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Assessment of the Physicochemical Quality of the Tilé River Water in Guinea : An Approach Based on the Water Quality Index (WQI)

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Abstract

Aquatic ecosystems play an important role in supporting local biodiversity through their abiotic components, which strongly influence species distribution and ecological functioning. To assess the ecological quality of the Tilé River, this study evaluated its physicochemical water quality using the Water Quality Index (WQI). Quarterly water sampling was conducted from 2023 to 2025 at five sampling stations selected along a longitudinal pollution gradient. A total of 11 physicochemical parameters were used as the basis for the assessment. The results yielded an overall WQI value of 29.74, corresponding to excellent water quality. Furthermore, the spatiotemporal variations in WQI revealed that upstream stations exhibited

good to excellent water quality during the rainy season, whereas a deterioration in water quality was observed at downstream stations during the dry season. This deterioration was associated with high concentrations of nitrite, nitrate, and iron ions, as well as turbidity, whose seasonal variations were highly significant. In view of these findings, complementary investigations based on biomonitoring using bioindicators are essential to better characterize the impact of pollution on water quality and aquatic communities.

Keywords: Water quality, pollution, WQI, Tilé River, Guinea

Introduction

Aquatic ecosystems are among the most productive and ecologically important components of the biosphere. They provide habitats for diverse biological communities, support essential ecological processes, and supply valuable resources for riparian populations, including water, fisheries, and agricultural resources (Foto et al., 2010). However, these ecosystems are increasingly threatened by anthropogenic activities, including urbanization, agricultural intensification, untreated wastewater discharge, dam construction, the introduction of non-native species, and eutrophication (Villanueva, 2004; Adjagodo, 2017). These pressures can alter water quality, disrupt ecological functioning, and threaten aquatic biodiversity. Climate change may further intensify these impacts by modifying hydrological regimes, water temperature, and pollutant dynamics.

In Guinea, freshwater ecosystems are essential to local livelihoods and socioeconomic activities. The Tilé River, one of the major watercourses crossing N'Zérékoré, is increasingly exposed to potential pollution from domestic wastewater, agricultural runoff, and urban activities. These inputs may alter its physicochemical characteristics and affect the ecological conditions required for aquatic organisms to survive and develop. Assessing the river's water quality is therefore essential to identify vulnerable sections and provide scientific information for sustainable water resource management.

Physicochemical monitoring is widely used to assess water quality through parameters such as temperature, pH, dissolved oxygen, electrical conductivity, turbidity, and nutrient concentrations. These variables reflect the influence of natural processes and human activities on aquatic environments and help identify potential sources of environmental degradation (Tshijik et al., 2016). However, interpreting individual parameters separately may provide an incomplete assessment of overall water quality. The Water Quality Index (WQI) addresses this limitation by combining selected physicochemical parameters into a single numerical

value, facilitating comparisons among sampling stations and seasons and the classification of water quality.

In this context, the present study aimed to assess the physicochemical quality of water in the Tilé River using the Water Quality Index (WQI). Specifically, it sought to characterize the physicochemical properties of the river water, analyze spatial and seasonal variations in environmental parameters, and determine the corresponding water quality classes. The findings are expected to contribute to improved environmental monitoring and support the sustainable management and protection of this freshwater ecosystem.

Methodology

Study area and data collection

The Tilé River is the main watercourse flowing through the city of N'Zérékoré, crossing the city from northeast to southwest over a distance of 10.6 km (Figure 1). The river originates in Galai, within the urban municipality of N'Zérékoré, and has a total length of approximately 33 km. N'Zérékoré is the only major city crossed by this watercourse before it flows into the Oulé River.

