Water Quality Index Percentage (WQI%) Enhancement of Water Sources in Rivers State Based on Physicochemical Parameters

S. C. Anyanwu[1]; E. R. Onukwugha[2]; O. H. Ibearugbulem[3]; O. C. Iwuamadi[4];
E. I. Iwuchukwu[5]; C. O. Okeke[6]; E. N Uzohuo[7]; C. N. Ononogbo[8]

[1,2,3]Department of Civil Engineering & Department Hydrology and Water Resources Management,
Federal Polytechnic Nekede, Owerri.
[4]Department of Electrical and Electronic Engineering, Federal Polytechnic Nekede, Owerri.
[5]Department of Agricultural and Bio–Environmental Engineering, Federal Polytechnic Nekede, Owerri.
[6,7]Department of Chemistry/Biochemistry, Federal Polytechnic Nekede, Owerri
[8]Department of Biology/ Microbiology, Federal Polytechnic Nekede, Owerri

Abstract: This study examined the influence of physicochemical parameters on the Water Quality Index percentage (WQI%) of groundwater and selected surface water sources in Rivers State, Nigeria. The research was conducted as a follow-up to earlier water quality assessments carried out in selected cities within the state, where significant variations in WQI% values were observed depending on whether all water quality parameters or only heavy metal parameters were considered. This observation prompted further investigation to better understand the individual and collective contributions of each parameter to the overall WQI outcome.

Water samples were collected from groundwater sources and selected rivers across different locations in Rivers State, and laboratory analyses were carried out around March 2022. The parameters analyzed included pH, temperature, electrical conductivity, turbidity, total dissolved solids (TDS), hardness, chloride, nitrate, phosphate, biological oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), and heavy metals such as lead (Pb), mercury (Hg), cadmium (Cd), copper (Cu), chromium (Cr), and manganese (Mn), as well as microbiological indicators including *Escherichia coli* and total coliforms.

The Weighted Arithmetic Water Quality Index (WAWQI) method was used to compute WQI% values under two conditions: first, by considering all analyzed parameters, and second, by excluding parameters with zero or negligible values (≤0.0001). The comparison of results highlights the sensitivity of WQI% to parameter selection and underscores the importance of comprehensive parameter inclusion in water quality assessment.

Keywords: Water Quality Index (WQI), physicochemical parameters, groundwater, surface water, heavy metals, Rivers State, Nigeria.

I. INTRODUCTION

This study focuses on the computation of the Water Quality Index percentage (WQI%) of surface water and groundwater samples collected from different local government areas in Rivers State, Nigeria, with particular emphasis on the influence of physicochemical parameters on the evaluated water quality. The research aims to determine whether significant differences exist in the WQI values obtained from surface water and groundwater sources across the study area.

Water samples were first characterized based on the measured physicochemical parameters present in each sample. The study adopted a two-stage analytical approach in which parameters with zero or negligible values were initially included in the WQI computation and subsequently excluded in a second computation. The resulting WQI values from both

stages were compared using statistical tools such as mean, variance, standard deviation, Student's *t*-test, *t*-statistics, and *F*-test to assess the level of variation and significance between the two datasets. Graphical representations, including bar charts and line graphs, were employed to visually demonstrate variations in WQI values, while correlation analysis was used to interpret relationships between the two sets of computed indices.

The Weighted Arithmetic Water Quality Index (WAWQI) method was applied to calculate the WQI using the laboratory test results. According to the WAWQI classification, WQI values of 0–25% indicate excellent water quality, 26–50% good, 51–75% moderate, 76–100% very poor, and values above 100% indicate water unsuitable for drinking. A total of 31 water samples were collected, comprising 20 groundwater samples from boreholes and 11 surface water samples from rivers. WQI computations were carried out in two stages—without and with heavy metal parameters. While the first stage showed a relatively well-distributed water quality status, the inclusion of heavy metals in the second stage led to the disappearance of mid-range quality classifications. This finding highlights the strong influence of heavy metals on WQI outcomes and suggests that WQI calculations should consider only parameters present in each water sample for accurate water quality assessment.

II. MATERIALS AND METHODS

➤ *Study Area*

The study area comprises selected boreholes and river water sources across thirteen local government areas in Rivers State, Nigeria. These include Ogba/Egbema/Ndoni, Ahoada East, Emohua, Ikwere, Obio/Akpor, Port Harcourt, Oyigbo, Etche, Okrika, Tai, Gokana, Khana, and Eleme, as previously identified in an earlier study (Anyanwu et al., 2022). The geographical coordinates (latitude and longitude) of each sampling location were obtained using leveling instruments to accurately determine the spatial distribution of the sampling points. These coordinates are presented in the results tables.

➤ *Experimental Methods and Parameters Measured*

Atomic Absorption Spectrometry (AAS) was employed for the determination of heavy metal concentrations in the water samples, following standard procedures outlined in ASTM D3557, ASTM D1691, ASTM D1688, ASTM D3559, ASTM D858, ASTM D1687, and ASTM D3223 (1996). The physicochemical parameters analyzed included pH, temperature, electrical conductivity, turbidity, total dissolved solids (TDS), hardness, chloride, nitrate, phosphate, biological oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), and selected heavy metals such as lead (Pb), mercury (Hg), cadmium (Cd), copper (Cu), chromium (Cr), and manganese (Mn). Microbiological indicators, including total coliforms, were also assessed (Anyanwu et al., 2022).

➤ *Weighted Arithmetic Water Quality Index (WAWQI) Method*

The Weighted Arithmetic Water Quality Index (WAWQI) method was used to evaluate and classify water quality based on commonly measured physicochemical parameters (Chidiac et al., 2023; Patel et al., 2023). The WQI was computed using Equation (1):

$$WQI = \frac{\sum Q_i W_i}{\sum W_i} \qquad \ldots\ldots\ldots \qquad 1$$

The quality rating scale (Q_i) for each parameter was calculated using Equation (2):

$$Q_i = 100 \left(\frac{V_i - V_0}{S_i - V_0} \right) \qquad \ldots\ldots\ldots. \qquad 2$$

where V_i represents the measured concentration of the parameter, V_0 is the ideal value in pure water (except for pH = 7.0 and DO = 14.6 mg/L), and S_i is the recommended standard value.

The unit weight (W_i) of each parameter was calculated using Equation (3):

$$W_i = \frac{K}{S_i} \qquad \ldots\ldots\ldots \qquad 3$$

where K is the proportionality constant obtained from Equation (4):

$$K = \frac{1}{\sum \frac{1}{S_i}} \qquad \ldots\ldots\ldots \qquad 4$$

Based on WQI values, water quality was classified as excellent (0–25), good (26–50), poor (51–75), very poor (76–100), and unsuitable for drinking (>100) (Satish et al., 2017; Olayiwola & Olubunmi, 2016).

➤ *WQI Computation Procedure*

The WQI computation followed five main stages: (i) collection and analysis of physicochemical parameters, (ii) determination of the proportionality constant K, (iii) calculation of quality ratings (Q_i), (iv) determination of unit weights (W_i), and (v) final computation of WQI values (Ioanna et al., 2020; Kizar, 2018).

➤ *Statistical and Comparative Analysis*

Comparative analysis of the two sets of WQI data was carried out using hypothesis testing. The null hypothesis *Ho*: *H* assumed no significant difference between the mean WQI values ($\mu_1 = \mu_2$), while the alternative hypothesis (H_A: H_1) assumed a significant difference ($\mu_1 \neq \mu_2$).

Statistical analyses, including pooled variance, standard deviation, Student's *t*-test, *t*-statistics, *F*-test, ANOVA, and Principal Component Analysis (PCA), were performed using appropriate statistical software. These analyses aided in interpreting variations and drawing reliable conclusions (Allen, 2011; Shaun, 2022).

III.   RESULTS AND PRESENTATION

The results of this study are systematically organized and presented using tables and graphical illustrations to clearly depict variations in water quality across the study area. Tables 1, 2, and 3 present detailed information on the sampling locations, physicochemical characteristics, and computed Water Quality Index (WQI%) values for all water samples collected from Rivers State, Nigeria. The tables include sample identification numbers, elevation data obtained from GIS analysis, WQI values computed using all analyzed parameters, WQI values computed using only parameters present in each sample, corresponding water quality classifications, water source types (surface water or groundwater), and the respective local government areas.

