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(Research Article)

Phytoplankton Dynamics in the Bafing River under Artisanal Gold Mining Pressure, Côte d'Ivoire

Roméo N'Guessan LOZO *, Siaka BERTE and Yao Sinaï KOUAME

Laboratory of Natural Environments and Biodiversity Conservation, UFR Biosciences, Félix Houphouët-Boigny University, 22 BP 582 Abidjan, Côte d'Ivoire.

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Abstract

The Bafing River, the main right-bank tributary of the Sassandra River, was investigated to characterize its physicochemical parameters and phytoplankton community. Located in northwestern Côte d'Ivoire, this study aimed to assess the diversity, composition, and spatial distribution of phytoplankton in the Sassandra River basin. Physicochemical parameters (pH, temperature, conductivity, and dissolved oxygen) were measured in situ using a HANNA portable multiparameter device (model HI9828), while phytoplankton samples were collected with a 20 µm mesh plankton net from April to December 2022. Qualitative analysis identified 82 taxa distributed across 35 genera, 17 families, 12 orders, 9 classes, and 5 phyla. Chlorophyta (56.09%) and Euglenophyta (17.07%) were the most diverse groups, followed by Heterokontophyta (14.63%), Cyanoprokaryota (9.75%), and Dinophyta (3.65%). Spatially, the highest algal densities were observed at the Gorlo station and Lac Ranch (downstream), while the lowest densities were recorded upstream, notably at the Min, Bafing, and Godigui stations. Physicochemical analysis indicated relatively cool, acidic, and relatively oxygenated waters. These results provide an essential reference for ecological monitoring and water quality assessment of the Bafing River, particularly under anthropogenic pressures such as artisanal gold mining.

Keywords: Diversity; Phytoplankton; Gold mining; Bafing River; Côte d'Ivoire

1. Introduction

Freshwater biodiversity is a vital ecological heritage and provides essential food, economic, cultural, and educational resources, yet it is often undervalued [1]. In northwestern Côte d'Ivoire, ecosystems face increasing pressures from floodplain inundation and mining activities, with the region rich in minerals such as gold, nickel, and iron (Mont Nimba and Mont Gao) [2]. The Bafing River, a major tributary of the Sassandra River, is impacted by human settlements, mining, and large-scale agricultural plantations of cashew, maize, cotton, and beans. These activities can alter its biodiversity, particularly microalgae, which are among the first organisms to respond to pollution and environmental changes [3]. Phytoplankton play a central role in energy transfer and nutrient cycling in aquatic food webs [4]; [5]. This study aims to assess the diversity and composition of phytoplankton in the Bafing River, providing baseline data for ecological monitoring and water quality evaluation under anthropogenic pressures, particularly mining.

2. Materials and Methods

2.1. Study Area

The Bafing River, located between 7°09' and 8°01' N latitude and 7°02' and 7°86' W longitude, is a transboundary river between Côte d'Ivoire and Guinea. Approximately 280 km long, it is the main right-bank tributary of the Sassandra River

* Corresponding author: Roméo N'Guessan LOZO

and originates in Guinea. The river flows from west to east, joining the main course of the Sassandra River within the Mont Sangbé National Park. Its course is sinuous and interrupted by numerous rapids, with an average slope of 3.14% [6]. Five sampling stations were selected based on several criteria, including accessibility. These include the main course of the Bafing River and four of its tributaries: the Min, Gorlo, Godigui, and the river locally known as “Lac Ranch” (Figure 1).

