

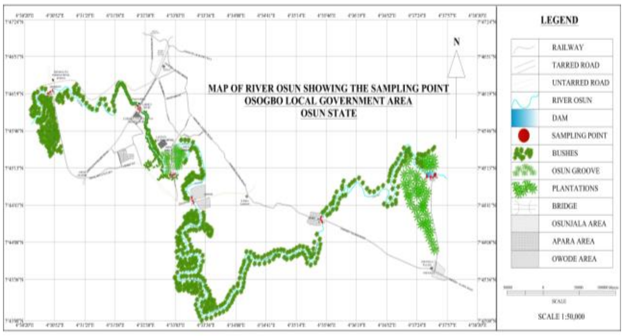


Figure 1. Map of River Osun and the Sampling Point from the Study Are.

3.2 Method of Analyses

Forty (40) water samples were collected from upstream (7^0 45' 26", 4^0 37' 22") (Kajola,Owode), midstream (7^0 44' 17", 4^0 33' 20") (Oke-Jetu, Isale-Osun), and downstream (7^0 45' 06", 4^0 32' 41") (Gbodofon, Ebunoluwa) sampling points on River Osun from May 2015 to January 2016. The Temperature of the samples was taken by using mercury thermometer. King County Dirty water regression method equation was used to determine CBOD value. Dissolved Oxygen (DO) was measured in-situ electrometrically using HANA H19147 Dissolved Oxygen meter. Spectroscopic determination of Nitrite-Nitrogen was carried out by treating a liquor of the sample with 1M NOH and 0.2M EDTA,

NO_3-N was determined by HI93728 Nitrate meter using the Cadim reduction method. The model 9300 was used in

Table 1. Result of Water Sample Analysis for Rainy Season.

S/N	Samples Label	Parameters										
		TDS (mgL^{-1})	TSS (mgL^{-1})	TS (mgL^{-1})	DO (mgL^{-1})	BOD_5 (mgL^{-1})	NO_3^- (mgL^{-1})	COD (mgL^{-1})	cBOD (mgL^{-1})	NO_2 (mgL^{-1})	PO_4^{3-} (mgL^{-1})	TEMP (^OC)
1	Apara/Kajola Dam P20	90	70	160	6.8	1.2	4.85	1.42	15.25	0.838	4.36	26.0
2	Apara/Kajola Dam P19	90	90	180	7.2	0.8	3.94	1.42	14.96	0.976	4.07	26.0
3	Kajola/Apara P18	90	210	300	6.8	1.2	0.47	7.79	15.25	1.145	4.20	25.0
4	Kajola/Apara P17	90	50	140	7.6	1.4	3.25	1.42	15.40	1.099	3.68	25.0
5	Owode P16	90	40	130	6.8	0.8	7.41	1.42	14.96	0.715	4.50	25.0
6	Owode P15	90	260	350	6.8	0.8	1.17	5.66	14.96	1.038	4.52	25.0
7	Owode P14	90	100	190	6.0	0.4	0.47	6.37	14.66	0.844	3.67	24.9
8	Owode P13	90	140	230	7.6	2.0	4.85	2.12	15.84	0.853	3.64	24.9
9	Okejetu P12	100	150	250	6.4	1.2	0.47	7.08	15.25	0.807	4.00	26.2
10	Okejute P11	100	80	180	6.4	0.8	3.25	4.96	14.96	0.853	3.81	26.4
11	Okejetu P10	100	90	190	7.2	0.8	0.0	4.96	14.96	0.730	3.88	26.3
12	Isale Osun P9	110	90	200	5.6	1.2	1.17	1.42	15.25	0.792	4.13	25.0
13	Isale Osun P8	110	70	180	6.8	2.4	4.85	7.79	16.14	0.792	5.88	25.0
14	Isale Osun P7	110	240	350	6.0	0.8	0.47	2.83	14.96	0.976	5.91	25.0
15	Gbodofon P6	110	20	130	7.6	1.6	3.94	2.12	15.55	0.945	3.78	28.0
16	Gbodofon P5	110	120	230	6.8	0.4	0.0	3.54	14.66	1.037	4.36	28.0
17	Gbodofon P4	110	310	420	6.8	1.2	0.47	5.66	15.25	0.761	4.10	27.3
18	Ebunoluwa P3	110	110	220	6.4	1.2	4.85	4.25	15.25	0.838	4.55	28.9
19	Ebunoluwa P2	110	240	350	6.0	0.4	6.02	5.66	14.66	0.976	4.94	28.9
20	Ebunolowa P1	110	50	160	5.2	0.8	3.25	8.50	14.96	1.130	4.00	28.9

