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Assessment of the physico-chemical quality of the Bandama water River at Lamto Scientific Reserve (West Africa, Côte d'Ivoire)

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Abstract

The Bandama water River at Lamto Scientific Reserve plays a vital role in protecting and renewing fish stocks. Indeed, the part of this river shelters spawning grounds zones of fish, allowing them to replenish their stocks. Besides this importance, the water quality is subject to the human activities effects carried out upstream of the river. The aim of this study was to assess the water quality from the parameters determined. Ten physico-chemical parameters (Temperature, dissolved oxygen, pH, Total Dissolved Solids, electrical conductivity, Transparency, NO_2^-, NO_3^-, NH_4^+ and PO_4^{3-}) were measured at three stations from March 2021 to February 2022. These data were subjected to statistical analysis to highlight the spatial variability and seasonal variation of the parameters studied, as well as their contribution to the discrimination of stations. Data were compared with the existing standard values. The results did not reveal significant variability in the physico-chemical parameters distribution depending on the stations. However, the water studied exhibits poor quality during the rainy seasons. In addition, this water is warm, basic, cloudy, and less oxygenated. The nutrient salt concentrations of nitrite, nitrate, and ammonium tend towards the tolerable standard indicated to trigger eutrophication of the environment. However, the orthophosphate contents are well above the indicated standard. These salt contents, if they increase, could have a direct influence on water pollution by the mass development of plants. These results challenge managers and planners about the water quality degradation in this part of the Bandama River, which is supposed to be protected.

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Introduction

Water is a natural resource essential for life in any ecosystem (Tampo *et al.*, 2015). Maintaining its quality is a major concern for a society that has to meet increasing water needs (Foto *et al.*, 2011). It plays a very important role in socio-economic development at local, regional, and national levels. Thus, water resources are a major concern in African countries as they are absolutely essential for the development of human activities, economic and social. Lévêque and Paugy (1999) point out that continental hydro systems are particularly affected by anthropogenic activities taking place both in the aquatic environment and in the catchment area. According to Wootton (1992), the resulting living conditions could be unfavourable for aquatic species.

In Côte d'Ivoire, despite many services rendered to the population, the Bandama River, which is entirely Ivorian (Iltis and Lévêque, 1982) and considered the most important in the country, does not escape this sad reality. According to Halle and Bruzon (2006), like the other rivers and reservoirs, the Bandama River shows signs of eutrophication characterized by the presence of invasive plants. This observed phenomenon is due to the fact that this river is subject to several anthropogenic pressures. Indeed, the main course of the Bandama River is under the influence of two large hydroelectric dams (Kossou, Taabo), several hydro-agricultural, agro-pastoral dams, and illegal gold mining activities. Industrial and agricultural activities using chemical fertilizers and pesticides are noted in the watershed of this river(Halle et Bruzon, 2006).

These activities lead to risks of water degradation in quantity and quality. The Bandama River at the Lamto Scientific Reserve is facing all these anthropogenic pressures. Indeed, this part of the river, which is supposed to be protected, is not immune to the effects of gold mining carried out upstream and the agricultural practices of the riparian population.

To our knowledge, no study relating to water quality has been carried out on the Bandama River at the Lamto Scientific Reserve. Taking into account the fact that in conditions of total absence of hygiene and sanitation measures, the ecotoxicological risks are high, the water quality is compromised, and the aquatic fauna is strongly threatened. Therefore, it is urgent that this study be conducted.

This study aimed to characterize the Bandama River at the Lamto Scientific Reserve in order to provide the first data on the water quality based essentially on physico-chemical parameters.

Material and methods

Study area

With a length of 1050 km, the Bandama River has a catchment area of 97500 km². It rises in the north of Côte d'Ivoire at an altitude of 480 m between Korhogo and Boundiali towns. Due to its North-South orientation, it covers different climatic and bio-geographic zones. Its main tributaries are the Marahoué on the right and the N'Zi on the left (Fig. 1). As part of the country's development process, hydroelectric, agro-pastoral, and hydro-agricultural dams have been built in the centre and north of this basin (Lévêque *et al.*, 1983; Traoré, 1996). The study area concerns the river located at Lamto Scientific Nature Reserve (6°9''N and 6°15''N and 5°0' W and 5°02' W) (Fig. 1).