Table 1 provides a comprehensive summary of the WQI results for the 31 analyzed water samples, comprising 20 groundwater samples from boreholes and 11 surface water samples from rivers. The WQI values calculated using all parameters indicate that a large proportion of the samples fall within the "excellent" category. However, when the WQI was recalculated using only parameters present in each sample, a substantial shift in water quality classification was observed, with many samples transitioning into "poor," "very poor," or "unsuitable for drinking" categories. This trend was particularly evident in samples influenced by elevated concentrations of heavy metals and other critical contaminants. Similar patterns have been reported in previous studies conducted within Rivers State (Onyeugbo et al., 2021; Kalagbor et al., 2021).

Table 1 Detailed Information for All Water Samples Collected in River State Nigeria

Samples	Eleve.	WQI % All Parameters	Water Quality Status With All Parameters	Source of Water	WQI % Only Parameters Presents	Water Quality Status With Only Value Parameters	LGA
WQI1	517	2.74	EXCELLENT!	BH	62.35	POOR	Ogba/Egbema/Ndoni
WQI2	518	61.54	POOR	BH	1324.58	UNSUITABLE	Ogba/Egbema/Ndoni
WQI3	518	1913.50	UNSUITABLE	RIVER	2717.87	UNSUITABLE	Ogba/Egbema/Ndoni
WQI4	510	0.19	EXCELLENT!	BH	49.44	GOOD	Ahoada East
WQI5	507	494.91	UNSUITABLE	RIVER	703.17	UNSUITABLE	Ahoada East
WQI6	509	0.11	EXCELLENT!	BH	37.47	GOOD	Emohua
WQI7	516	506.10	UNSUITABLE	BH	719.04	UNSUITABLE	Emohua
WQI8	530	0.31	EXCELLENT!	BH	67.93	POOR	Emohua
WQI9	534	0.45	EXCELLENT!	BH	88.62	VERY POOR	Ikwere
WQI10	503	179.85	UNSUITABLE	BH	255.90	UNSUITABLE	Obio/Akpor
WQI11	512	4657.01	UNSUITABLE	RIVER	6264.07	UNSUITABLE	Obio/Akpor
WQI12	513	0.38	EXCELLENT!	BH	84.46	VERY POOR	Obio/Akpor
WQI13	501	1730.71	UNSUITABLE	RIVER	2327.97	UNSUITABLE	Obio/Akpor
WQI14	502	132.18	UNSUITABLE	RIVER	200.06	UNSUITABLE	PortHarcourt
WQI15	502	397.14	UNSUITABLE	BH	8523.66	UNSUITABLE	PortHarcourt
WQI16	515	0.14	EXCELLENT!	BH	41.02	GOOD	Obio/Akpor
WQI17	515	285.15	UNSUITABLE	BH	429.24	UNSUITABLE	PortHarcourt
WQI18	518	2.92	EXCELLENT!	BH	66.61	POOR	Oyigbo
WQI19	519	0.29	EXCELLENT!	RIVER	66.58	POOR	Oyigbo
WQI20	523	0.09	EXCELLENT!	BH	36.12	GOOD	Etche
WQI21	513	1736.82	UNSUITABLE	RIVER	2466.92	UNSUITABLE	Oyigbo
WQI22	522	2542.55	UNSUITABLE	BH	3825.66	UNSUITABLE	Etche
WQI23	501	14.79	EXCELLENT!	RIVER	320.79	UNSUITABLE	Okirika
WQI24	499	297.12	UNSUITABLE	BH	422.29	UNSUITABLE	Okirika
WQI25	510	0.31	EXCELLENT!	BH	69.81	POOR	Okirika
WQI26	515	3.20	EXCELLENT!	BH	72.58	POOR	Tai
WQI27	520	0.10	EXCELLENT!	BH	35.35	GOOD	Gokana
WQI28	580	8.60	EXCELLENT!	BH	189.28	UNSUITABLE	Gokana
WQI29	504	9.46	EXCELLENT!	RIVER	206.13	UNSUITABLE	Khana
WQI30	518	1657.13	UNSUITABLE	RIVER	2353.75	UNSUITABLE	Khana
WQI31	501	0.15	EXCELLENT!	BH	46.35	GOOD	Eleme
		16635.94			34075.07		

The cumulative WQI value obtained using all parameters was 16,635.94, whereas the cumulative WQI value computed using only parameters present in the samples increased significantly to 34,075.07. This marked difference highlights the sensitivity of WQI calculations to parameter selection. The inclusion of parameters with ideal or zero values tends to artificially improve the WQI outcome, thereby masking the true water quality status. These findings emphasize that effective water quality assessment and management should focus on parameters actually present in

the water samples. Reducing or eliminating elevated contaminant levels through appropriate treatment processes can significantly improve water quality, as also noted by Ashwani and Anish (2009) and Etim et al. (2013).

However, while Table 1 presents comprehensive information for all analyzed water samples, Table 2 focuses exclusively on groundwater (borehole) samples collected across Rivers State, Nigeria. The table provides detailed information on sample elevation, Water Quality Index (WQI%) values computed using all analyzed parameters, corresponding water quality classifications, WQI% values computed using only parameters present in each sample, water source type, and the respective local government areas.

Table 2 Data of Groundwater Samples Collected in River State Nigeria

Samples	Eleve.	WQI % All Parameters	Water Quality Status With All Parameters	Source of Water	WQI % Only Parameters Presents	Water Quality Status With Only Value Parameters	LGA
WQI1	517	2.74	EXCELLENT!	BH	62.35	POOR	Ogba/Egbema/Ndoni
WQI2	518	61.54	POOR	BH	1324.58	UNSUITABLE	Ogba/Egbema/Ndoni
WQI4	510	0.19	EXCELLENT!	BH	49.44	GOOD	Ahoada East
WQI6	509	0.11	EXCELLENT!	BH	37.47	GOOD	Emohua
WQI7	516	506.10	UNSUITABLE	BH	719.04	UNSUITABLE	Emohua
WQI8	530	0.31	EXCELLENT!	BH	67.93	POOR	Emohua
WQI9	534	0.45	EXCELLENT!	BH	88.62	VERY POOR	Ikwere
WQI10	503	179.85	UNSUITABLE	BH	255.90	UNSUITABLE	Obio/Akpor
WQI12	513	0.38	EXCELLENT!	BH	84.46	VERY POOR	Obio/Akpor
WQI15	502	397.14	UNSUITABLE	BH	8523.66	UNSUITABLE	PortHarcourt
WQI16	515	0.14	EXCELLENT!	BH	41.02	GOOD	Obio/Akpor
WQI17	515	285.15	UNSUITABLE	BH	429.24	UNSUITABLE	PortHarcourt
WQI18	518	2.92	EXCELLENT!	BH	66.61	POOR	Oyigbo
WQI20	523	0.09	EXCELLENT!	BH	36.12	GOOD	Etche
WQI22	522	2542.55	UNSUITABLE	BH	3825.66	UNSUITABLE	Etche
WQI24	499	297.12	UNSUITABLE	BH	422.29	UNSUITABLE	Okirika
WQI25	510	0.31	EXCELLENT!	BH	69.81	POOR	Okirika
WQI26	515	3.20	EXCELLENT!	BH	72.58	POOR	Tai
WQI27	520	0.10	EXCELLENT!	BH	35.35	GOOD	Gokana
WQI28	580	8.60	EXCELLENT!	BH	189.28	UNSUITABLE	Gokana
WQI31	501	0.15	EXCELLENT!	BH	46.35	GOOD	Eleme
		4289.14			16447.76		

A total of 20 borehole water samples were analyzed. The cumulative WQI value obtained when all parameters were considered was 4,289.14, whereas the cumulative WQI value calculated using only parameters present in the samples increased significantly to 16,447.76. This represents nearly a threefold increase in the WQI values when parameters with zero or negligible concentrations were excluded from the computation.

The observed increase highlights the strong influence of parameter selection on groundwater quality assessment. Including parameters with ideal or zero values tends to artificially lower WQI values, thereby portraying the groundwater quality as better than its actual condition. Conversely, restricting the WQI computation to parameters detected in the samples provides a more realistic representation of groundwater quality. This finding emphasizes the importance of careful parameter selection in WQI-based assessments and reinforces the need to focus on contaminants actually present in groundwater sources when evaluating water quality and designing appropriate treatment strategies.

