ASSESSMENT OF THE CORRELATION AMONG KEY PHYSICOCHEMICAL WATER QUALITY PARAMETERS IN AQUATIC ENVIRONMENT OF RIVER BENUE AROUND JIMETA YOLA

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ABSTRACT

The quality of surface water in the River Benue around Jimeta-Yola is increasingly threatened by anthropogenic activities, including agricultural runoff, industrial discharge, and domestic waste disposal, which compromise its physicochemical integrity. This study aimed to assess the correlation among key water quality parameters of temperature, pH, turbidity, conductivity, dissolved oxygen, total solids, total dissolved solids, total suspended solids, and nitrates are to better understand their interrelationships and identify indicators for effective water quality monitoring. Data spanning ten years (2011–2021) were obtained from the Adamawa State Ministry of Water Resources across four sampling locations. Pearson's correlation analysis, conducted using NCSS 2021 software, revealed mean values of 21.83 °C (temperature), 283.24 NTU (turbidity), 7.42 (pH), 339.58 µS/cm (conductivity), 16.15 mg/L (dissolved oxygen), 747.77 mg/L (total solids), 797.39 mg/L (total dissolved solids), 1663.39 mg/L (total suspended solids), and 45.50 mg/L (nitrates). While pH, conductivity, and temperature were within WHO permissible limits, turbidity, total solids, total dissolved solids, and nitrates exceeded safe thresholds, indicating contamination. Strong correlations were observed between temperature and total solids ($r = 1.000$, $p < .001$), temperature and turbidity ($r = -0.851$, $p < .001$), and conductivity and dissolved oxygen ($r = 0.725$, $p < .001$), suggesting their potential as indicator parameters. The study recommends regular water quality monitoring, improved waste management, and policy-based pollution control to safeguard the ecological and public health functions of the River Benue.

Keywords: water quality, Pearson correlation, temperature, turbidity, pH, conductivity, dissolved oxygen, total solids, total dissolved solids, total suspended solids, nitrates, pollution

1 INTRODUCTION

Water is one of the most essential resources for sustaining life, supporting biodiversity, and driving economic and industrial development. Despite its critical importance, the quality of surface water bodies, particularly in developing regions, is increasingly threatened by anthropogenic activities such as agriculture, urbanization, industrialization, and poor waste disposal practices [1]. In Nigeria, the River Benue plays a significant role in supporting domestic, agricultural, and commercial activities, especially in areas like Jimeta-Yola. However, these benefits are undermined by pollution stemming from the indiscriminate discharge of agricultural runoff, industrial effluents, and domestic waste into the river, thereby compromising its physicochemical and biological integrity. The quality of water is commonly assessed by analyzing key physicochemical parameters such as temperature, pH, electrical conductivity, turbidity, dissolved oxygen, total hardness, and ammonium concentrations. These parameters not only provide insights into the potability and ecological health of water bodies but also serve as indicators of contamination and potential risks to human health and aquatic ecosystems. For instance, elevated temperature can affect the solubility of gases and biological activity in aquatic environments, while extreme pH levels may render water corrosive or unpalatable. High conductivity often signifies the presence of dissolved salts, which may be unsuitable for agricultural or drinking purposes, and increased turbidity can foster microbial growth and reduce light penetration, adversely affecting aquatic life [2-4]. Understanding the interrelationships among these physicochemical parameters is essential for effective water quality monitoring and management. Correlation analysis among water quality indices can reveal potential sources of pollution and interactions between variables, thereby guiding targeted interventions. Despite the growing interest in water quality research in Nigeria, limited studies have explored the correlation among multiple water quality parameters in the River Benue ecosystem, particularly around the urban and agriculturally active Jimeta-Yola region. Therefore, this study seeks to assess the correlation among selected physicochemical water quality parameters in the aquatic environment of the River Benue at Jimeta-Yola. The objective is to provide empirical data that can inform water resource management policies and promote sustainable utilization of this vital water body.