This dead arm is subject to illegal gold panning of the main course of the river and industrial discharges. Furthermore, its catchment area is subject to a high intensity of human activities dominated by agriculture, leading to a very significant increase in important inputs of fertilizers and pesticides. Three stations have been defined. The first station Loumbossou (LB) is considered to be the upstream dead arm of the river in the study area. Itis located next to an opening channel of the dam. Its watershed supports maize, banana and palm plantations.The second station Yobouè (YB) was at the mid-section of the river,where many rocks took place. The last station Gbahan (GB) is downstream of the study area.In this catchment area, the agricultural activities were coconut and ananera plantations.

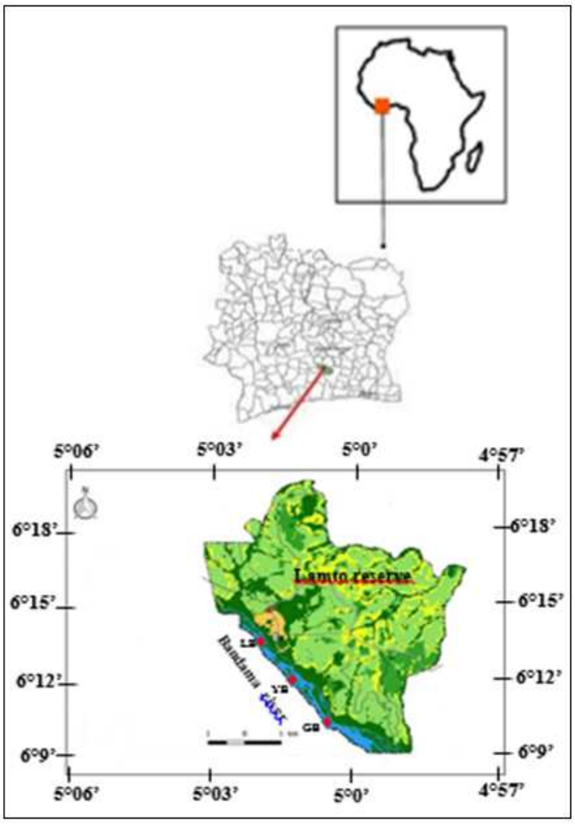

Fig. 1. Map of Bandama river at the Lamto Scientific Resrve showing sampling sites LB : Station Loumbossou, YB : Station Yobouè, GB : Station Gbahan.

Physicochemical analysis

Parameters such as pH, temperature, electrical conductivity, total dissolved solids and dissolved oxygen were measured in situ using a multi-parameter HACH from March 2021 to February 2022.Calibrated from the canoe, the device was introduced into the water and the results, which were displayed on the screen after a few minutes of stability, were taken. Transparency was measured with the Secchi disc. The principle consists of plunging the disc into the water with the help of a graduated string and observing it until it disappears. The water height at which the disc is no longer visible was noted in centimeter. The ionic composite determination such as nitrite (NO_2^-), nitrate (NO_3^-), ammonium (NH_4^+) and orthophosphates (PO_4^{3-}) is carried out using a multiparameter spectrophotometer of the HACH DR 6000 type in the laboratory. To this end, water samples from the study stations were taken in sterile bottles. The latter were hermetically sealed to avoid exchanges with the environment (Rodier *et al.*, 2009). These water samples were stored in a refrigerator until analysis in the laboratory. The measurement principle is based on the law of Beer Lambert, which indicates the optical density proportionality with the solution thickness (sample analyzed) and the chemical element sought concentration. After the addition of the appropriate reagent, the sample water-reagent mixture is introduced into the spectrophotometer, which displays the ion concentration in comparison with the control. The orthophosphates determination was carried out with the two reagents composed respectively of acid associated with ammonium molybdate and dimethylformamide combined with sodium bisulfate.