Table 2. Result of Water Sample Analysis for Dry Season.

S/N	Samples Label	Parameters							
		DO (mgL^{-1})	BOD_5 (mgL^{-1})	NO_3^- (mgL^{-1})	BOD (mgL^{-1})	NO_2 (mgL^{-1})	PO_4^{3-} (mgL^{-1})	TEMP (^{O}C)	TDS (mgL^{-1})
1	Apara/Kajola Dam P20	5.4	2.68	17.0	16.34	0.238	4.67	30.4	41.9
2	Apara/Kajola Dam P19	5.9	2.33	15.6	16.08	0.376	4.38	31.1	42.1
3	Kajola/Apara P18	5.7	1.93	13.9	15.79	0.545	4.51	30.4	42.6
4	Kajola/Apara P17	6.1	2.84	15.0	16.46	0.499	3.99	29.3	42.0
5	Owode P16	5.6	2.01	19.3	15.85	0.265	4.90	29.3	43.2
6	Owode P15	5.5	2.66	14.0	16.33	0.588	4.92	29.5	43.6
7	Owode P14	5.3	2.57	12.9	16.26	0.394	4.07	29.1	43.2
8	Owode P13	6.0	2.81	17.2	16.44	0.357	4.04	32.8	43.1
9	Okejetu P12	4.2	2.7	13.8	16.36	0.207	4.39	33.1	55.0
10	Okejute P11	4.5	2.48	14.9	16.19	0.253	4.20	32.5	55.3
11	Okejetu P10	5.6	2.49	9.01	16.20	0.130	4.27	29.4	55.1
12	Isale Osun P9	3.33	2.96	13.2	16.55	0.392	4.43	29.5	62.1
13	Isale Osun P8	4.56	2.89	17.4	16.49	0.392	6.18	30.1	63.0
14	Isale Osun P7	4.2	2.81	13.0	16.44	0.576	6.21	36.7	62.0
15	Gbodofon P6	6.10	2.84	15.6	16.46	0.405	4.12	36.5	64.0
16	Gbodofon P5	5.8	2.58	10.1	16.27	0.497	4.27	37.0	64.3
17	Gbodofon P4	5.3	2.53	13.4	16.23	0.221	4.34	38.9	63.9
18	Ebunoluwa P3	4.1	2.77	17.0	15.87	0.248	4.85	39.0	60.9
19	Ebunoluwa P2	3.8	2.35	18.2	16.10	0.386	5.24	38.7	61.0
20	Ebunolowa P1	3.21	2.87	15.0	16.48	0.622	4.30	28.9	60.7

conjunction with the BOD kit to analysed Biochemical Oxygen Demand (BOD) for all the water samples. The parameters were input into HEC-RAS software to simulate water quality on the river. Three hundred (300) developed questionnaires on the prevalence of water borne diseases in Osogbo were distributed to households and health workers. Pearson Correlation Coefficients (PCC) was used to analyse the data at 5% significance level.

4.0 Results and Discussion

4.1 Field Measurements Result

The Physical, Chemical and Biological Water Quality Parameters measured across River Osun for rainy and dry seasons are presented in Table 1 and 2

Table 3. Recommended Water Quality Criteria.