2 MATERIAL AND METHODS

2.1 Study Area

This study was conducted at four strategic locations along the River Benue within the Jimeta-Yola region of Adamawa State, Nigeria—namely Rugange (Yola South), Boranji and Under the Bridge (Yola North), and Liande (Girei LGA). The region lies between latitudes 9°7′30″ and 10°50′N, and longitudes 11°40′ and 13°20′E. The area falls within the sub-Sudan and northern Guinea savannah vegetation zones, characterized by sparse vegetation, grasses, shrubs, and scattered trees of both indigenous and exotic species. The River Benue traverses the region, which is predominantly flat and exhibits savannah-type ecology [5]. Climatically, the region experiences a tropical wet and dry season. Mean annual rainfall ranges below 1,000 mm in some parts, with spatial and temporal distribution influenced by altitude and orographic features. Rainfall typically begins in April–May and ends between September and November, depending on location. The rainy season spans 120 to 210 days. The thermal regime is consistent with the broader West African savannah, with temperatures gradually rising from January to April. Post-rainy season and harmattan periods bring notable fluctuations, with minimum temperatures reaching 18°C in December–January and maximum temperatures peaking at 40°C in April. Average monthly temperatures range from 26°C in the southern part to 27.8°C in the east [6, 7] As shown in Figure 1.

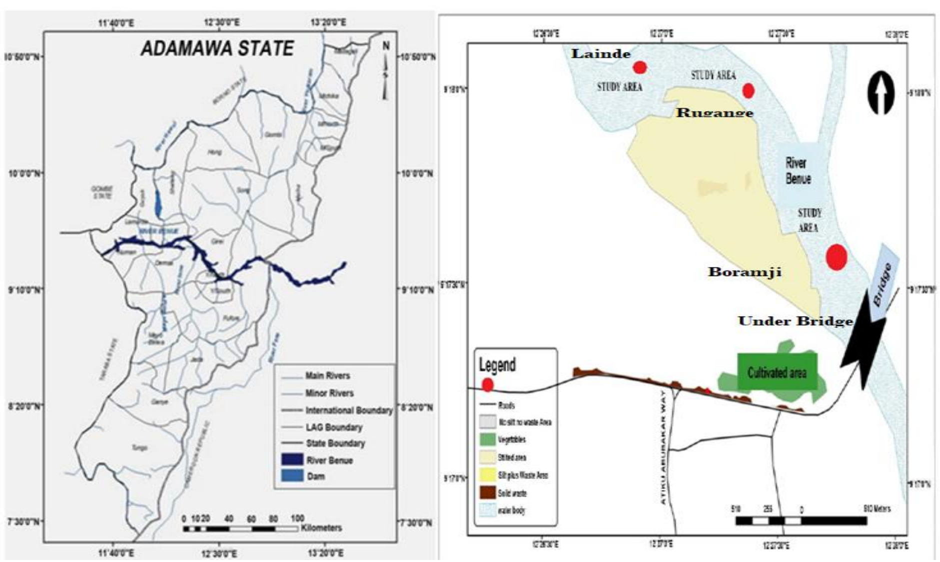

Figure 1. Doubeli bypass road, in Shinko Ward of Yola North Local Government Area, Adamawa State

2.2 Study Parameters

The time series of nine (9) selected water quality parameters that include dissolved oxygen DO, temperature, pH, conductivity, turbidity, Total Solids, Total Dissolved Solids, total suspended solids and nitrate in River Benue was studied in this research. The Permissible limit for surface Water Quality Parameters using World Health Organization (WHO) [8] standard is illustrated in Table 1.

Table 1. Water Quality Parameter Permissible limit.

Water Quality Parameter	Permissible limit for surface waters
pH	6.5 – 9.0
Temperature	Increase of 10°C affects aquatic life
Dissolved oxygen	Fresh water: 7mg/l – 9mg/l
	Early life fishes: 9.5 mg/l in cold water and 6.0 mg/l in warm water
Ammonium	Greater than 0.1mg/l and less than 1mg/l
Nitrate	50mg NO3/l
Nitrite	0.10 mg NO2/l
Turbidity	Based on dissolved solids
Phosphates	Less than 50μg/l at entry point and less than 25μg/l within the lake
Dissolved organic carbon	10mg/l threshold
Conductivity	Fresh water streams 150μS/cm to 500 μS/cm

2.3 Data collection

This research used the data from the selected water quality parameters of River Benue, which is the monitoring results of water board of the Adamawa state ministry of water resources for a monitoring period of 10 years 2011-2021 on Monthly bases to determine the level of correlation among the water quality parameters. In the period of the 10 years, the data for Nine (9) water quality parameters that were measured in different monitoring locations in the river Benue, specifically, specifically Under the Bridge, Liande, Boranji and Rugange all along the River Benue around Jimeta Yola, Adamawa State (see Figure 1).