Data analysis

Kruskal Wallis and Mann Whitney tests were performed to compare environmental variables between different sampling sites and seasons. The statistical analyses were performed at the 5% significance level using STATISTICA software version 7.1.

Results

In situ and laboratory results of water quality parameters according to sampling sites and seasons are presented in Tables 1, 2, 3 and 4. The temperature ranged between the lowest value of 27.6°C and the highest of 30°C obtained from Station GB. For this parameter, no significant difference was found between the stations (Kruskal Wallistest ;$p > 0.05$). In all three surveyed sites, the waters are slightly warm during the dry season (Mann-Whitney U test ; $p > 0.05$) with a value of 30°C. Dissolved oxygen ranged from 1.77 to 3.7mg/l. The lowest concentration was recorded at station YB and the highest one was obtained at station GB. Statistical difference was not noticed in the dissolved oxygen concentration among the stations (Kruskal Wallistest ;$p > 0.05$).In these stations, the differences in the values of this parameter recorded in the rainy seasons and in the dry seasons are significant (Mann-Whitney U test ; $p < 0.05$).

Table 1. Physico-chemical parameters of the Bandama River measured at Lamto.

		Parameters measured					
Stations	Values	T° (C)	Oz (mg/I)	pH	TDS (mg/I)	Cond {µSiem)	Trans (cm)
Loumbossou	Min	29	L9	6.8	59	172	98
	Mean	28	2.2	5.97	62	185	112
	Max	29.6	2.8	7.1	73	203	124
	SD	0.9	0.5	0.4	1.6	0.9	2
Yoboue	Min	28.79	1.77	6.17	51	111	120
	Mean	28.99	2.41	7.21	53.33	115.25	135.6
	Max	29.21	3.21	7.85	54	117	140
	SD	L2	0.01	1	1.4	L6	2.6
Gbahan	Min	27.6	3	7.23	53	156	113
	Mean	28	3.2	7.85	57	163	131
	Max	30	3.7	7.9	61	187	137
	SD	0.3	0.4	0.l	0.2	0.71	2.1
WHO Norm 2004		25	s	6.5-S.5	500-1500	≤250	

T° : Temperature ; o_2 : Dissolved oxygen ; pH : Hydrogen potential ; TDS: Total Dissolved Solids ; Cond: Conductivity ; Trans : Water transparency ; SD : Standard Deviation.

The pH of the Bandama water surface at Lamto Scientific Reserve fluctuated between a slight acidity and an alkalinity. At all stations, the water is generally alkaline. The lowest pH (6.17) was recorded at station YB and the highest (7.9) was registered at station GB. There were no significant differencesin the pH variation of the three study stations (Kruskal Wallis test ;$p > 0.05$).For this parameter, the highest value (7.92) was obtained in the rainy season. The variation in pH has shown no significant difference (Mann-Whitney U test ; $p > 0.05$) between seasons.

The variation in electrical conductivity and total dissolved solids followed a similar trend. The respective values of 51 mg/l and 111 µS/cm were obtained at station YB. In contrast, high values (73 mg/l and 203 µS/cm, respectively) of these parameters were recorded at station LB. The statistical tests carried out did not reveal any significant difference in the variation of these parameters in the three stations (Kruskal Wallis test ; $p > 0.05$).However, in this environment, the differences observed between the high average values of the conductivity and the rate of dissolved solids during the dry seasons (207 µS/cm and 75. 3 mg/l) and the rainy seasons (121 µS/cm and 57 mg/l) are significant (Mann-Whitney U test; $p < 0.05$).The water transparency fluctuated between 92 cm and 137 cm. The lowest value was obtained at station LB and the highest at station GB. The kruskall wallis test applied to the data showed no significant difference in water transparency between the stations ($p > 0.05$).This parameter is high in dry seasons (150 cm) and low in rainy seasons (88 cm) (Mann-Whitney U test ; $p < 0.05$).