Quality Factor	WHO Maximum Limit	NSDWA Limit	USEPA	U.S. Public Health Science
Temperature ^{o}C	Ambient	Anbient	-	_
TDS mg/l	500	_	-	_
NO_3-N	_	_	10	10
NO_2-N	>1	0.2	1.0	_
PO_4^{3-}	0.002	_	-	_
BOD	50	_	-	_
DO	6	_	-	_
COD	1000	_	-	_

Source: USEPA (2001), WHO (2005)

The concentration of Nitrate- Nitrogen in the river for rainy season ranged from 0.0 - 7.41mg/L while that dry season varied from 9.01-19.3 mg/L. There were significant differences in Nitrate concentration among locations and seasons. The high levels of nitrate obtained during dry season are in agreement with Adeyemo *et. al*. (2008), who reported that nitrate are usually built up during dry season and early rainy season. This is because the initial rains flushed out deposited nitrates from near surface soils into rivers but as the wet season a progress, the levels reduces drastically. The values of Nitrite varied from 0.715 -1.145 for rainy season while that of dry season ranged from 0.130 - 0.622 mg/L. Sampling points P1, P5, P15, P17 and P18 have higher values of Nitrite of 1.130, 1.037, 1.03,1.099 and 1.145mg/l, respectively. These values are higher than W.H.O and NSDWA standard value of 1.0mg/l and 0.2mg/l, respectively. Table 3 Shows the Pearson Correlation Coefficient which gives the relationship between residents affected with water borne diseases within the areas where samples were taken and the pollution source of River Osun. Significance correlation does occur between the pair of resident with water borne diseases and stations at upstream and midstream of the river. There is low correlation between the pair of other stations across the river and residents with water borne diseases. The interrelationship between variables by the correlations co-efficient table indicates a significant relationship between user of River Osun and water borne diseases patients registered and treated at the health centers. The correlation value was 0.8.

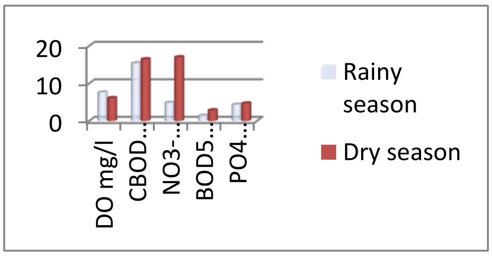


Figure 4.1. Maximum Temporal variation of Selected Parameters at Kajola Area (Station 1).

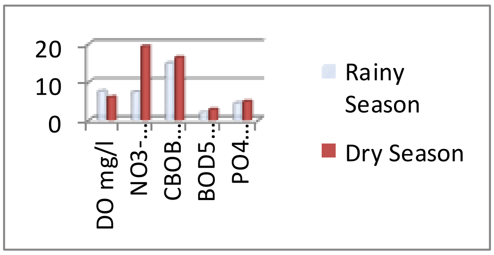


Figure 4.2: Maximum Temporal Variation of Selected Parameters at Owode Area (Station 2)

The temporal variations of some selected parameters are shown in Figure 4.1- 4.6.

NOTE: All y–axis represent values in mg/l and x-axis are in mg/l

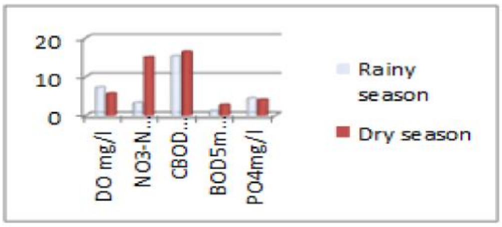


Figure 4.3: Maximum Temporal Variation of Selected Parameter at Okejetu Area (Station 3)