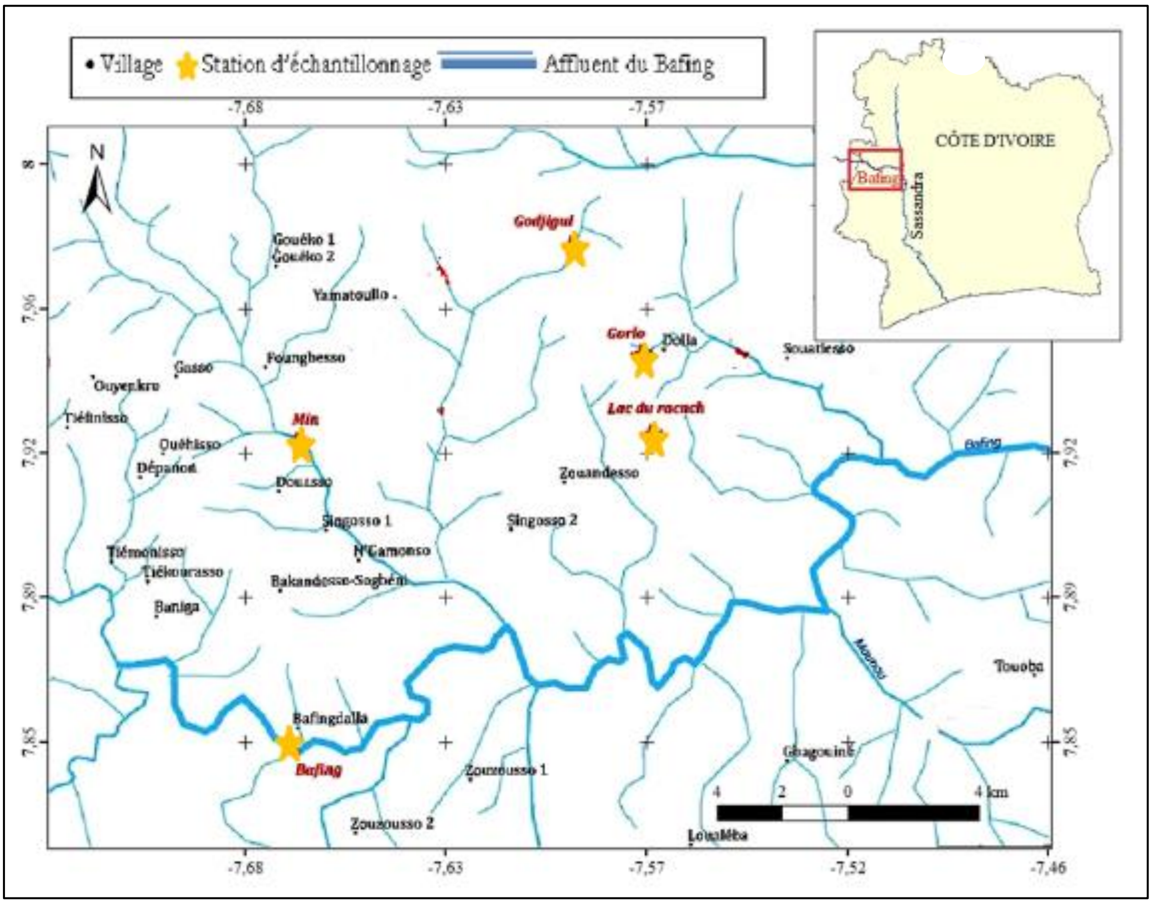

Figure 1 Location of the sampling stations in the Bafing River basin, Côte d’Ivoire

2.2. Measurement of Environmental Variables

At each station, the following physicochemical parameters were measured in situ: dissolved oxygen, pH, temperature, total dissolved solids (TDS), and conductivity. Measurements were conducted using a HANNA portable multiparameter device (model HI9828). Water transparency was assessed using a Secchi disk.

2.3. Phytoplankton Sampling and Observation

Phytoplankton samples were collected from April to December 2022 using a 20 µm mesh plankton net. The sampling procedure consisted of two steps: filtering five 10-liter buckets of water through the plankton net, followed by direct water collection from the environment using a sampling bottle. The collected samples were examined under a light microscope equipped with a 40× objective and a camera. Each taxon was photographed using the microscope camera and identified with reference to multiple sources: [7], [8], [9], [10], [11], [12], [13], and [14]. For all illustrations, the scale bar represents 10 µm. Taxonomic descriptions followed the classification system proposed by [15].

3. Results

3.1. Variation of Physico-Chemical Parameters

The physicochemical measurements conducted across the different stations of the Bafing River indicate slightly acidic to neutral, relatively cool and oxygenated waters. The mean pH was 6.78 ± 0.32, suggesting a slightly acidic environment consistent with freshwater ecosystems minimally impacted by alkaline effluents. Water temperature remained relatively low, with an average of 22.12 ± 1.56 °C, likely influenced by tributaries and riparian vegetation shading. The mean conductivity was 74.34 µS/cm, ranging from 61.3 to 97.6 µS/cm, indicating low mineralization and moderate dissolved ion content, typical of rivers in forested or minimally urbanized regions. Total dissolved solids (TDS) ranged from 40.2 to 65.5 mg/L, with a mean of 53.86 mg/L, confirming the low mineralization levels. Dissolved oxygen concentrations were relatively high, averaging 6.09 ± 1.71 mg/L, reflecting good biological support capacity and low pollutant load. Water transparency, measured using a Secchi disk, varied between bottom visibility and 100 cm across stations, reflecting moderate turbidity likely associated with suspended materials or local anthropogenic activities (Table 1).