In general, Nitrite, Nitrate, Ammonium and Orthophosphate ions concentration values were relatively constant at all stations. However, Nitrate ions concentrations were the highest. The nitrite (NO_2^-) content varied between 0.012 mg/l and 0.017 mg/l, with the smallest value obtained at station GB and the highest at LB.Nitrate (NO_3^-) concentration ranged from 1.8 at station GB to 2.4 mg/l at station YB. The lowest ammonium (NH_4^+) concentration value (0.013 mg/l) was noted at station GB and the highest (0.022 mg/l) at station YB. The Orthophosphate (PO_4^{3-}) ions concentration ranged from 0.48 mg/l to 0.53 mg/l, with the lowest value obtained at station GB and the highest at station LB. No statistical difference was noticed in the Nitrite, Nitrate, Ammonium and Orthophosphate ions concentration variation between the stations (Kruskal Wallis test; $p > 0.05$). The high values of Nitrite (0.017 mg/l), Nitrate (2.4 mg/l), Ammonium (0.019 mg/l) and Orthophosphate (0.6 mg/l) were recorded during the rainy season. The seasonal variation of these parameters shows asignificant difference (Mann-Whitney U test; $p < 0.05$) between dry and rainy seasons.

Table 2. Chemical parameters of the Bandama River measured at Lamto.

		Parameters measured			
Sfations	Values	NO_2- (mg/I)	NO_3-(mg/I)	NH_4+(mg/I)	$Po4^{3-}$ (mg/1)
	Min	0.016	2.1	0.016	0.51
Loumbossou	Mean	0.0l65	2.15	0.017	0.52
	Max	0.017	2.2	0.018	0.53
	SD	0.001	0.02	0.002	0.01
	Min	0.014	2.2	0.02	0.42
Yoboue	M	0.015	2.3	0.021	0.46
	Max	0,016	2,4	0.022	0.5
	SD	0.002	0.01	0.002	0.01
	Min	0.012	1.8	0.013	0.48
	M	0.013	1.835	0 .013 5	0.485
Gbahan	Max	0.014	1.87	0.014	0.49
	SD	0.001	0.02	0.001	0.02
WHO Norm 2004		≤S 0.2	≤S 50	≤S l.5	≤S 0.2

NO_2-: Nitrite ; NO_3- : Nitrate ; NH_4+: .Ammonium PO_43-: Orthophosphates; SD : Standard deviation_

Discussion

This study showed that the variability of the physico-chemical parameters of the sampling stations is not significant. This could be due to the small area of this part of the river compared to the Bandama River and the proximity between the surveyed stations. The catchment areas of these stations are also subject to almost the same anthropogenic activities, which have the same influence on the environmental parameters of the water.

Water temperature is an ecological factor that has important repercussions (Chapman *et al.*, 1996). It affects the density, viscosity, and solubility of gases in water, the dissociation of salts, as well as chemical and biochemical reactions, and the development and growth of organisms living in water, especially microorganisms (WHO, 1987).In this investigation, the temperature values recorded are above the maximum acceptable temperature (25°C) of the WHO (2004). Therefore, the Bandama water River temperatures are warm.The factors that determine variations in water temperature in aquatic ecosystems are latitude, sunshine durations, substrate composition, precipitation, wind, and vegetation cover (Welcomme, 1985). The observed increase in water temperature could be explained by the almost non-existent canopy cover on this river. However, these temperatures are in the range of 24°C to 35°C, which is favorable to the fish species' growth, according to Poumongne (1998).

The rise in temperature recorded during dry seasons could be explained by high ambient air temperatures and the phenomenon of absorption of solar radiation by particles during this season, as indicated by Welcomme (1985).

According to Chouti *et al.* (2010), the oxygen content gives indications on the course of water health and makes it possible, among other things, to assess the fish habitat quality. The oxygen levels measured in the surface water layers reveal that they are below the standard (5 mg/l) indicated by the WHO (2004).