2.4 Data Analysis

To evaluate the relationships among key water quality indicators; dissolved oxygen, temperature, ammonia, pH, conductivity, turbidity, phosphate, and nitrate. Correlation analysis was performed using NCSS 2021 Statistical Software (NCSS, LLC, Kaysville, Utah, USA). The objective was to identify statistically significant associations that could allow the estimation of certain parameters based on others, thereby simplifying and accelerating water quality assessments. The analysis employed Pearson's correlation coefficient (r), a statistical measure that quantifies the linear relationship between two variables as the ratio of their covariance to the product of their standard deviations.

3 RESULTS AND DISCUSSION

3.1 Comparison of Water Quality Parameters Standard

Table 2 presents key water quality parameters, including their mean values, standard deviations, ranges, minimum and maximum values, and associated standard guidelines. By comparing the mean values to the standard guidelines, valuable insights can be gained. The mean temperature of 21.825°C is slightly lower than the recommended range of 27 - 35°C, indicating relatively cooler conditions. The mean turbidity of 283.235 NTU was far above the World Health Organization's recommended limit of <5 NTU for drinking water, indicating high levels of suspended particles or impurities [9], suggesting elevated levels of suspended particles or impurities in the water. The pH levels, averaging at 7.415, fall within the standard range of 6.5 - 8.5, indicating neutral to slightly alkaline conditions which supports aquatic life and complies with permissible limits for potable water [10], which are generally acceptable. The conductivity, with a mean value of 339.575 µS/cm, aligns with the standard range of 0 - 1000 µS/cm, suggesting acceptable levels of ions or dissolved substances. The mean dissolved oxygen levels of 16.15 mg/l fall within the recommended range of 7 mg/l to 9 mg/l, indicating sufficient oxygen levels for aquatic life [10]. However, the mean values for total solids (747.765 mg/L) and total dissolved solids (797.385 mg/L) exceed the standard limit of 500 mg/L, indicating potential contamination or excessive dissolved substances in the water. The mean total suspended solids of 1663.39 mg/L also surpass the recommended range of 0 - 20,000 mg/L, indicating high levels of suspended matter. Nitrates, with a mean value of 45.495 mg/L, exceed the standard limit of 50 mg/L, suggesting potential nutrient enrichment based on [10]. This comparison emphasizes the importance of continuous monitoring and management efforts to maintain water quality within acceptable limits for ecological and human health.

Table 2. Statistical analysis of water quality parameters and comparison with Nigerian standard from different locations of Rugange, Under Bridge, Lainde and Boramji

Property	Mean	Std. Deviation	Range	Min.	Max.	Standard
Temperature (^{0}C)	21.825	1.487	4.3	19.9	24.2	(27 -35) ^{0}C
Turbidity NTU	283.23	29.63	83.8	228.6	312.4	(0 – 5) NTU
Ph	7.415	0.372	1.4	6.8	8.2	6.5 -8.5
Conductivity µS/cm	339.57	40.83	115.9	289.2	405.1	(0–1000) µS/cm
Dissolved Oxygen mg/L	16.15	1.45	4.7	13.8	18.5	(7 – 9) mg/L
Total Solids mg/L	747.76	168.64	594	328.1	922.1	(0 – 500) mg/L
Total Dissolved Solids mg/L	797.38	89.28	242.5	712.8	955.3	(0 – 500) mg/L
Total Suspended Solids mg/L	1663.39	2327.90	10518.5	1032.5	11551	(0-20,000) mg/L
Nitrates mg/L	45.495	13.159	34.9	21.9	56.8	(0-50) mg/L

3.2 Correlation among Temperature, Turbidity, PH, Conductivity, Dissolved Oxygen, Total Solids, Total Dissolved Solids, Total Suspended Solids, and Nitrates

The correlation coefficient (r) serves as a metric to quantify the strength and direction of the relationship between two variables, where one is considered as the dependent variable. A higher magnitude of the regression coefficient indicates a more robust fit, thereby enhancing the utility of the regression variables [11]. Correlation elucidates the interdependence between two variables, with a positive correlation indicating that an increase or decrease in the value of one parameter corresponds to a concurrent increase or decrease in the value of another parameter [12]. In the context of this study, the numerical values of the correlation coefficient (r) for the nine (9) distinct water quality parameters are meticulously shown in Figure 2, providing valuable insights into the intricate relationships among these parameters.