Table 1 Mean Physicochemical Parameters of the Bafing River and Its Tributaries

Stations	Temp (°C)	O_2 (mg/L)	pH	CND (µS/cm)	TDS (mg/L)	Trans (cm)
Gorlo	21,5	7,98	7,3	61,3	58,2	Fond visible
Lac du ranch	25,8	4,17	6,55	61,5	40,2	100
Min	20,2	6,8	6,64	87	57,1	70
Bafing	21,8	4,37	6,9	64,3	48,3	90
Godigui	21,3	7,13	6,55	97,6	65,5	Fond visible
Moy.	22,12	6,09	6,788	74,34	53,86	-

3.2. Taxonomic Composition of the Phytoplankton Community

The taxonomic study revealed that the algal flora of the Bafing River comprises 82 taxa, distributed across 35 genera, 17 families, 12 orders, 9 classes, and 5 phyla (Table 2). Chlorophyta were the most diverse group with 46 taxa (56.09 %), followed by Euglenophyta (14 taxa, 17.07 %), Heterokontophyta (12 taxa, 14.63 %), Cyanoprokaryota (8 taxa, 9.75 %), and Dinophyta (3 taxa, 3.65 %) (Figure 2). Regarding the spatial distribution of taxa (Figure 3), the Lac Ranch and Gorlo stations exhibited the highest diversity with 46 taxa each (36.22 %), whereas the Min station had 14 taxa (11.02 %). The Bafing and Godigui stations were less diverse, with 12 (9.44 %) and 10 taxa (7.87 %), respectively. The dominance of Chlorophyta and Euglenophyta reflects typical freshwater conditions, with algal communities adapted to the observed physicochemical parameters (slightly acidic pH, moderate oxygenation, and low conductivity). The higher taxonomic richness at Lac Ranch and Gorlo, located downstream, likely results from favorable conditions such as greater depth, higher nutrient availability, and reduced direct human disturbance compared to upstream sites. In contrast, the upstream stations (Min, Bafing, and Godigui) showed lower diversity, possibly due to higher flow rates, increased turbulence, and lower nutrient accumulation, which can limit phytoplankton development.