The Bandama Waters River adjoining the Lamto Scientific Reserve is less oxygenated. This low oxygen content could be attributed mainly to the high proportion of plant debris present in the environment. This debris would indirectly cause a depletion of the dissolved oxygen concentration by their accumulation and decomposition in the waterways (Wilcock *et al.*, 1995). Indeed, the bacteria responsible for the decomposition of organic matter increase the biochemical oxygen demand and release carbon dioxide into the environment through respiration (Wilcock *et al.*, 1995). In addition, this could be due to the anthropic activities that take place in or near the Bandama River. Indeed, the dead arm of this river, which was the subject of the study, receives agricultural fertilizer from the surrounding villages by runoff water. It is also now subject to artisanal gold mining. Therefore, the low dissolved oxygen obtained in the present study could be due to the high rate of organic decomposition resulting from human activities on the watershed, which produces sewage and agricultural runoffs into the reservoir, and this hasa negative impact on the water quality.

Table 3. Seasonal variations of physico-chemical paramètres of the Bandama River measured at Lamto.

			parameters measured					
Sfations	Seasons	Values	T°(C)	O_2(mg/I)	pH	TDS{mg/I)	Cond (uS/cm)	Trans(cm)
Loumbossou	DS	Mean	29.7	1.83	5.75	75.3	207	132
		SD	0.8	0-3	0.2	L3	0.8	1.5
	RS	Mean	28.3	2.81	7.18	57	121	72
		SD	0.6	0.2	0.4	1.5	0.5	0.8
Yoboue	DS	Mean	29.26	1.75	6.19	56	122	150
		SD	1.4	0.03	1.02	1.01	1.2	2.1
	RS	Mean	28.16	3.25	7.87	33	87	88
		SD	1.1	0.01	0.9	0.6	0.2	1.3
Gbahan	DS	Mean	30	1.98	6.52	63	188	138
		SD	0.2	0.1	0.4	0.3	0.8	2.4
	RS	Mean	27	3.75	7.92	41	95	78
		SD	0.1	0.3	0.1	0.5	0.68	2.6
WHO Norm 2004			25	5	6.5-8.5	500-1500	≤250	-

T° : Temperature; O_2: Dissolved oxygen; pH: Hydrogen potential; TDS: Total Dissolved Solids;
Cond: Conductivity; Trans: Water transparency; SD: Standard Deviation; DS: Dry Seasons; RS: Rainy Seasons.

The increase in dissolved oxygen levels during the rainy season is mainly due to water currents, which increase the exchange of oxygen between water and the atmosphere (Makhoukh *et al.*, 2011). The pH measures the hydrogen ions (H+) quantity in water. It is an indicator of acidityor the alkalinity of the water. The water's pH measured shows that the Bandama River at Lamto Scientific Reserve is relatively alkaline. The pH values obtained are within the WHO recommendation for the protection of aquatic life (6.5 and 8.5). It is well known that effects on aquatic life may occur at values of pH above this range. According to Dufour and Durand (1982), the waters of basic marine origin are alkaline,while those of continental origin are rather acidic. For these authors, natural factors such as geology, plant photosynthesis water, precipitation and land inputs wet can affect the pH of rivers.In the present study, the results could be attributed to the geological nature of the river watershed, as reported by Iltis and Levêque (1982). According to these authors, the pHis very weakly generally alkaline, with a mean of 7.35 in the Bandama river basin.The high water pH values during the rainy seasons could be explained by the large quantities of water coming from the tributaries during the rains. Indeed, during this season, the supply of water in phosphates, ammonia, and organic matter will cause the pH to rise to basic values.

Electrical conductivity refers to the water's ability to conduct current electric and it is determined by the content of dissolved substances, the charge ion, the ionization capacity, the mobility, and the water temperature. Consequently, it provides information on the water'sdegree of mineralization. In this study, electrical conductivity measured at different stations is below the standard set (≤ 250 µS/cm) by the WHO (2004). Therefore, these waters are weakly mineralized. In the same way, Ben Moussa *et al.* (2012) statedthat low conductivity electricity for a watercourse is also synonymous with low salt mineralization present in the environment. The low conductivity values obtained would be due to the water contributions that the environment receives, which contributes to their dilution, as reported by Zinsou *et al.* (2016) in the Ouémé delta water in

Benin.The results show that the water conductivities observed in the dry season have higher values than those recorded in the rainy season. Welcomme (1985) points out that in the natural environment, variations in water conductivity are influenced by a number of factors, including precipitation, evaporation, and the type of substrate. The results obtained would be explained by the fact that during the dry seasons, the evaporation combined with the lack of water supply causes an accumulation of ions, which would increase the conductivity, as indicated N'Goran (1989).

