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Comparative Study of the Physicochemical Quality of the Waters of the Méné River (Sassandra Watershed, Ivory Coast) in the Dry Season and in the Rainy Season

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Abstract

The study carried out on the waters of the Méné River led to an overall assessment of its water quality during the dry season and the rainy season. The analysis focused on eight (8) water samples taken from the river during a period of dry season (January-February) and a period of rainy season (June and September). The various physicochemical parameters were measured according to Afnor standardized methods. The readings of temperature, turbidity, pH and conductivity made it possible to account for the disturbances occurring in water quality. A temporal variation correlated with the seasons (dry or rainy) is noted. Turbidity depends on the concentration of suspended solids (SS) in the water and drained particles and therefore on the seasons. Just like the temperature, the conductivity changes with the season. The waters of the Méné River are generally acidic. The results obtained show that there is a low level of pollution by chlorides, phosphates, nitrites and nitrates. A slight pollution of the waters of Méné in organic matter (chemical oxygen demand values are less than 25 $mg{\cdot}L^{-1}$ during dry season and 32.33 ± 4.73 $mg{\cdot}L^{-1}$ during rainy season) was observed. The concentrations of metallic trace elements such as iron, manganese and aluminum indicate significant pollution of these waters by these elements. Overall, the waters of the Méné River are of satisfactory quality because all the physicochemical parameters analyzed have values below standards during the dry season as well as during the rainy season with the exception of COD and a few metallic trace elements.

Keywords

Méné, Physicochemical Parameters, River, Season, Water Quality

1. Introduction

Water is one of the earth's most vital commodities and a recyclable resource. However, it must be managed and protected because of its vulnerability to over-exploitation and pollution. Water pollution in developing countries is generally linked to anthropogenic activities due to uncontrolled urbanisation, often with a lack of appropriate treatment of the wastewater generated and its direct discharge into the natural environment [1]-[3]. Maintaining water quality is a major concern for a society that has to meet ever-increasing water needs [4]. This is the case in Ivory Coast, where the scarcity of drinking water sources due to pollution has led rural populations to use surface water bodies such as lakes, rivers, etc. [5]. The physicochemical quality of these watercourses is often linked to the combined influence of the hydroclimatic seasons and anthropic pressure [6]. The Méné River, like all other watercourses, is subject to this combined influence. In fact, it is a watercourse located in the mountainous western part of Ivory Coast, which is characterised by a mountain hydrological regime where altitude is responsible for the amount of rainfall. Rainfall varies between 1400 and 2300 mm [7]. The dry season is fairly short (November to February), with the harmattan persisting for about a month and a half, while the rainy season extends from March to October, with a peak in rainfall in September [8]. The river is also subject to numerous environmental pressures, such as fishing, swimming, domestic discharges from riverside residents and run-off from farmland using plant protection products [9]. All this inevitably leads to risks of deterioration in the water quality of this river, which deserves to be protected and well managed for the services it provides to the population. In order to ensure the sustainability of this river, the aim of this study is to assess the physicochemical quality of the water in the Méné River and to monitor its seasonal evolution. More specifically, the aim is firstly to determine the variations in the physicochemical characteristics of the river's water during the dry and rainy seasons, and then to compare the state of pollution of the water during these two seasons.

2. Material and Methods

2.1. Presentation of the Study Area

The study area is included in the Biankouma department in western Ivory Coast. Located in the Tonkpi region, approximately 635 km from Abidjan and 40 km from the city of Man (regional capital), Biankouma has an area of 3750 km^2. The hydrographic network of the study area is made up of the main river called Méné (Sassandra watershed) and its tributaries. It has its source in the South in the Yassigouine area and initially flows in a northwest direction. It is joined first on the left bank by a tributary coming from Kata and another which crosses Zoupleu to flow towards the north-east. Then, during its course, the Méné meets several tributaries on both sides including those coming from the village of Samapleu and the Bi River. It finally meets its most important tributary the Gouan coming from Sipilou and which has been swollen by the waters of the Sé and Blo

on the right bank. From this confluence, the Méné flows in an East-West direction towards the North of the village of Zocoma, collecting on the right bank the waters coming from the sub-prefecture of Yorodougou. Four (04) sampling sites were chosen along the Méné River. These were sites SM01 (located not far from the village of Gangbapleu), SM02 (located about 4 km from Yorodougou), SM03 (located downstream from site SM02) and SM04 (located 5 km from the village of Samapleu). These sites were chosen on the basis of their accessibility at all times and the various activities identified in the study area (domestic wastewater, agriculture, etc.). Figure 1 shows the location of the sampling sites.