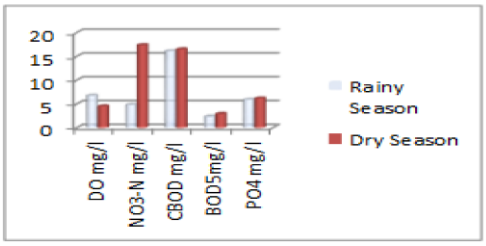


Figure 4.4: Maximum Temporal Variation of Selected Parameters at Isale-Osun Area (Station 4)

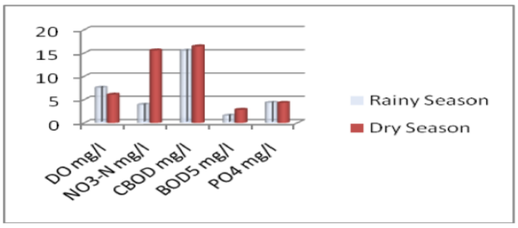


Figure 4.5: Maximum Temporal Variation of Selected Parameters at Gbodofon Area (Station 5)

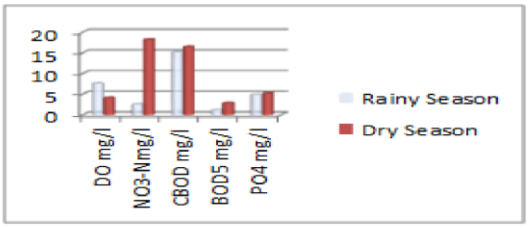


Figure 4.6: Maximum Spatial Variation of Selected Parameters at Ebunoluwa Area (Station 6)

Table 4. shows how the two hundred questionnaires were administered and percentage and frequency of water borne diseases cases reported and treated by the health centres in the study areas six months prior the date the questionnaires were administered.

Table 4. Percentage and Frequency of Water Borne Diseases.

Community	Frequency	Percentage
Kajola/Apara	32	13%
	38	
Owode	31	17.5%
	42	
Okejetu	41	12.5%
	36	
Isale Osun		21%
Gbodofon		20%
Ebunoluwa		16%
Total	220	100%

Table 5 Shows the Pearson Correlation Coefficient Table which gives the relationship between residents affected with water borne diseases within the areas where samples were taken and the pollution source of River Osun.

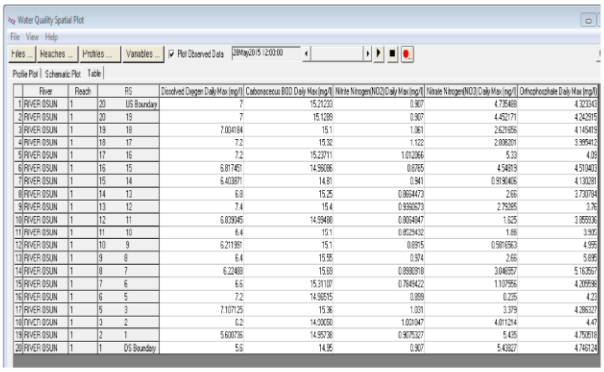
Table 5. Pearson's Correlation Coefficient Result for Questionnaires administered.

The Pair of Resident with Water Borne Diseases and Stations across River Osun	Coefficient of Correlation	
	High Pollution	Low Pollution
RAWBD/ Kajola Area	0.65	-0.56
RAWBD/ Owode Area	0.81	0.34
RAWBD/ Okejetu Area	0.55	0.33
RAWBD/ Isale Osun Area	0.82	0.31
RAWBD/ Gbodofon Area	0.47	0.55
RAWBD/ Ebunoluwa Area	0.33	0.65

RAWBD – Resident Affected with water borne diseases

4.3 Modelling Output

The summary of maximum predicted concentration for each parameter with their water quality cell length and station are presented in Figure 4.7 and 4.8. The DO, CBOD and NO2-N output from HEC-RAS for rainy and dry season varied from (5.6 -7.4)mg/l and (3.391-5.828)mg/l; (14.81-15.69)mg/l and (15.87-15.93)mg/l; (0.806484-1.22) and (0.2085-0.4041)mg/l, respectively. The values for NO3-N and PO4 varied from (0.235-5.43827)mg/l and (13.24-19.1) mg/l; (3.76-5.163567)mg/l and (4.124- 4.88) mg/l, respectively across the river.