As far as the Total Dissolved Solids (TDS) are concerned, they are equivalent to the total mineralization, which corresponds to the sum of the anions and the cations present in water (Kambiré *et al.*,2014).In this study, Total Dissolved Solids and electrical conductivity values evolve in the same direction. The TDS values obtained at the sampling stations are well below the WHO (2004) standard. Zinsou *et al.* (2016) asserted that the parameters of conductivity and TDS are closely related to the nature and concentration of dissolved substances in the environment. Taking this assertion into account, the low TDS and conductivity values obtained in the present study compared to the standard would be explained by the fact that being in a lotic environment, the solid particles are constantly carried downstream of the river. Just like the conductivity of the water, the high values of the rate of dissolved solids were noted in seasons. This could be due to evaporation and the type of substrate, as demonstrated in the case of water conductivity.Indeed, during the dry season, evaporation favors an accumulation of ions, which would increase the total dissolved solids (TDS) as mentioned N'Goran (1989).

The water transparency is related to the depth at which light will penetrate the water. The transmission of light in a body of water is extremely important since the sun is the main source of energy for all biological phenomena. Light is needed for photosynthesis, a process that produces oxygen and food for consumers. Transparency is also, along with phosphorus and chlorophyll-a, an indicator of the quality level of the water body a watercourse (Référence). The transparency data recorded at the various stations are within the range of values given by Laniel (2013) (≤ 1-2 m), indicating the waters are cloudy.These results are due to the fact that the Bandama River is nowadays exposed to very strong pressures, which deteriorate its quality. Liquid waste, as well as artisanal fabric dyeing products, dumped directly into the river, contribute to water pollution and, therefore, the habitat. In addition, the extraction of sand, clays, and mining promotes soil erosion but also the deposit in water of organic matter and suspended sediments. This could explain the presence of algae and colored compounds in the form of dissolved organic carbon in water. All these activities contribute to muddy all the waters of the river. These data allow us to conclude that the Bandama Waters River at Lamto Scientific Reserve is heavily loaded with dissolved particles and organic matter.The weak transparencies noted during rainy periods could be explained by the drainage towards the waters during this period, of an increased concentration of solids and suspended matter by runoff. The arrival of solids and suspended matter gives rise to water cloudier, hence the low transparencies.

In all the surveyed stations, the Nitrite (NO_2^-) ions values noted are well below the standard indicated by the WHO (2004), which is less than or equal to 0.2 mg/l. The low nitrite ion content of the water could be due to the instability of this form of nitrogen, which oxidizes quickly to give nitrate (Rodier *et al.*, 2009). Moreover, even if the nitrites toxicity on certain organisms, such as fish, depends on the species, it should already be emphasized that for values close to 0.015 mg/l of nitrite certain fish die from hypoxia (Gray *et al.*, 2002). The values being, for the most part, close to 0.015 mg/l should attract the attention of conservators and planner's becausehigh concentrations of nitrite can affect species development aquatic. Indeed, according to Vissin *et al.* (2010), water containing nitrites, even at low doses, can be considered suspicious or even lethal to fish.

The Ammonium (NH_4^+) ions values ranged from 0.013 to 0.022 mg/l against theWHO (2004) limit value which is 1.5 mg/l. The ammonium distribution in an aquatic environment varies according to the productivity level of the ecosystem and its degree of pollution by the presence of organic matter (Koudenoukpo *et al.*, 2017). Its presence in the waters of the river would result from the aerobic degradation of organic nitrogen (proteins, amino acids, urea, etc.), which comes largely from discharges of untreated water purified. Indeed, the Ammonium (NH_4^+) ions in themselvesare not harmful but can be transformed under certain conditions into ammonia (NH_3), a water-soluble and toxic gas for aquatic life (BE, 2012).Furthermore, authors such as Hébert and Légaré (2000) demonstrate that in a well-oxygenated environment, ammonium ions are quickly used and their concentration is weak. In the present study, the contents found present a risk for the Bandama water River at Lamto because it is poorly oxygenated.