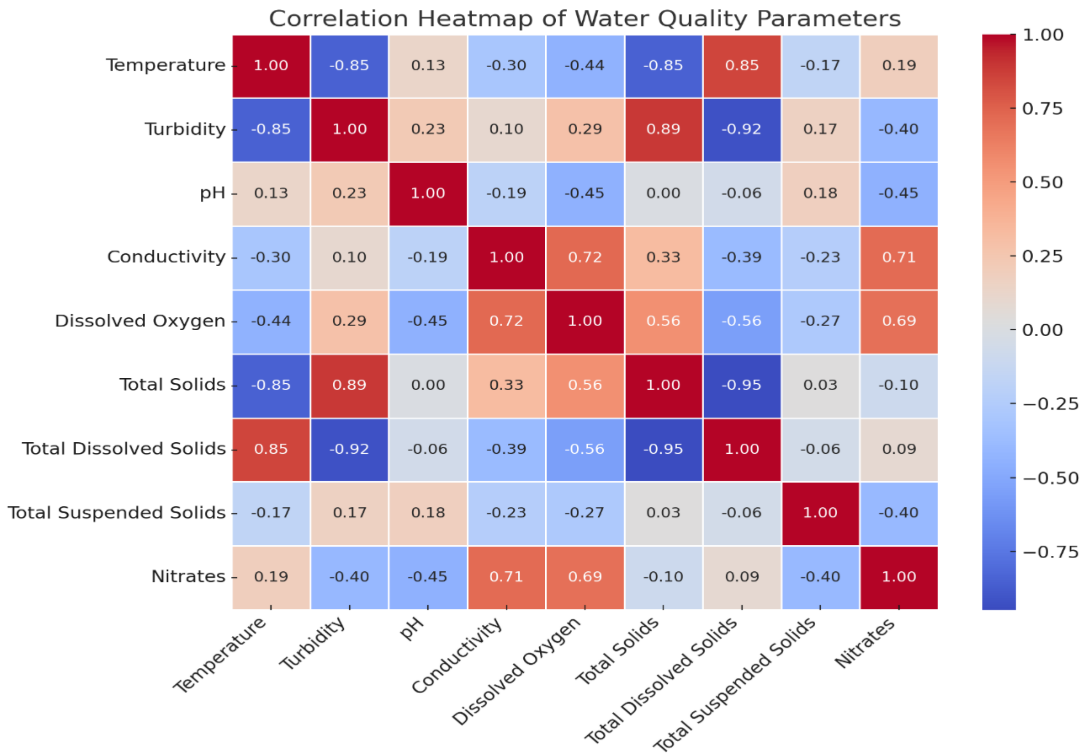

Figure 2. Correlation Heatmap of water quality parameters

The correlation Figure 2 illustrates the relationships between various water quality parameters of temperature, turbidity, pH, conductivity, dissolved oxygen, total solids, total dissolved solids, total suspended solids, and nitrates as indicated by Pearson's correlation coefficients (r) [13]. Each correlation coefficient represents the strength and direction of the linear relationship between two specific parameters. Additionally, the p-values associated with each correlation coefficient indicate the statistical significance of the observed correlations. Temperature illustrated significant correlations with several other parameters, such as turbidity, dissolved oxygen, and total solids. It indicated a strong positive correlation with total solids ($r = 1.000$, $p < .001$) and a strong negative correlation with turbidity ($r = -0.851$, $p < .001$) as shown in figure 2. The strong correlation with total solids could be due to temperature affecting the solubility of solids in water, leading to a direct relationship [14]. Similarly, the negative correlation with turbidity suggests that higher temperatures may lead to reduced turbidity due to increased biological activity or sediment settling [15]. This could be because temperature influences various chemical and biological processes in water bodies, affecting parameters like dissolved oxygen levels and the solubility of solids [16]. Turbidity showed strong negative correlations with temperature and total solids, indicating that higher temperatures and greater total solids content lead to reduced turbidity. A strong negative correlation with temperature ($r = -0.851$, $p < .001$) and a strong positive correlation with total solids ($r = 0.888$, $p < .001$), the negative correlation with temperature could be because higher temperatures increase microbial activity, leading to lower turbidity [14]. The positive correlation with total solids indicates that as turbidity increases, so does the concentration of suspended and dissolved solids in the water. Turbidity is often influenced by factors like sedimentation and organic matter, which can be affected by temperature variations and the presence of solids [15]. pH levels exhibited weak correlations with most other parameters in the heatmap. pH shows weak correlations with other parameters, with the highest correlation observed with turbidity ($r = 0.225$, $p = 0.341$), pH levels may not strongly correlate with other parameters in this dataset, suggesting that they are influenced by factors not measured here, such as specific chemical pollutants or geological characteristics [16]. pH is primarily influenced by the concentration of ions in water, which can be affected by factors like dissolved solids and certain pollutants. The weak correlations suggest that pH variations may not be strongly influenced by the other parameters measured in this study [14]. Conductivity showed moderate correlations with temperature and dissolved oxygen. The weak correlations with other parameters, with the highest correlation observed with dissolved oxygen ($r = 0.725$, $p < .001$). Conductivity is influenced by the concentration of ions in water, which can vary based on factors like dissolved solids content and temperature [13]. Conductivity is a measure of water's ability to conduct electrical current, which is influenced by the presence of ions. Temperature can affect the solubility of ions, while dissolved oxygen levels can influence ion concentrations through oxidation-reduction reactions [15]. Dissolved oxygen displayed strong correlations with temperature and conductivity. Dissolved oxygen exhibits strong correlations with conductivity ($r = 0.725$, $p < .001$) and temperature ($r = -0.444$, $p = 0.050$). Higher temperatures can