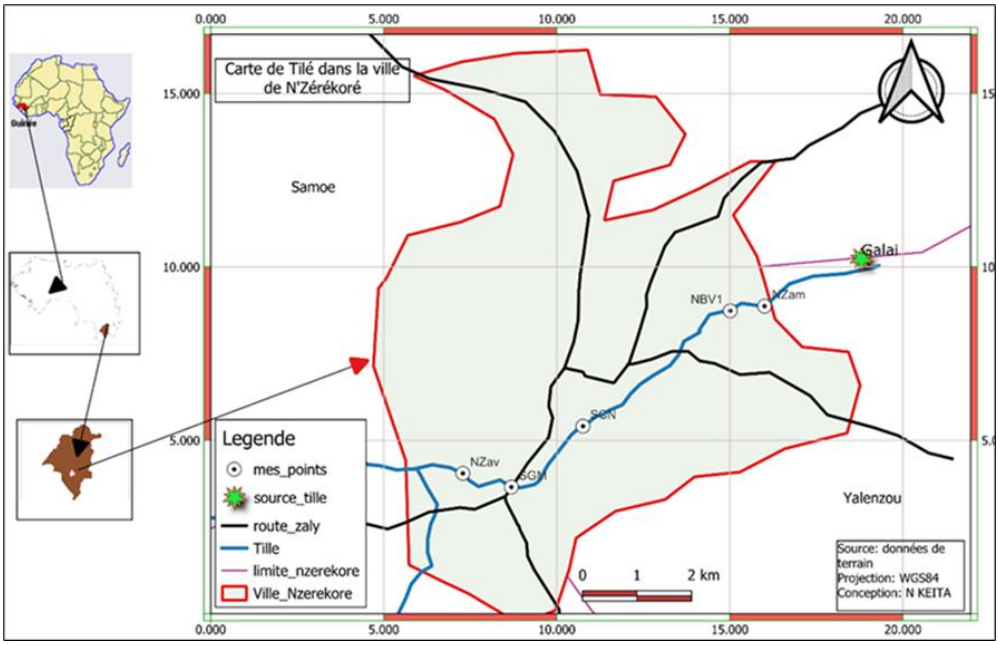


Figure 1 : Geographical location of the Tilé River and sampling stations

The watercourse flows through the following neighborhoods: Belle Vue, Dorota, Wessoua, Télépoulou, Kwitéyapoulou, Ossud, Mohomou, Gbangana, and Nakouyakpala. The river is fed by several tributaries,

including Linguéya (Mohomou), Zaly (Commercial), Konya (Tillépoulou), and Boréya (between Dorota and Horoya).

As part of this study, water samples were collected at five sampling stations distributed from upstream to downstream along the river (Table 1). The stations were selected based on their accessibility throughout the year, water depth, and pollution gradient, as indicated by the various human activities occurring along the riverbanks. At each station, geographic coordinates were recorded using a GARMIN GPS device (Table 1).

Data were collected quarterly over eight sampling periods between 2023 and 2025, taking into account the different hydrological seasons (dry and wet seasons) of the forest region where the river is located. The data comprised physical and chemical parameters measured both in situ and at the Analytical Chemistry Laboratory of the University of N'Zérékoré.

Table 1 : Characteristics of the sampling sites

Sampling site	Location			Pollution sources
	Altitude	Longitude	Latitude	
NZ AM	506.20m	-8.78620833	7.76560167	Upstream along the watercourse
NZ 01	504.80m	-8.79197833	7.76491000	Station with intensive agricultural activity on both banks
NZ 02	494.00m	-8.81644500	7.74586000	Station located near a commercial area
NZ 03	489.90m	-8.82843500	7.73584833	Station with intensive agricultural activity and increased pollution due to domestic wastewater
NZ AV	489.31m	-8.83643333	7.73816833	Downstream section of the watercourse

Physicochemical parameters, including temperature (T°), pH, dissolved oxygen (O_2), electrical conductivity (EC), and total dissolved solids (TDS), were measured in the field (in situ) using a waterproof HANA HI 98194 multiparameter meter (2015 version). Turbidity, nitrates ($N\text{-}NO_3^-$), nitrites ($N\text{-}NO_2^-$), iron (Fe), color, and total suspended solids (TSS) were analyzed in the laboratory using an AL450 photometer, following the analytical methods recommended by AFNOR (1997) and Rodier et al. (1996).

Calculation of the Water Quality Index (WQI)

The Water Quality Index (WQI) is a classification technique based on comparing water quality variables with international or Guinean national standards. The WQI summarizes large datasets on water quality into simple categories (Excellent, Good, Poor, Very Poor, etc.). In this study, the WQI was used to assess the influence of natural variables and anthropogenic factors based on key water quality parameters. Accordingly, six key parameters (pH, O_2, EC, T°C, $N\text{-}NO_2$, and $N\text{-}NO_3$) were selected for the

calculation of the Water Quality Index (WQI). The index was calculated using the weighted arithmetic index method described by Yidana and Yidana (2010). In this approach, a numerical value known as the relative weight (Wi), specific to each physicochemical parameter, was calculated using the following formula :

$$W_i = \frac{K}{S_i}$$

Where:

k: proportionality constant, which can also be calculated using the following equation:

$$\mathrm{K} = \frac{1}{\sum_{i=1}^{n} \frac{1}{S_i}}$$

n: number of parameters.