Table 4. Seasonal variations of Chemical parameters of the Banda.ma River measured at Lamto.

			Parameters measured			
Stations	Seasons	Values	NO_2- (mg/I)	NO_3-(mg/I)	NH_4+(mg/I)	$Po4^{3-}$ (mg/1)
Loumbossou	DS	Mean	0.009	1.52	0.009	0.32
		SD	0.001	0.01	0.001	0.02
	RS	Mean	0.017	2.2	0.019	0.53
		SD	0.001	0.02	0.002	0.02
Yoboue	DS	Mean	0.009	1.7	0.015	0.34
		SD	0.001	0.02	0.001	0.01
	RS	Mean	0,016	2.4	0.022	0.6
		SD	0.002	0.03	0.001	0.01
Ghahan	DS	Mean	0.008	1.1	0.009	0.4
		SD	0.001	0.01	0.001	0.02
	RS	Mean	0.015	1.89	0.015	0.52
		SD	0.001	0.02	0.001	0.01
WHO Norm 2004	2004		≤0.2	≤50	≤I.5	≤0.2

NO_2-: Nitrite; NO_3- : Nitrate; NH_4+: Ammonium; PO_4^{3-} : Orthophosphates; SD: Standard Deviation_ DS: Dry Seasons; RS: Rainy Seasons.

Occurring naturally and soluble in soil, Nitrateions enter soil and groundwater and flow into waterways. But these Nitrate ions (NO_3^-) are also provided synthetically by fertilizers and are one of the causes of water degradation (Khalaf *et al.*, 2007). Nitrate ions concentrations in the river varied between 1.8 and 2.4 mg/l. These values are below the standard indicated by the WHO (2004) but are higher than the standard international level set at 0.02mg/L (BE, 2012). These high nitrate concentrations are due to domestic and agricultural effluents resulting from human activity and originating from the watershed.

The Orthophosphate ions contents (PO_4^{3-}) ranged from 0.42mg/l to 0.53mg/l. These values are greater than the accepted tolerant values proposed by WHO (2004). This is due to the contribution of excessive leaching and runoff from the land-fertilized farms. In addition, Orthophosphates result from the degradation of organic phosphate bacteria from the discharge of wastewater (metabolism, powders to laundry, agro-food and chemical industries) and the use of fertilizers. Assimilated by plants and photosynthetic organisms, they intervene in a way that determines factors in the eutrophication phenomena of watercourses (BE, 2012). However, above a certain concentration and when the conditions are favorable (low current, adequate transparency), it can cause excessive algae growth and aquatic plants (ME, 2013).

In this study, the nitrite, nitrate, ammonium and orthophosphate contents become important in rainy seasons. These nutrient salts are drained by runoff water laden with products of leaching of watersheds and by the arrival of water continental, rich in organic matter. It is also linked to the misuse of chemical fertilizers during agricultural activities that occur along the river catchment during these seasons.

Conclusion

The study of the water quality of the Bandama River at Lamto Scientific Reserve allowed us to make a characterization of the physico-chemical parameters. Based on the main parameters such as temperature, pH, transparency and oxygen, the results showed that the waters are warm, basic, cloudy and less oxygenated. The concentrations of the nutrient salts such as nitrite, nitrate and ammonium tend towards the tolerable standard indicated to trigger the eutrophication of this hydro system. On the other hand, the orthophosphate contents are well above the indicated standard. These levels, if they increase, could have a direct influence on the pollution of these waters by the massive development of plants. The data from this investigation challenge managers and planners on the degradation of water quality in this area, which is supposed to be protected from the Bandama River. This information constitutes basic data for the establishment of a sustainable management plan for this river.

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