Water Quality Spatial Plot

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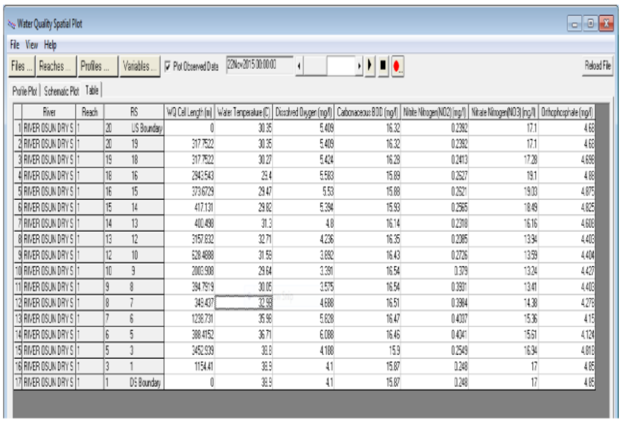
Profile Plot | Schematic Plot | Table

	River	Reach	RS		Dissolved Oxygen Daily Max (mg/l)	Carbonaceous BOD Daily Max (mg/l)	Nitrite Nitrogen(NO2) Daily Max (mg/l)	Nitrate Nitrogen(NO3) Daily Max (mg/l)	Orthophosphate Daily Max (mg/l)
1	RIVER OSUN	1	20	US Boundary	7	15.21233	0.907	4.735488	4.323343
2	RIVER OSUN	1	20	19	7	15.1289	0.907	4.452171	4.242915
3	RIVER OSUN	1	19	18	7.004184	15.1	1.061	2.621656	4.145419
4	RIVER OSUN	1	18	17	7.2	15.32	1.122	2.006201	3.995412
5	RIVER OSUN	1	17	16	7.2	15.23711	1.012066	5.33	4.09
6	RIVER OSUN	1	16	15	6.817451	14.96086	0.8765	4.54819	4.510403
7	RIVER OSUN	1	15	14	6.403871	14.81	0.941	0.9190406	4.130281
8	RIVER OSUN	1	14	13	6.8	15.25	0.8664473	2.66	3.730784
9	RIVER OSUN	1	13	12	7.4	15.4	0.9360673	2.79285	3.76
10	RIVER OSUN	1	12	11	6.839045	14.99488	0.8064847	1.625	3.855936
11	RIVER OSUN	1	11	10	6.4	15.1	0.8529432	1.86	3.905
12	RIVER OSUN	1	10	9	6.211991	15.1	0.8915	0.5816563	4.955
13	RIVER OSUN	1	9	8	6.4	15.55	0.974	2.66	5.895
14	RIVER OSUN	1	8	7	6.22488	15.69	0.8980918	3.046557	5.163567
15	RIVER OSUN	1	7	6	6.6	15.31107	0.7849422	1.107556	4.205598
16	RIVER OSUN	1	6	5	7.2	14.96515	0.899	0.235	4.23
17	RIVER OSUN	1	5	3	7.107125	15.36	1.031	3.379	4.286327
18	RIVER OSUN	1	3	2	6.2	14.00050	1.001047	4.011214	4.47
19	RIVER OSUN	1	2	1	5.600736	14.95738	0.9075327	5.435	4.750518
20	RIVER OSUN	1	1	DS Boundary	5.6	14.95	0.907	5.43827	4.746124

Figure 4.7. Water Quality Output Table for Rainy season.