Furthermore, Table 3 presents detailed information for surface water samples, including their elevation data and corresponding Water Quality Index (WQI%) values. The table summarizes results for water samples collected from rivers across different local government areas in Rivers State, Nigeria, and includes WQI values computed using all analyzed parameters as well as WQI values calculated using only parameters present in each sample.

Table 3 Data of Surfacewater Samples Collected in River State Nigeria

Samples	Eleve.	WQI % All Parameters	Water Quality Status With All Parameters	Source of Water	WQI % Only Parameters Presents	Water Quality Status With Only Value Parameters	LGA
WQI3	518	1913.50	UNSUITABLE	RIVER	2717.87	UNSUITABLE	Ogba/Egbema/Ndoni
WQI5	507	494.91	UNSUITABLE	RIVER	703.17	UNSUITABLE	Ahoada East
WQI11	512	4657.01	UNSUITABLE	RIVER	6264.07	UNSUITABLE	Obio/Akpor
WQI13	501	1730.71	UNSUITABLE	RIVER	2327.97	UNSUITABLE	Obio/Akpor

WQI14	502	132.18	UNSUITABLE	RIVER	200.06	UNSUITABLE	PortHarcourt
WQI19	519	0.29	EXCELLENT!	RIVER	66.58	POOR	Oyigbo
WQI21	513	1736.82	UNSUITABLE	RIVER	2466.92	UNSUITABLE	Oyigbo
WQI23	501	14.79	EXCELLENT!	RIVER	320.79	UNSUITABLE	Okirika
WQI29	504	9.46	EXCELLENT!	RIVER	206.13	UNSUITABLE	Khana
WQI30	518	1657.13	UNSUITABLE	RIVER	2353.75	UNSUITABLE	Khana
		12346.8			17627.31		

A total of 11 surface water samples were analyzed. The cumulative WQI value obtained when all parameters were considered was 12,346.80, while the cumulative WQI value calculated using only parameters present increased to 17,627.31. This represents a substantial increase, amounting to nearly one-and-a-half times the WQI value obtained from the full parameter set.

The results indicate that most surface water samples fall within the "unsuitable for drinking" category under both computation approaches, reflecting significant contamination levels. However, samples that initially appeared to exhibit "excellent" water quality when all parameters were included shifted to "poor" or "unsuitable" categories when only detected parameters were considered. This shift further confirms that the inclusion of parameters with ideal or zero values can mask the true quality status of surface water.

The pronounced difference between the two WQI computation approaches underscores the sensitivity of surface water quality assessments to parameter selection. These findings highlight the importance of focusing on parameters actually present in surface water samples to accurately assess pollution levels and to guide effective water quality improvement and management strategies.

➢ *Presentation of the WQI% Results*

In line with the results presented in Tables 1, 2, and 3, the Water Quality Index percentage (WQI%) values computed using all parameters and using only parameters present in each sample were further illustrated graphically for clearer comparison.
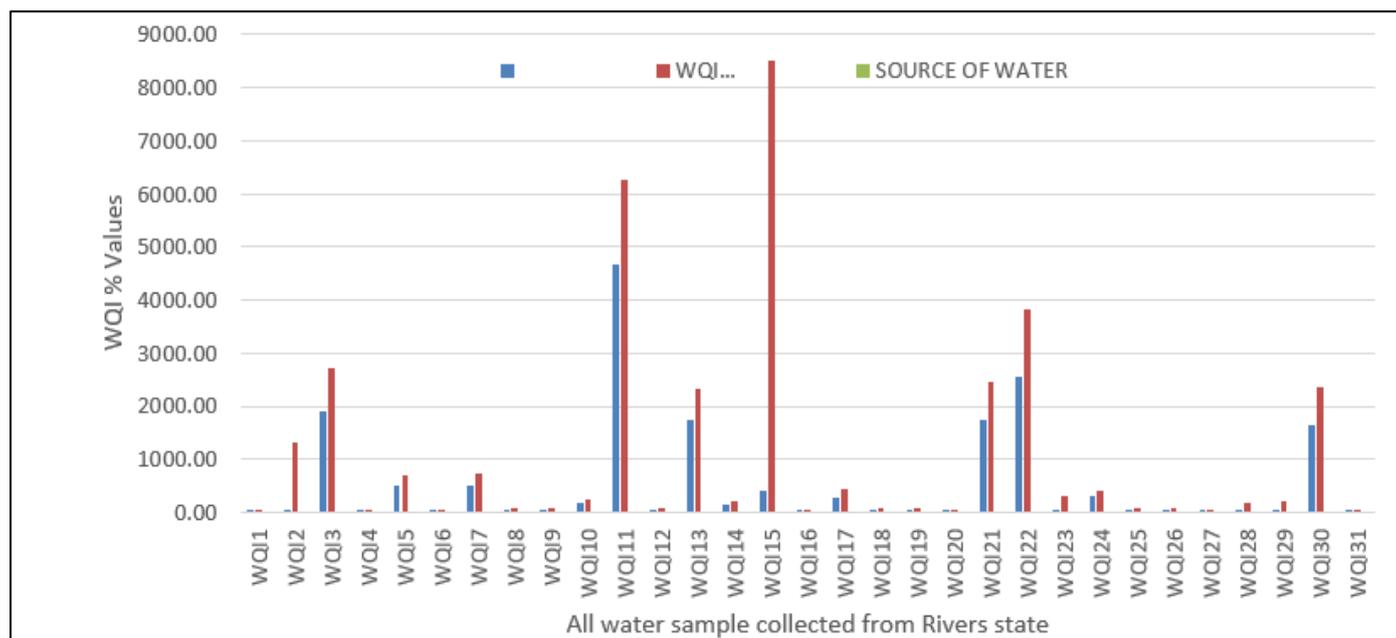

Fig 1 Bar Chart of All Water Sample Collected from Rivers State with Their WQI% Values

Bar charts were used to present the WQI% values plotted against the locus point label numbers of the water samples. Figure 1 presents the WQI% results for all water samples collected across Rivers State, including both groundwater and surface water sources. Figures 2 and 3 separately illustrate the WQI% results for groundwater samples and surface water samples, respectively. Two distinct colors were used to differentiate the computation approaches: red bars represent WQI% values calculated using only parameters present in the water samples, while blue bars represent WQI% values calculated using all analyzed parameters.

As shown in Figure 1, the WQI% values computed using only parameters present (red bars) are consistently higher than those computed using all parameters (blue bars) across all samples. This pattern indicates that the exclusion of parameters with zero or negligible concentrations leads to increased WQI values, thereby revealing poorer water quality conditions than initially suggested when all parameters are included. The graphical presentation therefore reinforces the tabulated results and clearly demonstrates the significant influence of parameter selection on WQI computation and interpretation.
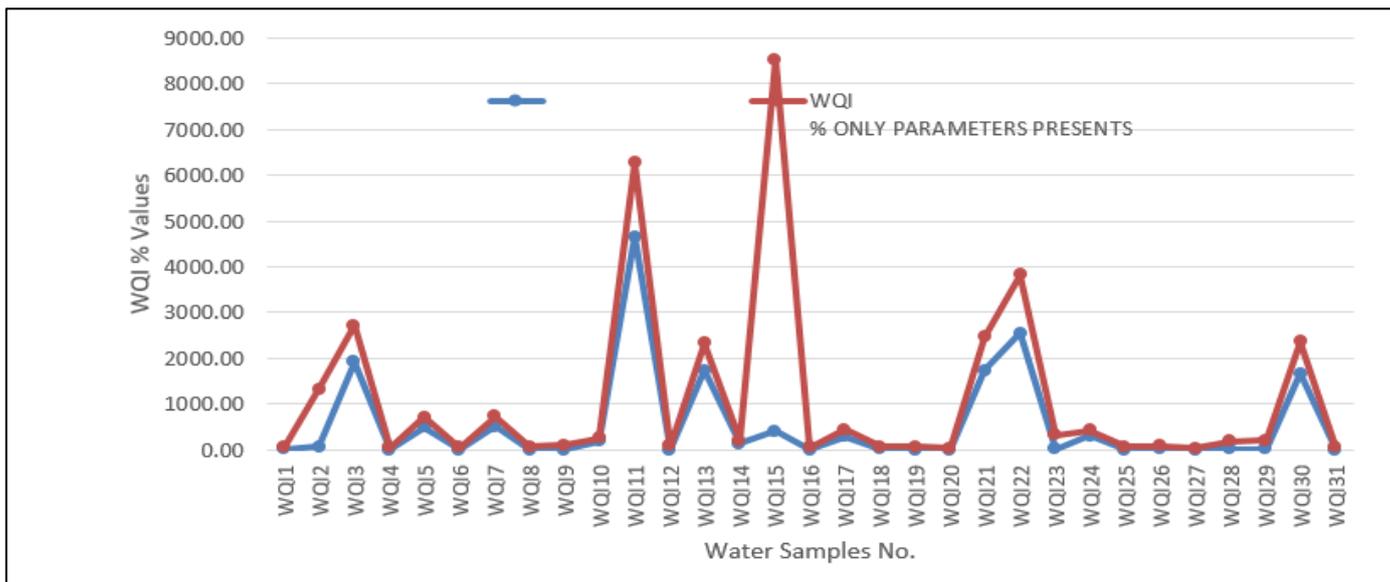
Fig 2 Line Graph of All Water Samples Collected from Rivers State with Their WQI% Values