reduce the solubility of oxygen in water, while conductivity is related to the presence of ions that can affect oxygen solubility [16]. Temperature influences the solubility of oxygen in water, while conductivity is related to the presence of ions that can affect oxygen solubility and biological oxygen demand [13]. Total Solids and Total Dissolved Solids exhibited strong correlations with each other and with temperature. They showed strong correlations with each other ($r = -0.947$, $p < .001$) and with temperature. Temperature can influence the solubility of solids in water, explaining the strong correlations observed [14]. Total solids represent all suspended and dissolved solids in water, while total dissolved solids specifically measure dissolved ions. Temperature can influence the solubility of solids, explaining the strong correlations observed [16]. Total suspended solids exhibited weak correlations with other parameters as illustrated in figure 2. With weak correlations with other parameters, with the highest correlation observed with total solids ($r = 0.030$, $p = 0.899$), suspended solids consist of particles that are not dissolved in water and can include sediment, organic matter, and pollutants. The weak correlations suggest that suspended solids may be influenced by factors not measured in this research [15]. Nitrates showed a strong correlation with conductivity, dissolved oxygen, and temperature. With a strong correlation with conductivity ($r = 0.711$, $p < .001$) and dissolved oxygen ($r = 0.695$, $p < .001$). Conductivity and dissolved oxygen levels can influence nitrogen cycling processes in water, affecting nitrate concentrations [14]. Nitrates are a common pollutant in water, often originating from agricultural runoff and wastewater [16]. Conductivity and dissolved oxygen levels can influence nitrogen cycling and the availability of nitrates in water, explaining the observed correlations [13]. The correlation heatmap provided useful information on the intricate relationships between water quality parameters. Understanding these interactions is critical for evaluating water quality, identifying potential pollutants, and adopting effective management techniques. Temperature appears as a prominent factor impacting many water quality metrics, with turbidity, dissolved oxygen, and conductivity also playing an important role [15].

4 CONCLUSIONS

This study assessed the interrelationships among critical physicochemical parameters of water quality in the River Benue around Jimeta-Yola over a ten-year monitoring period. The analysis revealed that while parameters such as pH, temperature, and conductivity generally fell within acceptable limits, others specifically turbidity, total solids, total dissolved solids, and nitrates—frequently exceeded national and international water quality standards. These exceedances suggest significant contamination likely driven by anthropogenic activities such as agricultural runoff, domestic waste discharge, and urbanization. The correlation analysis identified temperature, dissolved oxygen, and conductivity as central indicators influencing multiple other parameters. Strong correlations, both positive and negative, were observed among these variables, indicating that monitoring a select few could provide reliable insights into broader water quality conditions. This finding supports the potential for developing streamlined, cost-effective monitoring strategies that rely on key indicator parameters. Overall, the study underscores the urgent need for enhanced water quality management in the Jimeta-Yola region. Strategic interventions, including regular monitoring, improved pollution control measures, and sustainable land-use practices, are essential to mitigate water quality degradation and protect the ecological and public health functions of the River Benue.