Si: maximum permissible value specified by the Guinean standard for surface water quality.

Next, a quality rating scale (**Qi**) is calculated for each parameter by dividing its measured concentration by the corresponding standard value and multiplying the result by 100, according to the following formula :

$$Q_I = \left(\frac{C_i}{S_I}\right) \times 100$$

Qi: quality rating scale for each parameter.

Ci: concentration of each parameter (mg/L).

Finally, the overall Water Quality Index (WQI) is calculated using the following equation:

$$IQE = \frac{\sum_{i=1}^{n}(W_i * Q_i)}{\sum_{i=1}^{n} W_i}$$

Based on the Water Quality Index (WQI), five water quality classes were identified according to the WQI values (Table 2) :

Table 2 : Water quality classification and potential uses based on the WQI (Aher et al., 2016)

WQI Class	Water Quality Category	Potential use
0 - 25	Good quality	Drinking water, irrigation, and industrial use
25 - 50	Poor quality	Drinking water, irrigation, and industrial use
50 - 75	Very poor quality	Irrigation and industrial use
75 - 100	Unsuitable for drinking	Irrigation
>100	Unsuitable for drinking	Appropriate treatment required before use

Results

Spatial trend of physicochemical data

The mean and range values (standard deviation, minimum, and maximum) of the physicochemical parameters measured in the river are presented in Table 3. The Shapiro-Wilk test performed on the environmental variables indicated a normal distribution ($p < 0.05$). Descriptive statistics showed slightly alkaline pH values, with mean values ranging from 6.84 to 7.31 and a maximum value of 7.80 recorded downstream.

Water temperature exhibited an increasing longitudinal gradient, with mean values increasing from upstream to downstream (26.05 to 28.61 °C). Dissolved oxygen concentrations were very low at all stations, with mean values ranging from 0.91 to 2.05 mg/L. A clear longitudinal gradient was observed, with lower values downstream.

Water mineralization was relatively low, as indicated by mean electrical conductivity values ranging from 92.88 to 272.50 µS/cm, with the highest value recorded in the central section of the river. Similarly, mean turbidity values were moderate, ranging from 16.77 to 25.58 NTU, particularly in the downstream section of the river.

Nitrite concentrations were generally low, with mean values ranging from 0.01 to 0.27 mg/L, the latter being recorded downstream. Nitrate concentrations, however, were relatively high, with mean values ranging from 0.01 to 6.46 mg/L. Nevertheless, the highest nitrate concentration (48.42 mg/L) was recorded in the upstream section of the river.

Regarding ferric iron (Fe^{3+}), concentrations were relatively high at all stations, with mean values ranging from 2.40 to 3.17 mg/L.

Table 3 : Descriptive statistics of physicochemical parameters

Stations/Parameters	NZ am	NZ 01	NZ 02	NZ 03	NZ AV
pH					
Mean	6,840	7,224	7,280	7,115	7,308
Standard deviation	0,687	0,293	0,354	0,335	0,564
Maximum	7,600	7,650	7,660	7,830	7,800
Minimum	5,510	6,140	6,650	6,620	6,700
Temperature (°C)					
Mean	26,051	26,844	27,891	28,396	28,609
Standard deviation	2,366	2,451	1,478	1,993	1,630
Maximum	30,600	30,780	29,550	30,700	30,600
Minimum	23,770	23,000	25,000	25,800	25,920
Oxygen (mg/L)					
Mean	1,606	2,009	0,907	1,098	2,051
Standard deviation	1,526	1,891	1,341	1,262	0,545
Maximum	5,800	3,560	3,400	3,250	2,950
Minimum	0,190	1,200	0,010	0,000	0,000
Conductivity (µS/cm)					
Mean	92,875	100,875	272,500	264,857	224,250
Standard deviation	47,153	44,408	39,141	58,252	27,426