- *Figure 2: Line Graph of WQI% Values for All Water Samples Collected in Rivers State*

Figure 2 presents a line graph illustrating the Water Quality Index percentage (WQI%) values for the two computation approaches: WQI calculated using all analyzed parameters and WQI calculated using only parameters present in each water sample. Consistent with the bar chart results in Figure 1, the red line, representing WQI% values computed using only detected parameters, remains consistently above the blue line, which represents WQI% values computed using all parameters.

This trend clearly demonstrates the significant difference between considering only parameters present in the water samples and including all expected parameters in the WQI computation. Parameters with zero or negligible concentrations tend to artificially improve the WQI outcome when included, thereby masking the true water quality status. In contrast, restricting the analysis to parameters actually detected in the samples provides a more realistic assessment of potential health risks.

From a public health perspective, even trace concentrations of certain contaminants can accumulate in the human body over time. Therefore, emphasis should be placed on ensuring the availability of safe, high-quality drinking water to minimize long-term exposure to harmful substances. This is particularly important for protecting vital organs such as the kidneys from conditions associated with prolonged ingestion of contaminated water, including kidney stones and infections. Consequently, water quality management strategies should prioritize the reduction of detected contaminants to ensure water safety and protect public health.

➢ *WQI% for Groundwater and Surface Water Samples*
Figure 3 presents the Water Quality Index (WQI%) values for all groundwater (borehole) samples, illustrating both WQI calculated using all parameters and WQI calculated using only parameters detected in each sample.
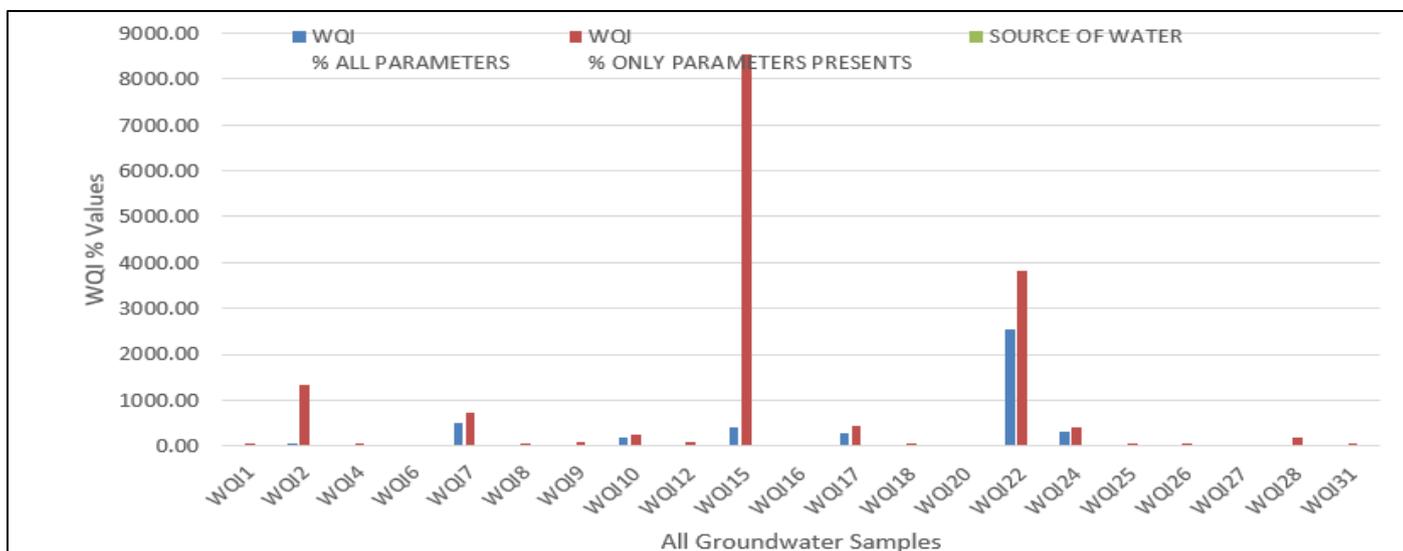

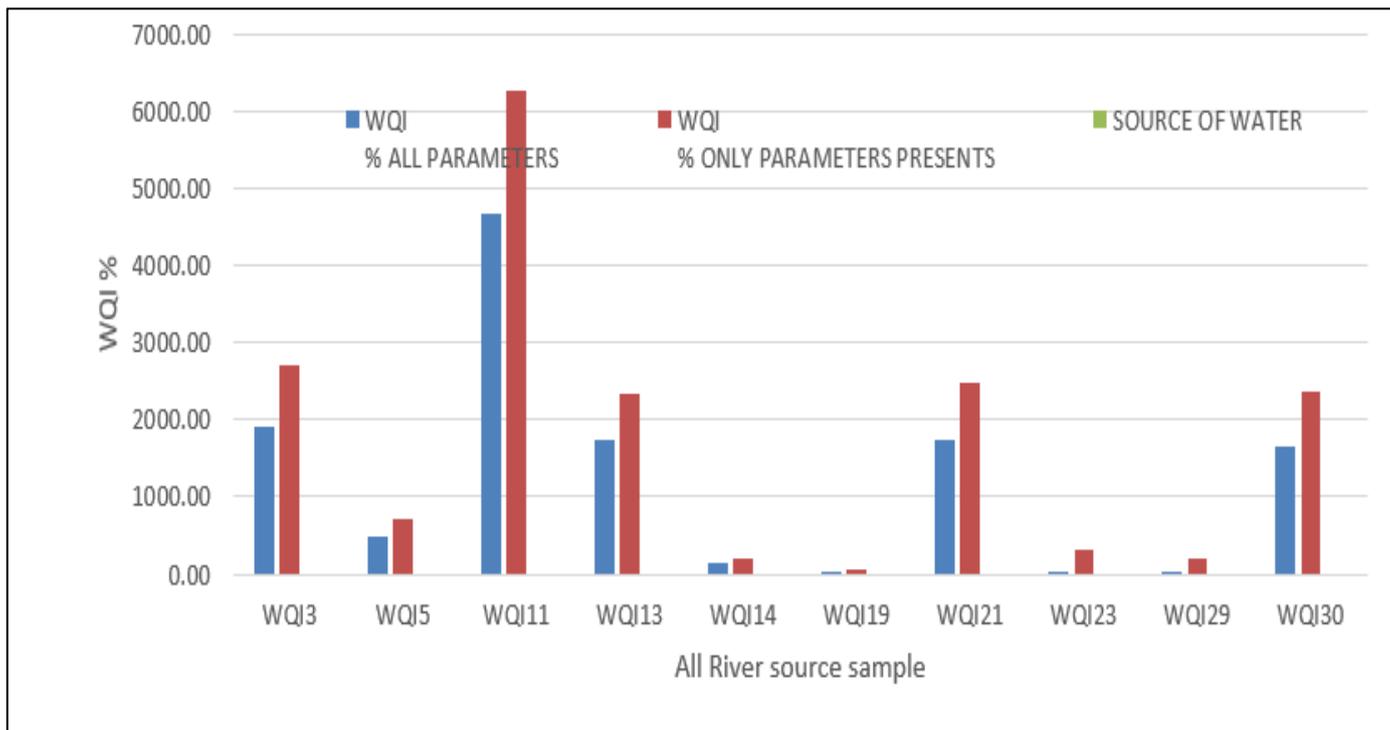Fig 3 WQI % of All Groundwater Source Samples and Its Parameters

Fig 4 WQI % of All River Source Samples and Its Parameters

Similarly, Figure 4 shows the WQI% values for all surface water (river) samples with the same two computation approaches. In both cases, WQI% values computed using only detected parameters consistently exceed those computed using all parameters, highlighting the impact of including or excluding negligible or zero-value parameters in water quality assessment.