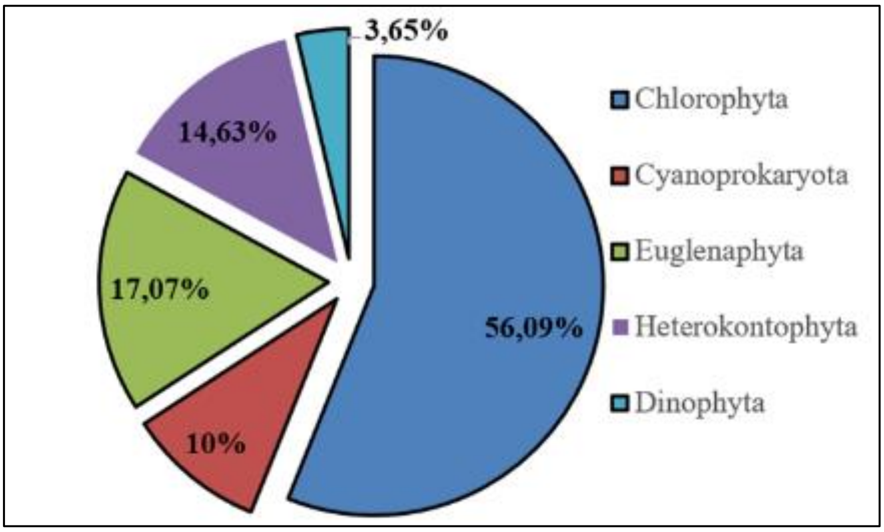

Figure 2 Proportion of Phytoplankton Phyla Observed in the Bafing River

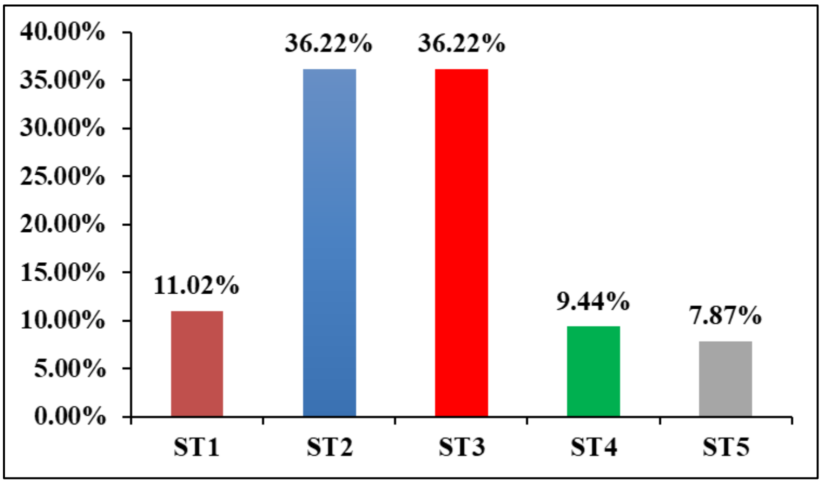

Figure 3 Distribution of Phytoplankton Taxa Across Sampling Stations

Table 2 List of taxa recorded at the different stations of the Bafing River (Côte d'Ivoire)

Taxons	**F**	**ST1**	**ST2**	**ST3**	**ST4**	**ST5**
CYANOPROKARYOTA Anagnostidis komárek						
Cyanophyceae Sachs						
Chroococcales Wettstein et Westerheim						
Chroococcaceae Nägeli						
Chroococcus dispersus (Keissler) Lemmermann	*		X			
Microcystaceae Elenkin	*					
Microcystis aeruginosa (Kützing) Kützing	*		X			
Microcystis wesenbergii Komárek	*		X			
Nostocales (Borzi) Gétler						
Nostocaceae Dumortier						
Anabaena sp.	**	X		X	X	X
Oscillatoriales Elenkin						
Oscillatoriaceae (Gray) Bory de St. Vincent						
Oscillatoria mougeotii (Kützing) *Lemmermann*	*			X		
Oscillatoria sp.	*			X		
Spirulina major Kützing ex Gomont	*			X		
Spirulina princeps West & G.S. West	*			X		
Chlorophyta Cavalier-Smith						
Chlorophyceae Wille in Warming						
Sphaeropleales Luerssen						
Scenedesmaceae Oltmanns						
Actinastrum gracillimum G. M. Smith	*		X			
Crucigenia quadrata Morren	*		X			
Crucigenia tetrapedia (Kirchner) W. G. S. West	*		X			

Crucigeniella apiculata Morren	*		X			
Crucigeniella crucifera (Wolle) *Collins*	*		X			
Crucigeniella fenestrata (Schmidle) *Schmidle*	*		X			
Crucigeniella neglecta (Fott & Ettl) *Komárek*	*		X			
Desmodesmus quadricaudata (Turpin) Hegewald	*		X			
Desmodesmus opoliensis var. *mononensis* (Chodat) Hegewald	*		X			
Scenedesmus quadricauda (Turpin) *Brébisson var. quadricauda*	*		X			
Scenedesmus quadrispina	*		X			
Scenedesmus sp.	*		X			
Trebouxiophyceae						
Chlorellales						
Chlorellaceae						
Acanthosphaera sp.	*		X			
Dictyosphaerium pulchellum Van Goore	*		X			
Zygnematophyceae Van Den Hoek et al.						
Chlorococcales Pascher						
Hydrodictyaceae (Gray) Dumortier						
Monactinus simplex Meyen	**		X	X	X	
Monactinus simplex var. *clathratum* (Schrot)	***	X	X	X	X	
*Monactinus simple*x var. *duodenarium* (Bail) Rabenh	***	X	X	X		X
Monactinus simplex var. *echinulatum* Wittrock	**		X	X		
Monactinus simplex var. simplex Meyen	***		X			
Monactinus simplex var*. sturmii echinulaum*	*		X	X	X	X
Crucigeniella neglecta (Fott & Ettl) Komárek	*		X			
Conjugatophyceae Engler						
Desmidiales Bessey						
Closteriaceae Bessey						
Schroederia nitzschioides (G. S. West) Korshikov	*			X		
Closterium abruptum W. West var. *brevius* W. & G.S. West	*			X		
Closterium cynthia De Notaris	*			X		
Closterium eboracense Turner	*			X		
Closterium lineatum var. *africanum* (Schmidle) Krieger	*			X		
Closterium rostratum Ehrenberg	*			X		
Closterium setaceum Ehrenberg ex Ralfs	*			X		
Closterium strigosum Brébisson var. *elegans* (G.S. West) Krieger	*			X		
Closterium tumidum Johnson var*. nylandicum* Grönblad	*			X		
Closterium venus (Kützing) *Ralfs*	*			X		
Cosmarium contractum Kirchner var*. minutum* (Delp.) West et West	*			X		