Maximum	200,000	200,000	320,000	380,000	251,000
Minimum	46,000	55,000	191,000	182,000	178,000
TDS (mg/L)					
Mean	46,375	40,750	133,125	121,250	111,250
Standard deviation	22,902	9,627	20,040	25,302	11,830
Maximum	81,000	59,000	160,000	179,000	122,000
Minimum	23,000	27,000	96,000	91,000	89,000
Turbidity (NTU)					
Mean	17,536	19,499	25,579	18,306	16,774
Standard deviation	11,511	3,747	7,956	4,734	2,423
Maximum	44,330	27,600	41,900	28,200	21,600
Minimum	6,290	13,600	17,530	13,460	14,200
Total Suspended Solids (mg/L)					
Mean	52,400	21,500	23,500	20,656	11,750
Standard deviation	78,410	5,500	9,124	9,497	2,046
Maximum	254,000	35,000	42,000	32,000	14,000
Minimum	1,200	15,000	15,000	0,250	8,000
Nitrite (mg/L)					
Mean	0,023	0,010	0,079	0,049	0,274
Standard deviation	0,017	0,013	0,069	0,054	0,312
Maximum	0,041	0,032	0,190	0,130	0,940
Minimum	0,000	0,000	0,000	0,000	0,066
Nitrates (mg/L)					
Mean	6,459	0,006	0,163	0,015	0,580
Standard deviation	15,084	0,005	0,172	0,011	0,484
Maximum	48,425	0,010	0,400	0,025	1,250
Minimum	0,000	0,001	0,000	0,000	0,020
Iron (mg/L)					
Mean	2,574	2,401	2,725	2,494	3,170
Standard deviation	0,560	0,675	0,911	0,875	0,375
Maximum	3,050	3,400	4,500	3,990	3,850
Minimum	1,730	1,460	1,520	1,450	2,800
Color (HU)					
Mean	205,000	174,375	233,750	317,500	234,375
Standard deviation	80,351	49,335	67,070	146,948	83,869
Maximum	350,000	260,000	380,000	570,000	350,000
Minimum	100,000	100,000	150,000	130,000	120,000

Seasonal variation in environmental variables

Seasonal variations in the physicochemical parameters of the Tilé River water during the dry and rainy seasons across the different sampling periods are presented in Figure 2. The results of the Kruskal–Wallis test applied to these descriptors (Table 4) revealed that only nitrite, nitrate, iron, temperature, and color exhibited statistically significant seasonal variations ($p < 0.05$). For nitrite and nitrate ions, the highest concentrations were recorded during both the dry and rainy seasons of 2024. Similarly, water temperature exhibited a comparable seasonal pattern. Regarding iron, the

highest concentrations were recorded during the dry seasons of 2024 and 2025.

Table 4 : Summary of Kruskal-Wallis comparison test results regarding seasonal variations in physicochemical parameters

Paramètres	H	P	Significativité
pH	1,95	0,583	NS
Conductivity (µS/cm)	1,41	0,703	NS
TDS	2,16	0,539	NS
Turbidity	5,721	0,126	NS
Nitrite (mg/L)	10,317	0,016	***
Nitrate (mg/L)	14,963	0,001	***
Iron (mg/L)	9,191	0,026	***
Oxygen (mg/L)	7,409	0,059	NS
Temperature (°C)	19,915	0,001	***
TSS	2,937	0,401	NS
Color (CU)	11,508	0,009	***