> *Correlation Analysis*

To further examine the relationship between the WQI values calculated using all parameters and those calculated using only detected parameters, correlation analysis was performed. The strength of the relationship was assessed using the coefficient of determination (R^2), and the results were graphically presented in Figures 5–7.
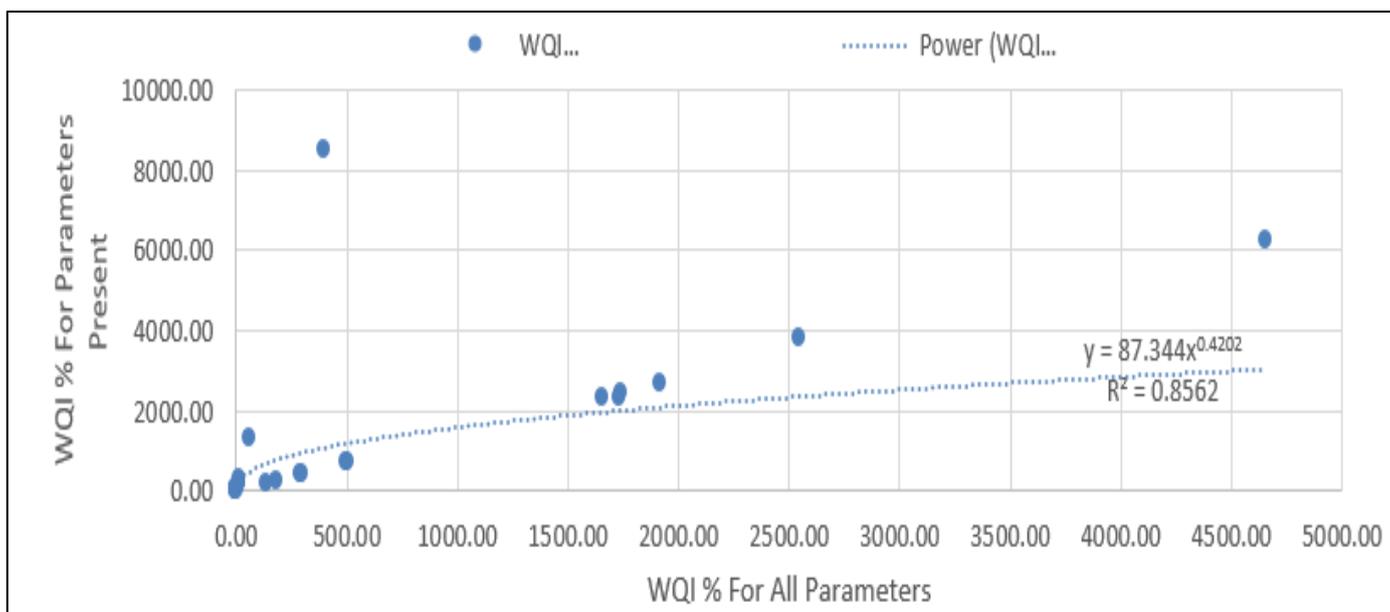
Fig 5 WQI % Values Relation of All Water Samples Collected from Rivers State Based on Parameters Presents

Figure 5 shows the correlation between the two sets of WQI values for all water samples collected from Rivers State, including both groundwater and surface water sources. The obtained R^2 value of 0.856 indicates a strong correlation, while the graph demonstrates a noticeable deviation, confirming significant differences between the two computation approaches.

Fig 6 WQI % Relation Based on PARAMETERS PRESENTS for Borehole Water Source

Figure 6 illustrates the correlation of WQI values for groundwater (borehole) samples only. The computed R^2 value of 0.8 suggests a strong, yet slightly lower correlation compared to the combined dataset, indicating moderate variation in groundwater quality when comparing the two WQI calculation methods.
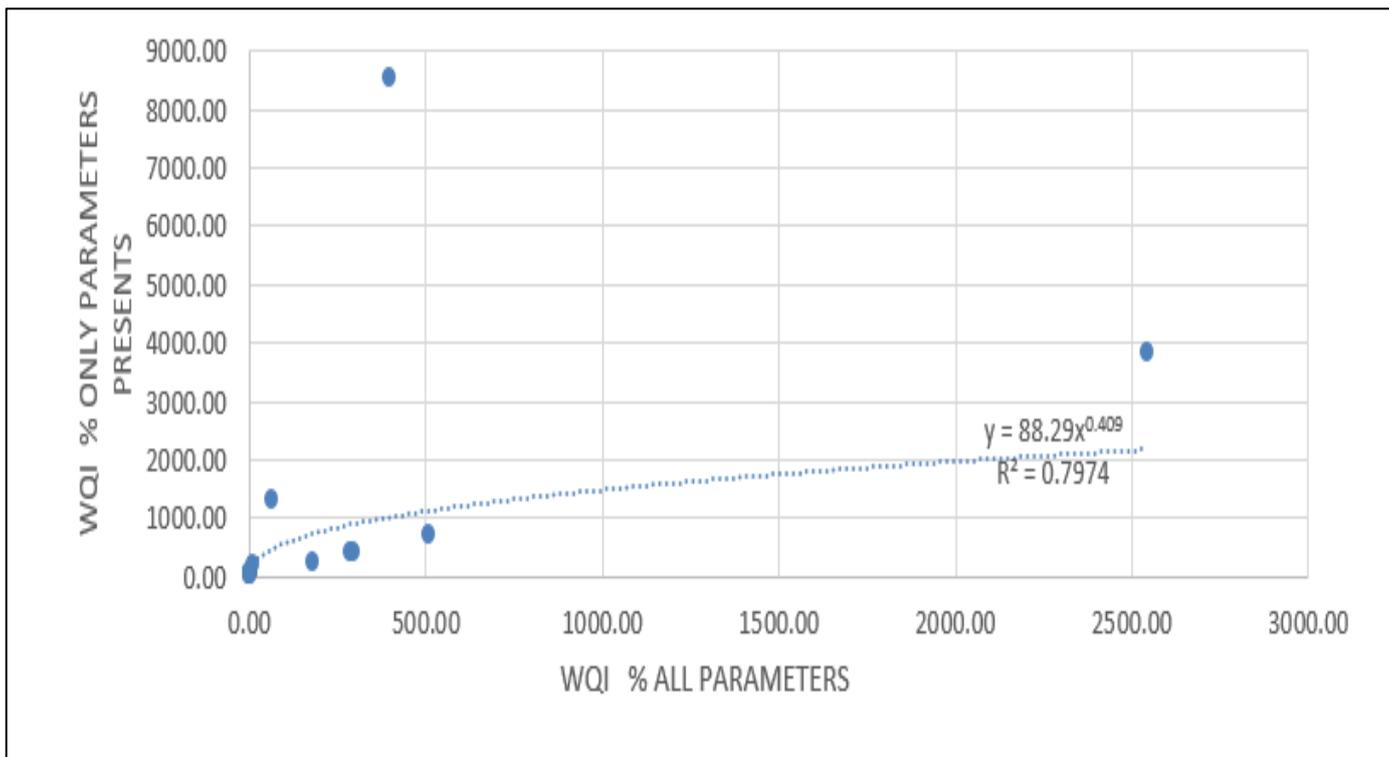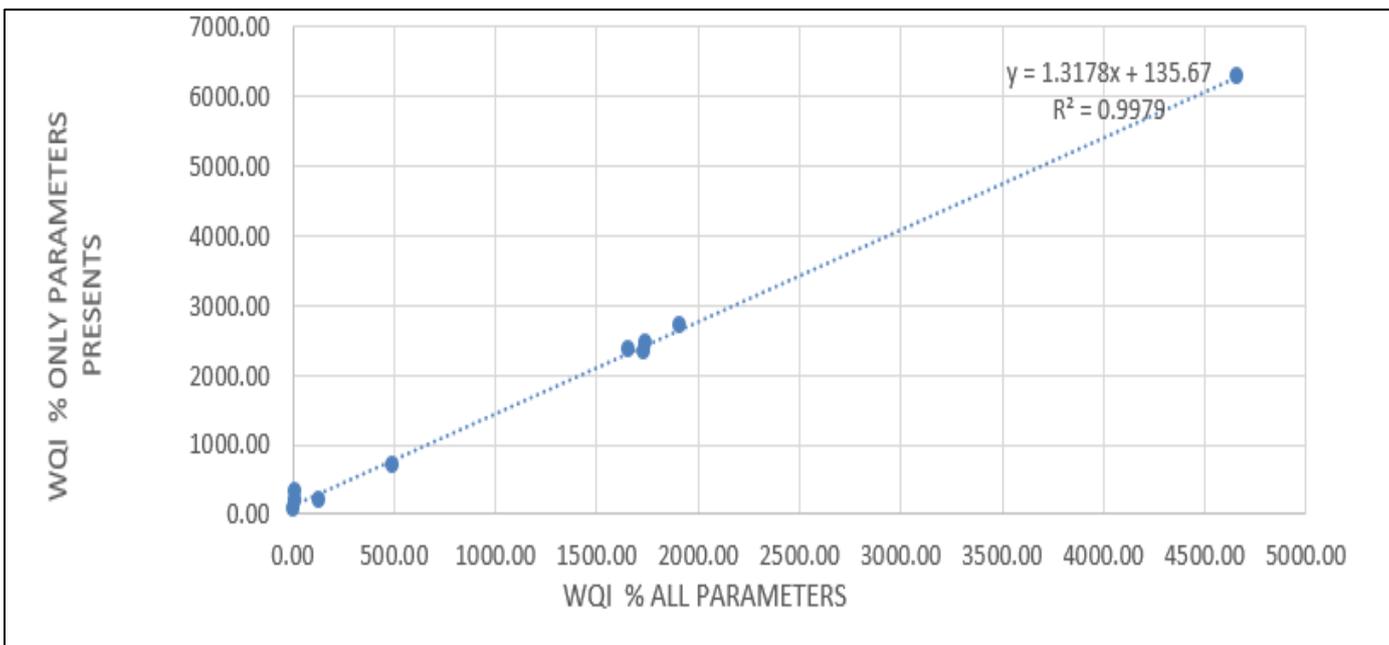