Cosmarium trilobulatum Reinsch	*			X		
Staurastrum boreale W. & G.S. West	*		X			
Staurastrum brachioprominens Borge var. *archerianum* Bohlin	*		X			
Staurastrum forficulatum Lundell var. *minus* (Fritsch & Rich)	*		X			
Staurastrum gladiosum Turner	*		X			
Staurastrum tetracerum Ralfs	*		X			
Staurastrum volans W. et G. S. West	*		X			
Staurastrum sp.	*		X			
Staurastrum sp.1	*		X			
Staurastrum sp.2	*		X			
Staurodesmus glaber Teiling	*		X			
Staurodesmus mamillatus (Nordsted) Teiling	*		X			
Teilingia granulata (Roy et Bisset) Bourrelly	*		X			
Peniaceae Haeckel						
Gonatozygon pilosum Wolle	*			X		
Euglenophyta Pascher						
Euglenophyceae Schoenichen						
Euglenales Engler						
Euglenaceae Stein						
Euglena proxima (Dangeard) Lemmermann	**		X	X		
Lepocinclis acus (Müller) Marin et Melkonian	**		X	X		
Lepocinclis ovum (Ehrenberg) Lemmermann	**			X	X	
Lepocinclis ovum var. *bütschlii* (Lemmermann) Conrad	**			X	X	
Lepocinclis turbiniformis Deflandre	*			X		
Lepocinclis sp.	**			X		X
Phacus longicauda var. *tortus* Lemmermann	**		X	X		
Phacus lefevrei Bourrelly	**		X	X		
Phacus platalea Drezepolski	*		X	X		
Phacus swirenkoi Skvortzov	**	X		X		
Trachelomonas hispida var. *duplex* Deflandre.	***	X	X	X		
Trachelomonas hispida (Perty) Stein *emend*. Deflandre	***	X	X	X		
Trachelomonas similis Stokes	***	X	X	X		
Trachelomonas Ehrenberg (sp)	**		X	X		
HETEROKONTOPHYTA VAN DEN HOEK ET AL.						
Diatomophyceae Rabenhorst						
Centrales Schütt						
Gomphonemataceae Kützing						
Gomphonema affine Kützing	**	X		X	X	

Gomphonema sp.1	**	X		X		
Pennales Schütt						
Fragilariaceae Hustedt						
Fragilaria crotonensis Kitton	***	X		X	X	X
Fragilaria ulna (Nitzsch) Lange-Bertalot	***	X		X	X	X
Ulnaria ulna var. *acus* (Kützing) Lange-Bertalot	***	X		X	X	X
Naviculaceae Kützing						
Craticula halophila (Grunow ex Van Heurck) Mann	***	X		X	X	X
Frustulia rhomboides (Ehrenberg) De Toni	***	X		X	X	X
Pinnularia major (Kützing) Rabenhorst	**	X		X		
Surirellaceae Kützing						
Surirella elegans Ehrenberg	**	X		X		
Xanthophyceae Allorge ex Fritsch						
Mischococcales Fritsch						
Centritractaceae Pascher						
Centritractus belonophorus Lemmermann	*		X			
Ophiocytiaceae Lemmerman						
Ophiocytium capitatum Wolle	*		X			
Dinophyta Bütschli						
Dinophyceae Pascher						
Peridiniales Haeckel						
Peridiniaceae Ehrenberg						
Bagredinium crenulatum	*		X			
Peridinium sp.	*		X			
Peridinium cunninglonii (O. Müller) Ehrenberg	*		X			
TOTAL = 82		14	46	46	12	10

F: occurrence frequency; ***: constant taxon, **: accessory taxon; *: accidental taxon; x: presence of taxa; ST1: Min; ST2: Gorlo; ST3: Lac Ranch; ST4: Bafing; ST5: Godigui