SS = Dry season; SP = Rainy season; p = Kruskal-Wallis test result

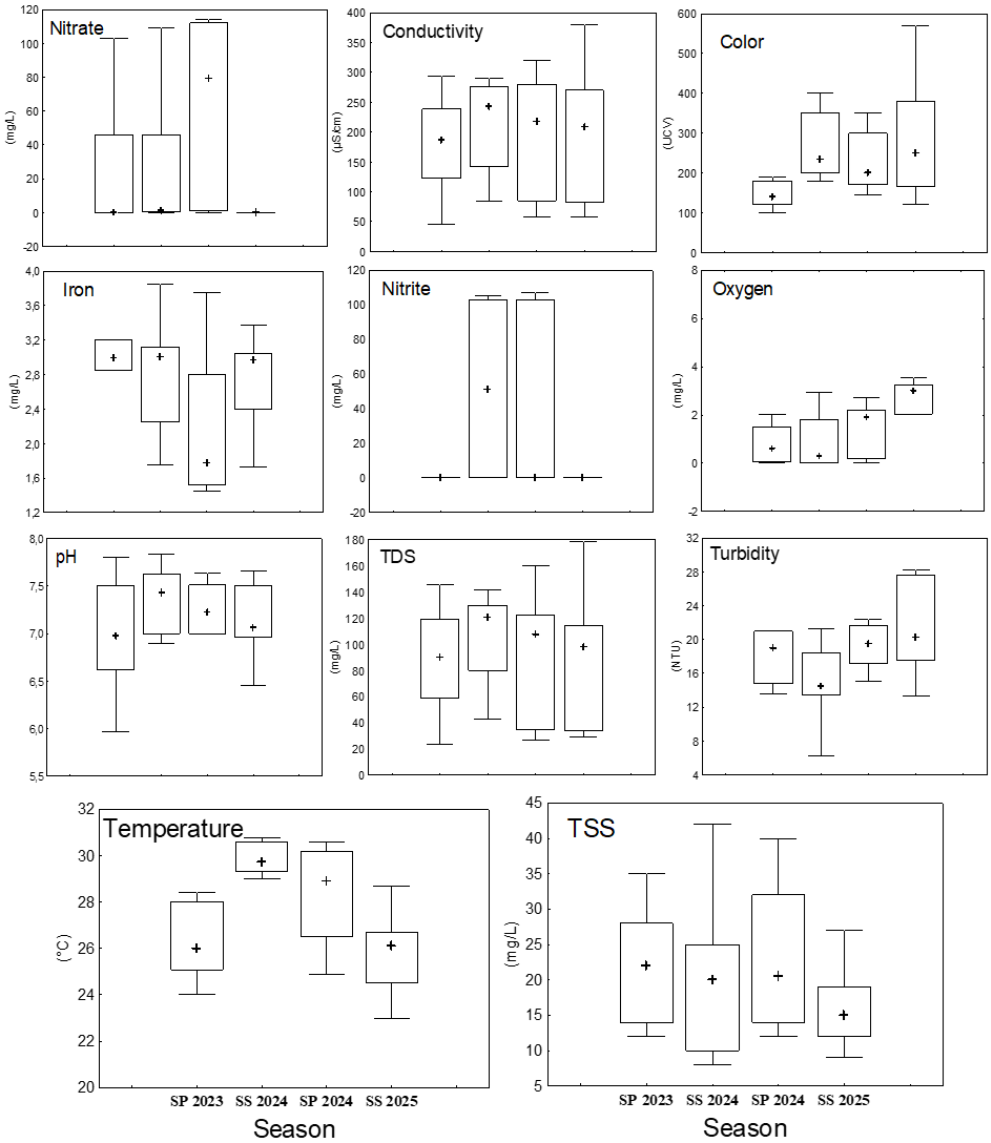


Figure 2 : Seasonal variations in the physical parameters of the Tilé River water

Determination of the WQI and assessment of water quality

The relative weight (Wi) of each physicochemical parameter and the proportionality constant (k) were first calculated using the maximum values from WHO standards combined with Guinean water standards for the physicochemical parameters studied (Table 5). Analysis of the table shows a proportionality constant (K) of 0.338 and a Water Quality Index (WQI) of 29.74.

Following the calculation of the Water Quality Index (WQI) based on physicochemical analysis results and the standard values from the 2011

WHO drinking-water quality guidelines, the water quality class of the Tilé River was determined for the five sampling stations. Five water quality classes (excellent, good, poor, very poor, and non-potable) were identified across the seasonal sampling campaigns conducted in 2023, 2024, and 2025 (Table 5).