Fig 7 WQI % Relation Based on Parameters Presents for River Source Samples

Figure 7 presents the correlation for surface water (river) samples. The observed R^2 value of 0.997 indicates an almost perfect correlation, demonstrating that surface water WQI values are highly consistent between the two computation methods. However, as with the other datasets, the absolute values differ, reflecting the significant effect of parameter selection on WQI outcomes.

These correlation analyses reinforce the conclusion that WQI calculations are highly sensitive to whether all parameters or only detected parameters are considered, highlighting the need for careful selection of parameters in water quality assessment.

➤ *Comparison and Hypothesis Significance Test*

To determine whether there is a significant difference between WQI values calculated using all parameters versus only detected parameters, a Student's t-statistic significance test was performed. The analysis was conducted for all water samples, groundwater samples, and surface water samples separately.

Table 4: T-Statistic Significance Test for the First Experiment Calibrated (Equation 4.18)

	All_p	$Only_p$	A_pO_p	$A_p{}^{\wedge}2$	$O_p{}^{\wedge}2$	$di = A_p–O_p$	$di - \bar{d}$	$(di - \bar{d})^\wedge2$
1	2.74	62.35	170.839	7.5076	3887.523	-59.61	502.943	252951.7
2	61.54	1324.58	81514.65	3787.172	1754512	-1263.04	-700.487	490682
3	1913.5	2717.87	5200644	3661482	7386817	-804.37	-241.817	58475.46
4	0.19	49.44	9.3936	0.0361	2444.314	-49.25	513.303	263480
5	494.91	703.17	348005.9	244935.9	494448	-208.26	354.293	125523.5
6	0.11	37.47	4.1217	0.0121	1404.001	-37.36	525.193	275827.7
7	506.1	719.04	363906.1	256137.2	517018.5	-212.94	349.613	122229.2
8	0.31	67.93	21.0583	0.0961	4614.485	-67.62	494.933	244958.7
9	0.45	88.62	39.879	0.2025	7853.504	-88.17	474.383	225039.2
10	179.85	255.9	46023.62	32346.02	65484.81	-76.05	486.503	236685.2
11	4657.01	6264.07	29171837	21687742	39238573	-1607.06	-1044.51	1090995
12	0.38	84.46	32.0948	0.1444	7133.492	-84.08	478.473	228936.4
13	1730.71	2327.97	4029041	2995357	5419444	-597.26	-34.707	1204.576
14	132.18	200.06	26443.93	17471.55	40024	-67.88	494.673	244701.4
15	397.14	8523.66	3385086	157720.2	72652780	-8126.52	-7563.97	57213597
16	0.14	41.02	5.7428	0.0196	1682.64	-40.88	521.673	272142.7
17	285.15	429.24	122397.8	81310.52	184247	-144.09	418.463	175111.3
18	2.92	66.61	194.5012	8.5264	4436.892	-63.69	498.863	248864.3
19	0.29	66.58	19.3082	0.0841	4432.896	-66.29	496.263	246277
20	0.09	36.12	3.2508	0.0081	1304.654	-36.03	526.523	277226.5
21	1736.82	2466.92	4284596	3016544	6085694	-730.1	-167.547	28072
22	2542.55	3825.66	9726932	6464561	14635674	-1283.11	-720.557	519202.4
23	14.79	320.79	4744.484	218.7441	102906.2	-306	256.553	65819.44
24	297.12	422.29	125470.8	88280.29	178328.8	-125.17	437.383	191303.9
25	0.31	69.81	21.6411	0.0961	4873.436	-69.5	493.053	243101.3
26	3.2	72.58	232.256	10.24	5267.856	-69.38	493.173	243219.6
27	0.1	35.35	3.535	0.01	1249.623	-35.25	527.303	278048.5
28	8.6	189.28	1627.808	73.96	35826.92	-180.68	381.873	145827
29	9.46	206.13	1949.99	89.4916	42489.58	-196.67	365.883	133870.4
30	1657.13	2353.75	3900470	2746080	5540139	-696.62	-134.067	17973.96
31	0.15	46.35	6.9525	0.0225	2148.323	-46.2	516.353	266620.4
∑	16635.94	34075.07	60821455	41454164	1.54E+08	-17439.1	0.013	64427967

Table 4 presents the t-statistic significance test for the 31 water samples collected from Rivers State. The mean difference between WQI values ($\bar{d}$) was calculated as -562.55, with a variance of 2,147,598.91 and a standard deviation of 1,465.47. The resulting t-statistic was -2.137, indicating a significant difference between the two sets of WQI values.

Computation of t-statistic test and its parameters were achieved using Equations 3.36 to 3.37, and its shows as follows;

The mean difference, $\bar{d} = \dfrac{\sum d_i}{n} = \dfrac{-17439.13}{31} = -562.55$

Variance, $s_d^2 = \dfrac{\sum(d_i - \bar{d})^2}{N-1} = \dfrac{64427967.19}{30} = 2147598.906$

Standard deviation, $s_d = \sqrt{s_d^2} = \sqrt{2147598.906} = 1465.468835$

t-statistic, $t = \dfrac{\bar{d}}{s_d/\sqrt{n}} = \dfrac{-562.55}{1465.468835/\sqrt{31}} = -2.137299523$

Where;

U = specific substrate utilization rate from first set of experiment

U_m = the measured values of specific substrate utilization rate, SSUR

U_{mc} = the measured values of specific substrate utilization rate, SSUR on calibration

Y_{mc} = the measured values of graphical regression linear equations on calibration

y_{uc} = the predicted values of graphical regression linear equations on calibration

di = is the difference between the pairs of the two solutions

$\bar{d}$ = is the mean of the differences between the pairs of solution

Table 5 PCA Analysis / ANOVA to Accept or Reject Ho

Standard Value	Ap	Op	Df= Ap – Op	Y	Remark
mean	536.6432	1099.196	-562.553	Ho	rejected
variance	1049245	3773289	-2724044		
Standard Deviation	1024.327	1942.496	-918.169		
T.Student		0.527325	1.896363		
T.Test	0.040842	$T_{.1,.5\ 31}$	1.697	H1	Accepted
F.Test	0.000757	$F_{31,2}$	3.32 @5% 5.39 @1%		

The hypothesis test was carried out on two distributions of the thirty-one (31) Water Quality Index (WQI%) values obtained from groundwater and surface water samples collected across Rivers State. The first distribution was computed using all the parameters adopted for water quality characterization, while the second distribution was computed using only the parameters that were actually determined during analysis.