3.3. Occurrence Frequency

The occurrence frequency, or percentage of appearance, of taxa recorded across the different stations of the Bafing (Table II) allowed their classification into three categories: constant (14.63 %), accessory (26.82 %), and accidental (58.52 %). The constant taxa include: *Anabaena* sp., *Fragilaria crotonensis* Kitton, *Trachelomonas similis* Stokes, *Trachelomonas hispida* (Perty) Stein emend. Deflandre, *Trachelomonas hispida* var. *duplex* Deflandre, *Pediastrum simplex* var. *duodenarium* (Bail) Rabenh., *Pediastrum simplex* var. *clathratum* (Schrot), and *Pediastrum simplex* var. *simplex* Meyen. This classification highlights the most representative and stable taxa in the Bafing River, which are likely to play key ecological roles in structuring and sustaining the local phytoplankton communities.

4. Discussion

The mean surface water temperature of the Bafing River (22.12 °C) is relatively low, reflecting a slight cooling during the dry season. These results are consistent with [16], who reported that temperatures in Ivorian rivers rarely fall below 25 °C, particularly in northern rivers and mountain streams such as the Bafing. The observed decrease may also be influenced by tributaries and riparian vegetation that moderate the river's thermal regime. Measured pH values at all stations were below 7, indicating slightly acidic conditions. This acidity may result from local biological activities, as microbial decomposition of organic matter produces organic acids, including through fermentation processes, which lower water pH. Moreover, the relatively high dissolved oxygen concentration (6.09 ± 1.71 mg/L) is consistent with the lotic nature of the river, where water flow promotes gas exchange at the air–water interface [17]. The average conductivity (74.34 µS/cm) and moderate TDS (53.86 mg/L) indicate that Bafing River waters are weakly mineralized. This low mineralization may be due to limited ion input and evaporation, which can concentrate existing ions [18].

Regarding phytoplankton, 82 taxa were identified, distributed across 35 genera, 17 families, and 5 phyla. This taxonomic richness is high for a single sampling campaign and may be attributed to dry-season and Harmattan conditions, which favor water stagnation and allow complete reproductive and developmental cycles of microalgae. High diversity may also reflect nutrient enrichment from anthropogenic inputs, as reported by [18] for the Bia and Agnéby rivers. Rich algal composition often indicates relative ecosystem stability in the face of environmental disturbances [19]. The Lac Ranch and Gorlo stations, each with 46 taxa, exhibited the highest diversity, while Min, Bafing, and Godigui stations were less diverse, with 14, 12, and 10 taxa, respectively. This spatial variation may be linked to watershed land use. Rich stations are influenced by large industrial plantations, factories, manganese washing stations, artisanal gold mining, and urban wastewater inputs, which promote microalgal growth. In contrast, less diverse stations receive fewer organic and mineral inputs. The dominance of Chlorophyta and Euglenophyta is characteristic of environments rich in decomposable organic matter, influenced by agricultural, industrial, and domestic effluents. Genera such as *Scenedesmus* and *Pediastrum* are well known for their affinity to eutrophic waters sensu lato [20]. Classification of taxa based on occurrence frequency showed a majority of accidental taxa (48), followed by accessory taxa (22) and constant taxa (12). The predominance of accidental taxa may result from passive transport via runoff, fishing nets, or detachment of fixed taxa. Constant taxa, in contrast, reflect their ability to adapt to hydrological and physicochemical variations, while accessory taxa indicate intermittent influence from anthropogenic disturbances that limit their permanent presence.

In summary, the physicochemical characteristics and phytoplankton composition of the Bafing River indicate a relatively healthy ecosystem, albeit strongly influenced by human activities, particularly agriculture and artisanal gold mining, which locally affect microalgal diversity and distribution. These results provide an essential baseline for ecological monitoring and water quality assessment of the river.

5. Conclusion

The study of the Bafing River allowed for the characterization of its physicochemical parameters and phytoplankton composition. The waters are slightly acidic, weakly mineralized, relatively oxygenated and moderately warm, indicating a relatively healthy environment. The phytoplankton community is rich, with 82 taxa distributed across five phyla, and the dominance of Chlorophyta and Euglenophyta reflects environments enriched in organic matter. The spatial distribution of taxa shows that downstream stations, more exposed to anthropogenic activities such as agriculture, artisanal gold mining, and urban effluents, exhibit higher diversity than upstream stations. The predominance of accidental taxa suggests a significant influence of environmental disturbances and passive transport. These results provide a solid reference for ecological monitoring and water quality assessment of the Bafing River under increasing anthropogenic pressures.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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