Table 5 : Weighting of physicochemical parameters and 2011 WHO standard

Paramètres	**Standard OMS**	**Si**	**1/Si**	**Ci**	**Wi**	**Qi**	**Wi+Qi**
pH	6- 9	8,0	0,125	7,4	0,042	92,50	3,910
Conductivity (µS/cm)	< 1125	1125,0	0,001	82	0,001	7,29	0,000
TDS	50	50,0	0,020	41	0,007	82,00	0,560
Turbidity	35	35,0	0,028	20,03	0,009	57,23	0,550
Nitrite (mg/L)	0.015	0,5	2,000	0	0,676	0,00	0,000
Nitrate (mg/L)	50	50,0	0,020	0,001	0,007	0,00	0,000
Iron (mg/L)	2	2,0	0,500	2,4	0,169	120,00	20,310
Oxygen (mg/L)	≥ 5	5,0	0,200	2,04	0,068	40,80	2,760
Temperature (°C)	25	25,0	0,040	26,7	0,014	106,80	1,450
TSS	< 50	50,0	0,020	15	0,007	30,00	0,200
Total			2,954		1	**IQE**	**29,74**
		k=1/Σ (1/Si)	0,338				

Temporally, during the 2023 rainy season (RS), the WQI ranged from 17.44 to 34.89, corresponding to water quality classes ranging from good to excellent at most sampling stations. During the 2024 dry season (DS), two water quality classes were identified, with WQI values showing an increasing trend from 34.88 (good quality) to 139.73 (unsuitable for drinking). Conversely, during the 2024 rainy season (RS), WQI values showed a decreasing trend, with the water quality class improving from poor (73.16) to excellent (14.99). Finally, during the 2025 dry season (DS), a deterioration in water quality was observed, with WQI values ranging from 23.54 (excellent quality) to 81.47 (very poor quality).

Spatially, station NZ 01 exhibited relatively stable water quality across the study seasons, changing from excellent quality in 2023 to good quality in 2024, before returning to excellent quality in 2025. In contrast, station NZ AM showed moderate fluctuations in WQI values across the seasons, with a relatively low peak value of 49.93 recorded during the 2024 dry season. Station NZ 02, located in the city center, experienced a marked deterioration in water quality, changing from good quality in 2023 to poor quality in 2024 and very poor quality in 2025. Finally, stations NZ 03 and NZ AV showed a severely degraded condition, with occasional periods of good water quality. However, the WQI reached a peak of 139.73 at NZ AV in 2024, indicating water unsuitable for drinking and highly unfit for human consumption.

The non-parametric Kruskal–Wallis test performed on WQI values among sampling sites confirmed significant differences ($H = 13.94$, $p = 0.008 < 0.05$). In contrast, no statistically significant difference was observed among WQI values across the different sampling seasons from 2023 to 2025 ($p = 0.41 > 0.05$). These results indicate that water quality was more strongly associated with spatial differences among sampling sites than with temporal variation over the study period.

Table 6 : IQE index values and water quality class of the Tilé River during the sampling periods

Stations	SP 2023	Quality Class	SS 2024	Quality Class	SP 2024	Quality Class	SS 2025	Quality Class
NZ am	27,735	Excellent quality	49,935	Good quality	20,65	Excellent quality	23,545	Excellent quality
NZ 01	17,445	Excellent quality	34,88	Good quality	14,995	Excellent quality	30,245	Good quality
NZ 02	34,89	Good quality	35,695	Good quality	73,165	Poor quality	55,7	Poor quality
NZ 03	31,205	Good quality	40,115	Good quality	58,01	Poor quality	81,475	Very poor quality
NZ av	35,92	Good quality	139,735	Non-potable water	63,21	Poor quality	44,035	Good quality

Discussion

This study assessed the physicochemical quality of water in the Tilé River using the Water Quality Index (WQI) and revealed spatial and seasonal variations in all the descriptors considered. Regarding spatial trends, the mean pH values indicated a slight tendency toward alkalinity, particularly in the downstream section of the river. This pattern may result from alkaline discharges, probably originating from domestic wastewater associated with commercial and agricultural activities carried out by populations living around these stations. In an initial physicochemical characterization of the Tilé River based on a three-month sampling campaign, Keita *et al.* (2025) reported similar results, consistent with the findings of Viaho *et al.* (2020), who observed that these pH values were not unfavorable to aquatic life.

The relatively low temperatures recorded along the river may be explained by the location of the river in the forest region of Guinea, which is characterized by dense vegetation cover that reduces solar radiation through the existing canopy. However, an increase in temperature toward the downstream section was observed, probably due to urbanization and the removal of trees for various purposes. Regarding mineralization-related parameters (electrical conductivity, TDS, and nitrogenous compounds), their

concentrations were generally low across the sampling stations, possibly due to the inflow of water into the system, which contributes to their dilution. Nevertheless, a relative increase in the concentrations of these parameters was observed at the central and downstream stations, probably as a result of nutrient-rich runoff from upstream areas and domestic and livestock inputs, which strongly influence the water characteristics of rivers (Derwich *et al.*, 2010; Camara *et al.*, 2014).