Initially, measures of central tendency and dispersion were examined for both distributions. Substantial differences were observed in the statistical parameters, with differences in the mean, variance, and standard deviation of −562.553, −2,724,044, and −918.169, respectively. These large discrepancies indicate that the two distributions are statistically different. Consequently, the null hypothesis (H₀) was rejected, while the alternative hypothesis (H₁) was accepted.

Furthermore, a correlation hypothesis test was conducted using the Student's t-test. The calculated t-value was 1.8964, which exceeds the critical t-value of 1.697 at both the 10% and 5% significance levels for 31 degrees of freedom. Based on this significant difference, the null hypothesis (H₀) was again rejected, and the alternative hypothesis (H₁) was accepted.

Table 5 shows the corresponding PCA/ANOVA results for all samples. The mean, variance, and standard deviation differences (-562.55, -2,724,044, and -918.17, respectively) confirm that the null hypothesis (Ho: no difference between WQI values) is rejected. The alternative hypothesis (H1) is accepted. The t-student test value (1.896) exceeds the critical table value (1.697 at 5% significance, 31 degrees of freedom), confirming the significance of the difference.

- *Groundwater Samples*

Table 6 T-Statistic Significance Test for the Groundwater Sample Experiment Calibrated

	All_p	$Only_p$	A_pO_p	$A_p{}^2$	$O_p{}^2$	$di = A_p–O_p$	$di - \bar{d}$	$(di - \bar{d})^2$
1	2.74	62.35	170.839	7.5076	3887.523	-59.61	519.372	269747.3
2	61.54	1324.58	81514.65	3787.172	1754512	-1263	-684.1	467935.3
3	0.19	49.44	9.3936	0.0361	2444.314	-49.25	529.732	280616
4	0.11	37.47	4.1217	0.0121	1404.001	-37.36	541.622	293354.4
5	506.1	719.04	363906.1	256137.2	517018.5	-212.94	366.042	133986.7
6	0.31	67.93	21.0583	0.0961	4614.485	-67.62	511.362	261491.1
7	0.45	88.62	39.879	0.2025	7853.504	-88.17	490.812	240896.4
8	179.85	255.9	46023.62	32346.02	65484.81	-76.05	502.932	252940.6
9	0.38	84.46	32.0948	0.1444	7133.492	-84.08	494.902	244928
10	397.14	8523.66	3385086	157720.2	72652780	-8126.5	-7547.5	56965330
11	0.14	41.02	5.7428	0.0196	1682.64	-40.88	538.102	289553.8
12	285.15	429.24	122397.8	81310.52	184247	-144.09	434.892	189131.1
13	2.92	66.61	194.5012	8.5264	4436.892	-63.69	515.292	265525.8
14	0.09	36.12	3.2508	0.0081	1304.654	-36.03	542.952	294796.9
15	2542.55	3825.66	9726932	6464561	14635674	-1283.1	-704.13	495796.2
16	297.12	422.29	125470.8	88280.29	178328.8	-125.17	453.812	205945.3
17	0.31	69.81	21.6411	0.0961	4873.436	-69.5	509.482	259571.9
18	3.2	72.58	232.256	10.24	5267.856	-69.38	509.602	259694.2
19	0.1	35.35	3.535	0.01	1249.623	-35.25	543.732	295644.5
20	8.6	189.28	1627.808	73.96	35826.92	-180.68	398.302	158644.5
21	0.15	46.35	6.9525	0.0225	2148.323	-46.2	532.782	283856.7
∑	4289.14	16447.76	13853704	7084243	90072173	-12158.6	0.002	62409387

For the 21 borehole water samples (Table 6), the mean difference was -578.98, variance 3,120,469.35, and standard deviation 1,766.49. The t-statistic was calculated as -1.502.

Computation of t-statistic test and its parameters were achieved using Equations 3.36 to 3.37, and its shows as follows;

The mean difference, $\bar{d} = \frac{\sum d_i}{n} = \frac{-12158.6}{21} = -578.98$

Variance, $s_d^2 = \frac{\sum(d_i-\bar{d})^2}{N-1} = \frac{62409387}{20} = 3,120,469.35$

Standard deviation, $s_d = \sqrt{s_d^2} = \sqrt{3,120,469.35} = 1,766.485$

t-statistic, $t = \frac{\bar{d}}{s_d/\sqrt{n}} = \frac{-578.98}{1,766.485/\sqrt{21}} = -1.501976907$

Table 7 Analysis / ANOVA to Accept or Reject Ho

Standard Value	Ap	Op	Df= Ap – Op	Y	Remark
mean	204.2447619	783.2267	-578.982	Ho	rejected
variance	295628.9717	3675707	-3380078		
Standard Deviation	543.7177317	1917.213	-1373.5		
T. Student calculated		0.283598	3.526119	H1	Accepted
T.Test excel	0.148726651	$T_{.1,.5\ 21}$	1.721		
F.Test excel	5.14657E-07	$F_{21,2}$	3.5@5% 5.78@1%		

Table 7 presents the corresponding PCA/ANOVA analysis. The statistical tendencies—mean difference (-578.98), variance difference (-3,380,078), and standard deviation difference (-1,373.5)—indicate that Ho is rejected and H1 accepted. The t-student test (3.526) is higher than the critical value (1.721 at 5% significance), confirming a statistically significant difference in WQI computation for groundwater samples.

The Water Quality Index (WQI%) hypothesis test was conducted on two distributions derived from twenty-one (21) water samples collected in Rivers State. The first distribution was obtained using all parameters considered in the water quality characterization, while the second distribution was computed using only the parameters with measured values.

An assessment of the measures of central tendency and dispersion, including the mean, variance, and standard deviation, revealed substantial differences between the two distributions. The recorded differences in mean, variance, and standard deviation were -578.982, $-3,380,078$, and $-1,373.5$, respectively. These marked variations indicate a significant statistical difference between the two datasets. Consequently, the null hypothesis (H₀) was rejected, while the alternative hypothesis (H₁) was accepted.

Furthermore, a correlation hypothesis test was performed using the Student's t-test. The calculated t-value of 3.526199 exceeds the critical t-value of 1.721 at both the 10% and 5% significance levels for 21 degrees of freedom. Based on this statistically significant result, the null hypothesis (H₀) was rejected, and the alternative hypothesis (H₁) was accepted.

- *Surface Water Samples*

Table 8 T-Statistic Significance Test for the Surface Water Sample Experiment Calibrated

S/N	All$_p$	Only$_p$	A$_P$O$_p$	A$_p$^2	O$_p$^2	di = A$_P$–O$_p$	di - $\bar{d}$	(di - $\bar{d}$)^2
1	1913.5	2717.87	5200644	3661482	7386817	-804.37	-276.319	76352.19
2	494.91	703.17	348005.9	244935.9	494448	-208.26	319.791	102266.3
3	4657.01	6264.07	29171837	21687742	39238573	-1607.06	-1079.01	1164260
4	1730.71	2327.97	4029041	2995357	5419444	-597.26	-69.209	4789.886
5	132.18	200.06	26443.93	17471.55	40024	-67.88	460.171	211757.3
6	0.29	66.58	19.3082	0.0841	4432.896	-66.29	461.761	213223.2
7	1736.82	2466.92	4284596	3016544	6085694	-730.1	-202.049	40823.8
8	14.79	320.79	4744.484	218.7441	102906.2	-306	222.051	49306.65
9	9.46	206.13	1949.99	89.4916	42489.58	-196.67	331.381	109813.4
10	1657.13	2353.75	3900470	2746080	5540139	-696.62	-168.569	28415.51
∑	12346.8	17627.31	46967751	34369921	64354969	-5280.51	1.14E-12	2001009

For the 10 surface water samples (Table 8), the mean difference was -528.05, variance 222,334.33, and standard deviation 471.52. The resulting t-statistic was -3.541.