Water Quality Spatial Plot

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	River	Reach	RS		WQ Cell Length (m)	Water Temperature (C)	Dissolved Oxygen (mg/l)	Carbonaceous BOD (mg/l)	Nitrite Nitrogen(NO2) (mg/l)	Nitrate Nitrogen(NO3) (mg/l)	Orthophosphate (mg/l)
1	RIVER OSUN DRY S	1	20	US Boundary	0	30.35	5.409	16.32	0.2392	17.1	4.68
2	RIVER OSUN DRY S	1	20	19	317.7522	30.35	5.409	16.32	0.2392	17.1	4.68
3	RIVER OSUN DRY S	1	19	18	317.7522	30.27	5.424	16.28	0.2413	17.28	4.698
4	RIVER OSUN DRY S	1	18	16	2943.543	29.4	5.583	15.89	0.2627	19.1	4.88
5	RIVER OSUN DRY S	1	16	15	373.6729	29.47	5.53	15.88	0.2621	19.03	4.875
6	RIVER OSUN DRY S	1	15	14	417.131	29.82	5.394	15.93	0.2565	18.49	4.825
7	RIVER OSUN DRY S	1	14	13	400.498	31.3	4.8	16.14	0.2318	16.16	4.608
8	RIVER OSUN DRY S	1	13	12	3157.832	32.71	4.236	16.35	0.2085	13.94	4.403
9	RIVER OSUN DRY S	1	12	10	528.4888	31.59	3.892	16.43	0.2726	13.59	4.404
10	RIVER OSUN DRY S	1	10	9	2003.908	29.64	3.391	16.54	0.379	13.24	4.427
11	RIVER OSUN DRY S	1	9	8	394.7919	30.05	3.575	16.54	0.3901	13.41	4.403
12	RIVER OSUN DRY S	1	8	7	349.437	32.99	4.688	16.51	0.3984	14.38	4.278
13	RIVER OSUN DRY S	1	7	6	1238.731	35.98	5.828	16.47	0.4037	15.36	4.15
14	RIVER OSUN DRY S	1	6	5	388.4152	36.71	6.088	16.46	0.4041	15.61	4.124
15	RIVER OSUN DRY S	1	5	3	3452.939	38.8	4.188	15.9	0.2549	16.94	4.818
16	RIVER OSUN DRY S	1	3	1	1154.41	38.9	4.1	15.87	0.248	17	4.85
17	RIVER OSUN DRY S	1	1	DS Boundary	0	38.9	4.1	15.87	0.248	17	4.85

Figure 4.8.Water Quality Output Table for Dry Season.

4.4 Calibration and Validation of HEC-RAS Model

HEC-RAS model was calibrated and validated by using a year (rainy and dry seasons) hydrological records and laboratory analysis results of water quality parameters from the river. Coefficient of regression value of 0.85 was obtained between the measured and simulated laboratory result. Validation of the water quality assessment was done by using water quality parameters analysed in the laboratory from 2014 -2015 (rainy and dry seasons). The computed results were compared with the simulated values at each sampling point. There exists a good agreement between simulated and analysed values with variation between (2-10) percent.

5.0. Conclusions and Recommendation

The following conclusions were drawn based on the obtained results:

i. The high concentration of some determined parameters such as PO_4^{3-} (rainy and dry seasons), NO_3^- (dry season), NO_2 (rainy season) as well as low concentration values of DO (dry season) and BOD compared to the water quality criteria shows that the river is highly polluted due to anthropogenic activities.

ii. There is significant relationship between user of River Osun and water borne diseases cases in the study area.

iii. HEC-RAS output gives simulated results of quality parameters concentration and predicted the levels, distributions and risk of chemical pollutants across the river by calculating maximum values of each chemical parameters and their corresponding temperature at main channel distance.

The following recommendations were made from this study

1. The continuous water quality assessment across River Osun both in dry and rainy seasons will help to know and control possible sources of pollution.
2. There should be provision for continuous risk management of River Osun as well as information necessary for its continuous water quality management.
3. Continuous modelling of River Osun will help to know the spatial variation of its water quality simulation.
4. Government should strictly enforce legislation against deforestation of a permanent vegetation band neighbour to aquatic system along Osun River top.

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