Dissolved oxygen concentrations were consistently very low, indicating hypoxic to near-anoxic conditions, probably resulting from the continuous decomposition of organic matter. Such conditions may negatively affect aquatic biodiversity (Mukwita Ntwabwa *et al.*, 2023). Finally, turbidity and water color varied significantly, with higher values recorded downstream. This pattern suggests a substantial organic pollutant load associated with agricultural practices, household waste, pig farming, and deforestation. These factors may promote the proliferation of potentially toxin-producing algae, thereby altering the trophic balance within aquatic communities of the river.

Regarding the temporal variation in the parameters investigated, the results showed that only nitrite, nitrate, iron, temperature, and color exhibited highly significant seasonal variation. Nitrite concentrations were low at all stations but showed a peak during the dry season, probably due to the rapid oxidation of nitrite into nitrate. Similarly, nitrate and ferric iron concentrations were higher during the dry seasons and may be associated with intensified denitrification processes (Groga, 2012), as well as soil erosion from iron-rich soils and the high prevalence of mining activities in the region. Furthermore, given the slightly alkaline nature of the water observed during the study, the low concentrations recorded during periods of high flow may be related to the volatilization of NH_4^+ into NH_3 (Tchobanoglous *et al.*, 2003). Regarding temperature, the highest values were recorded during the dry season, whereas the lowest values occurred during the rainy season. These findings are consistent with observations reported by Zinsou (2017) in the Ouémé Delta. Nevertheless, the mean water temperatures recorded in the Tilé River fall within the ecological preferences of many aquatic organisms and may therefore support their growth and development, as physiological processes such as oxygen consumption, feeding, and the activity of certain enzymes are influenced by water temperature (Covich *et al.*, 1999).

The overall Water Quality Index (WQI) value was 29.74, corresponding to excellent water quality according to the classification adopted in this study. Considering the spatiotemporal variation in WQI values, the upstream stations, NZ AM and the station located near the source, NZ 01, fell within the good-to-excellent water quality range during the 2023

and 2024 rainy seasons. This finding suggests relatively low environmental impacts and a moderate influence of the different descriptors considered. In contrast, during the dry seasons of 2024 and 2025, WQI values ranged from good to very poor quality, and even to water unsuitable for drinking, particularly at the central station NZ 02 and the downstream stations NZ 03 and NZ AV, indicating a deterioration in water quality.

This deterioration may be related to higher concentrations of nitrogenous nutrients resulting from reduced water dilution, on the one hand, and increased anthropogenic pressures, on the other. A slight improvement in WQI at certain downstream stations was also observed, which may indicate a temporary tendency toward ecosystem recovery through self-purification, potentially associated with water dilution. However, this improvement appears short-lived because of the strong urbanization and associated anthropogenic pressures in these sections of the river. These results are similar to those of Talhaoui et al. (2020) regarding the surface waters of the Moulouya River (Northeastern Morocco), where seasonal variation in the WQI is characterized by an increase in the mean, minimum, and maximum values of all physicochemical parameters studied from March (end of winter) to August (summer), thereby reducing overall water quality.

Conclusion

Overall, the analysis of the results showed that the Tilé River is subject to substantial anthropogenic pressures that alter its water quality. The assessment of water quality using the Water Quality Index (WQI), based on the different environmental descriptors measured, revealed marked spatial and temporal variations in water quality, thereby providing insights into the ecological functioning of the river. The WQI showed relatively pronounced seasonal variations, with generally excellent water quality in the upstream section during the rainy season, followed by a progressive deterioration downstream during the dry season. This deterioration was associated with high concentrations of nitrate and iron ions, hypoxic conditions, and inputs of domestic and agricultural wastewater.

Given the importance of these findings, particular attention should be paid to preserving aquatic biodiversity and water quality, which supports a wide range of uses for local populations that depend on this resource.

Further investigations should focus on assessing the composition and structure of aquatic fauna and flora to better characterize the impacts of pollution on aquatic biodiversity and provide a more comprehensive assessment of the ecological quality of the Tilé River.

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