Computation of t-statistic test and its parameters were achieved using Equations 3.36 to 3.37, and its shows as follows;

The mean difference, $\bar{d} = \frac{\sum d_i}{n} = \frac{-5280.51}{10} = -528.051$

Variance, $s_d^2 = \frac{\sum(d_i - \bar{d})^2}{N-1} = \frac{2001009}{9} = 222{,}334.33$

t-statistic, $t = \frac{\bar{d}}{s_d/\sqrt{n}} = \frac{-528.051}{471.52/\sqrt{10}} = -3.541406262$

Standard deviation, $s_d = \sqrt{s_d^2} = \sqrt{222{,}334.33} = 471.52$

Table 9: PCA Analysis / ANOVA to Accept or Reject Ho

Standard Value	Ap	Op	Df= Ap – Op	Y	Remark
mean	1234.68	1762.731	-528.051	Ho	rejected
variance	1912557	3328276	-1415719		
Standard Deviation	1382.952	1824.356	-441.404		
		Ap/Op	Op/Ap		
T. Student		0.758049	1.319175		
T. Test	0.0063	$T_{.1,.5,10}$	1.812	Ho	Accepted
F. Test	0.421763	$F_{10,2}$	4.1@5% 7.56@1%		

Table 9 shows the PCA/ANOVA results. Despite the mean, variance, and standard deviation differences (-528.05, -1,415,719, -441.40), the t-student correlation test value (1.319) was below the critical value (1.812 at 5% significance, 10 degrees of freedom). This indicates that while the statistical tendencies show differences between WQI computation methods, the correlation test does not fully reject Ho. However, the overall trend still supports that excluding zero-value parameters provides a more realistic assessment of water quality.

The hypothesis test was conducted on two distributions of the ten (10) Water Quality Index (WQI%) values obtained from surface water samples collected in Rivers State. The first distribution was computed using all parameters considered in the water quality characterization, while the second distribution was based on only the parameters that were actually determined.

Initially, measures of central tendency and dispersion, including the mean, variance, and standard deviation, were evaluated. Noticeable differences were observed between the two distributions, with differences in mean, variance, and standard deviation of −528.051, −1,415,719, and −441.404, respectively. These variations indicate a numerical disparity between the two datasets.

However, further hypothesis testing was carried out using the Student's *t*-test to assess the statistical significance of the correlation between the two distributions. The calculated *t*-value was 1.319175, which is lower than the critical *t*-value of 1.812 at both the 10% and 5% significance levels with 10 degrees of freedom. Based on this result, the null hypothesis (H₀) was accepted, indicating that the observed differences are not statistically significant. Consequently, the alternative hypothesis (H₁) was rejected for the correlation test.

- *Summary*

The hypothesis testing confirms that WQI values calculated using only detected parameters differ significantly from those computed using all parameters, particularly for groundwater and combined water samples. The difference is attributed to the influence of zero or negligible-value parameters, which artificially improve the WQI when included. Surface water samples also show differences, though correlation analysis indicates a closer relationship between the two computation methods. Overall, the results validate the importance of considering only detected parameters for accurate water quality evaluation.

IV. CONCLUSION

This study demonstrates that water quality is largely influenced by the quantity and significance of physicochemical parameters present in the water. The absence of some parameters can lead to an apparent improvement in water quality, whereas the presence of a few critical parameters has a direct effect on water quality. Similar studies by Shweta et al. (2016) highlight the importance of drinking water for human and animal health and emphasize the value of groundwater as a critical water resource.

When all physicochemical parameters were considered in calculating the Water Quality Index (WQI), most water samples fell into categories of excellent, poor, or unsuitable quality, spanning both surface water and groundwater sources. However, when only the significant parameters present in the samples were considered, the number of samples categorized as excellent disappeared, leaving water qualities classified as good, poor, very poor, or unsuitable. This indicates that considering only the detected parameters provides a more realistic assessment of water quality.

Correlation analysis of WQI values further confirmed the relationship between the two methods. The coefficient of determination (R²) was 0.856 for all water samples, 0.797 for groundwater samples, and 0.997 for surface water samples, indicating strong correlations. Finally, hypothesis testing and calibration analyses revealed significant differences between the two sets of WQI values. The null hypothesis (H₀) was consistently rejected, while the alternative hypothesis (H₁) was accepted, confirming that excluding negligible parameters produces more accurate water quality assessments.

REFERENCES

[1]. Allen-O'Donnell, M., Nowak, T. C., Snyder, K. A., & Cottingham, M. D. (2011). Impact of group settings and gender on meals purchased by college students. *Journal of Applied Social Psychology, 49*(9). https://doi.org/10.1111/j.1559-1816.2011.00804.x

[2]. Anyanwu, S. C., Onukwugha, E. R., Ibearugbulem, O. H., Iwuamadi, O. C., Iwuchukwu, E. I., Okeke, C. O., Uzohuo, E. N., & Ononogbo, C. N. (2022). Early wet season quality assessment of water sources from selected cities in Rivers State, Nigeria. *International Journal of Scientific & Engineering Research, 13*(10), 3645.

[3]. Chandra, D. S., Asadi, S. S., & Raju, M. V. S. (2017). Estimation of water quality index by weighted arithmetic water quality index method: A model study. *International Journal of Civil Engineering and Technology, 8*(4), 1215–1222. http://iaeme.com/Home/issue/IJCIET?Volume=8&Issue=4

[4]. Chidiac, S., El Najjar, P., Ouaini, N., El Rayess, Y., & El Azzi, D. (2023). A comprehensive review of water quality indices (WQIs): History, models, attempts and perspectives. *Reviews in Environmental Science and Biotechnology, 22*(2), 349–395. https://doi.org/10.1007/s11157-023-09650-7

[5]. Chinwendu, E., Nweke, B., Osere, J., & Ihunwo, C. K. (2020). Water quality index for the assessment of selected borehole water quality in Rivers State. *European Journal of Environment and Earth Sciences, 1*(6). https://doi.org/10.24018/ejgeo.2020.1.6.101

[6]. Etim, E. E., Odoh, R., Itodo, A. U., Umoh, S. D., & Lawal, U. (2013). Water quality index for the assessment of water quality from different sources in the Niger Delta region of Nigeria. *Frontiers in Science, 3*(3), 89–95. https://doi.org/10.5923/j.fs.20130303.02

[7]. Hoque, J. M. Z., Aziz, N. A. A., Alelyani, S., Mohana, M., & Hosain, M. (2022). Improving water quality index prediction using regression learning models. *International Journal of Environmental Research and Public Health, 19*(20), 13702. https://doi.org/10.3390/ijerph192013702

[8]. Kalagbor, I. A., Echem, O. G., & Banwo, E. (2021). Water quality assessment of Ntawogba Stream in Port Harcourt metropolis, Rivers State, Nigeria. *International Journal of Water Resources and Environmental Engineering, 13*(1), 76–87. https://doi.org/10.5897/IJWREE2020.0926

[9]. Kizar, F. M. (2018). A comparison between weighted arithmetic and Canadian methods for a drinking water quality index at selected locations in Shatt Al-Kufa. *IOP Conference Series: Materials Science and Engineering, 433*(1), 012026. https://doi.org/10.1088/1757-899X/433/1/012026

[10]. Kumar, A., & Dua, A. (2009). Water quality index for assessment of water quality of River Ravi at Madhopur (India). *Global Journal of Environmental Sciences, 8*(1), 49–57.

[11]. Olayiwola, O., & Fasakin, O. (2016). The use of water quality index method to determine the potability of surface water and groundwater in the vicinity of a municipal solid waste dumpsite in Nigeria. *American Journal of Engineering Research, 5*(10), 96–101.

[12]. Onyeugbo, J., Obunwo, C. C., Ubong, I., & Amaibi, P. (2021). Determination of the water quality index (WQI) of Okulu River in Eleme, Rivers State, Nigeria. *Journal of Basic Physical Research, 10*(1).

[13]. Patel, D. D., Mehta, D. J., Azamathulla, H. M., Shaikh, M. M., Jha, S., & Rathnayake, U. (2023). Application of the weighted arithmetic water quality index in assessing groundwater quality: A case study of the South Gujarat region. *Water, 15*(19), 3512. https://doi.org/10.3390/w15193512

[14]. Turney, S. (2022). *Null & alternative hypotheses: Definitions, templates & examples*. Scribbr. https://www.scribbr.com/statistics/null-and-alternative-hypotheses/

[15]. Zotou, I., Tsihrintzis, V. A., & Gikas, G. D. (2020). Water quality evaluation of a lacustrine water body in the Mediterranean based on different water quality index (WQI) methodologies. *Journal of Environmental Science and Health, Part A, 55*(5), 1–12. https://doi.org/10.1080/10934529.2019.1710956