REFERENCES

1. Akhtar, N., Syakir Ishak, M.I., Bhawani, S.A. and Umar, K. (2021). Various Natural and Anthropogenic Factors Responsible for Water Quality Degradation: A Review. *Water*, vol. 13, no. 19, pp. 26-60. [Online]. Available: https://www.mdpi.com/2073-4441/13/19/2660.
2. Murhekar, G. (2011). Determination of physicochemical parameters of surface water samples. Akot city, India. *International Journal of Current Research and Academic Review*, vol. 2, no. 12, pp. 31-41.
3. Akintoye, O.A., Obi, C.N., Etim, O.A., Olorundami, T., Ukata, S.U. and Harrison, U. (2014). Seasonal variation in the physicochemical characteristics of surface water in Etche River, Niger Delta Area of Nigeria. *Journal of Environmental Science, Toxicology and Food Technology*, vol. 8, no. 7, pp. 1-7.
4. Kumar, M. and Kumar, R. (2012). Assessment of physico-chemical properties of ground water in granite mining areas in Jhansi, UP. *International Journal of Engineering Research and Technology*, vol. 1, pp. 1-9.
5. Adzandeh, A.E., Hamid-Mosaku, I.A., Olayinka-Dosunmu, D.N., Badejo, O.T. and Okolie, C.J. (2024). Integrating GIS and AHP for a multi-criteria flood vulnerability assessment in the Benue River Basin, Nigeria. *Dutse Journal of Pure and Applied Sciences*, vol. 10, no. 3b, pp. 106-123.
6. Adebayo, A. and Tukur, A. (1999). Climate, sunshine, temperature, evaporation and relative humidity. *Adamawa state in maps*, pp. 20-22.
7. Tukur, A., Bashir, B. and Mubi, A. (2004). Agricultural land use and land degradation in Adamawa State. *Global Journal of Environmental Sciences*, vol. 3, no. 1, pp. 27-31.
8. WHO (2017). Guidelines for Drinking-water Quality WHO, Geneva.
9. WHO (2006). Turbidity and microbial risk in drinking water: A technical review for regulators. WHO in World Health Organization. [Online]. Available: https://studylib.net/doc/26120955/who-fwc-wsh-17.01-eng.
10. Kumar, M. and Puri, A. (2012). A review of permissible limits of drinking water. *Indian journal of occupational and environmental medicine*, vol. 16, no. 1, pp. 40-44.
11. Daraigan, S.G., Wahdain, A.S., Ba-Mosa, A.S. and Obid, M.H. (2011). Linear correlation analysis study of drinking water quality data for AlMukalla City, Hadhramout, Yemen. *International Journal of Environmental Sciences*, vol. 1, no. 7, pp. 1692-1701.
12. Jothivenkatachalam, K., Nithya, A. and Mohan, S.C. (2010). Correlation analysis of drinking water quality in and around Perur block of Coimbatore District, Tamil Nadu, India. *Rasayan Journal of Chemistry*, vol. 3, no. 4, pp. 649-654.
13. Yang, S., Liang, M., Qin, Z., Qian, Y., Li, M. and Cao, Y. (2021). A novel assessment considering spatial and temporal variations of water quality to identify pollution sources in urban rivers. *Scientific Reports*, vol. 11, no. 1, p. 8714.
14. Kibena, J., Nhapi, I. and Gumindoga, W. (2014). Assessing the relationship between water quality parameters and changes in landuse patterns in the Upper Manyame River, Zimbabwe. *Physics and Chemistry of the Earth, Parts A/B/C*, vol. 67, pp. 153-163.
15. Samah, O.H. (2012). Microbiological and physico-chemical assessment of surface water quality along Asukawkaw River in the Volta Region.
16. Xu, F.L., Jørgensen, S.E. and Tao, S. (1999). Ecological indicators for assessing freshwater ecosystem health. *Ecological Modelling*, vol. 116, no. 1, pp. 77-106.