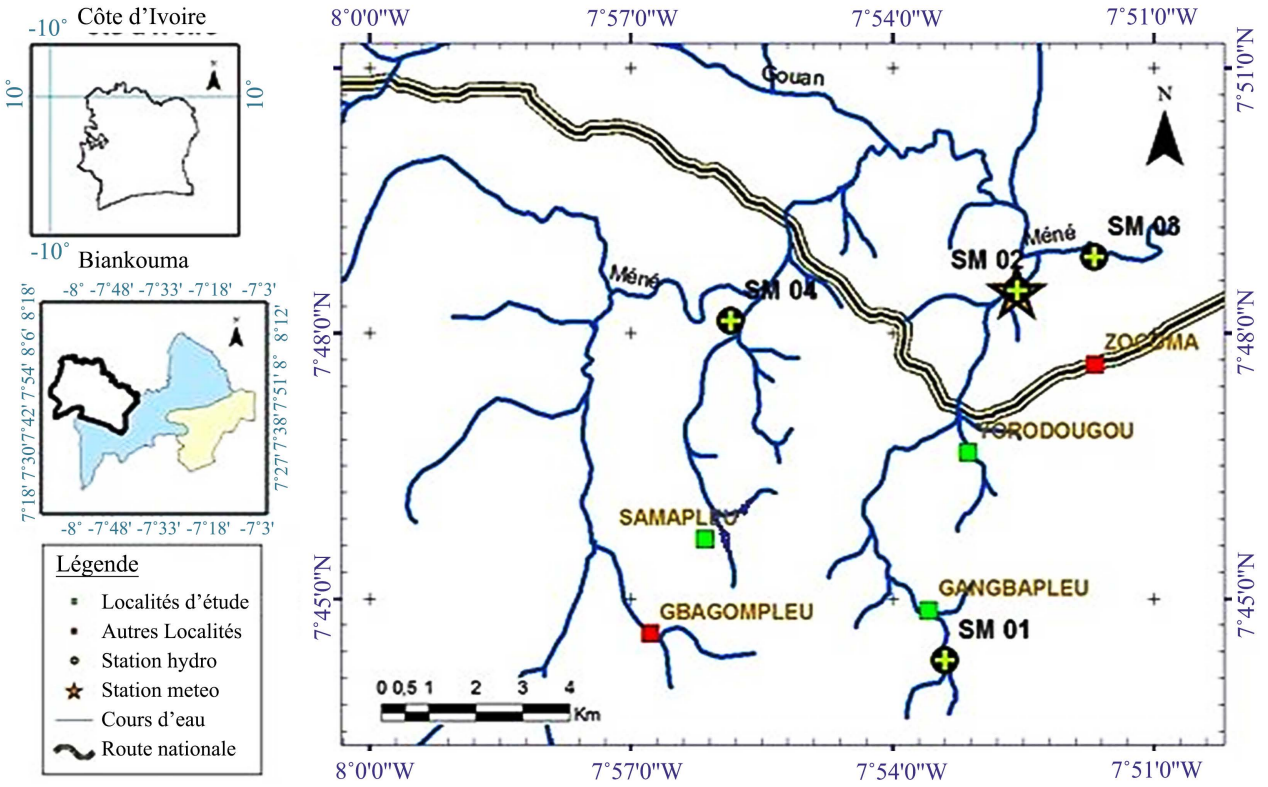

Figure 1. Mapping of the study area.

2.2. Materials

✓ **Study material**

The study material used for the analyses of physicochemical parameters is the Méné River on which four (04) sampling sites were distributed.

✓ **Sampling equipment**

The water samples were collected in polyethylene bottles with a capacity of 1000 mL, previously rinsed with site water. The samples were then kept in a cooler containing ice during transport to the laboratory for analysis.

✓ **Analysis equipment**

During sampling, pH and temperature were measured using an Orion brand pH meter, model 230A, conductivity using a WTW type conductivity meter, model Cond. 340i and turbidity using a DRT100B type turbidimeter, model

20012. In the laboratory, nitrate, nitrite and phosphate ions and the metallic trace elements (iron, manganese and aluminum) were measured using a turbidity spectrophotometer (type DR 2010). A Selecta brand mineralizer was used to mineralize the samples. Biochemical oxygen demand (BOD_5) was measured using a BODTrack.

2.3. Methodology

Sampling and Measurement of Physicochemical Parameters

Water from the Méné River was taken over 4 months. This four-month study period includes two months of the wet season (June and September) and two months of the dry season (January and February). Sixteen (16) water samples were taken in total from the four sites, one sample per site per month. In the field, the bottles, previously washed with 10% nitric acid then with distilled water, were rinsed three times with the water to be sampled. The samples were taken manually at the site's water entry point, each time immersing the bottle up to 30 cm deep with the neck directed against the current. The bottle filled with water is removed from the body of water and closed tightly. The carefully labeled samples are transported to the Laboratory. The analyses were carried out according to the standardized methods summarized in **Table 1** [10].

Table 1. Summary of analysis methods.

Parameter	Method
Temperature and pH	Electrochemical using a glass electrode (NF T 90-008)
Conductivity	Electrochemical with the probe (NF EN 27888)
Turbidity	Measurement by formazin nephelometry (NF EN ISO 7027)
Nitrates	Sodium salicylate method (NF T 90-012)
Nitrites	Colorimetric method by diazotization (NF T 90-013)
Orthophosphates	Spectrophotometric method (NF T 90-023)
COD	Potassium dichromate oxidizability method (NF T 90-101)
BOD_5	Manometric method (AFNOR EN 1899-2) T 90-103-2
Chloride	Mohr's method (AFNOR NF ISO 9297) T 90-014
Aluminum	Determination by spectrophotometry (NF EN ISO 12020) T 90-138
Iron	Determination by spectrophotometry (AFNOR NF T 90-017)
Manganese	Determination by spectrophotometry (AFNOR NF T 90-024)

3. Results

3.1. Water Quality of the Méné River in the Dry Season

The average values of the physicochemical parameters of the eight (8) water samples taken during the dry season (December-February 2015) are grouped in **Table 2**. Of all the waters evaluated during the dry season, the average tempera-

ture obtained is 21.03˚C ± 2.54˚C, the average pH value is 6.34 ± 0.24 and electrical conductivity has an average of 86.50 ± 19.60 µS/cm. The concentrations of chlorides (average value 1.34 ± 0.83 mg/L), nitrates with an average content of 0.25 ± 0.11 mg/L, nitrites (contents < 0.05 mg/L) and phosphates with an average concentration of 0.05 ± 0.00 mg/L comply with normal values in unpolluted natural waters (see Table 2). As for the average value of turbidity (5.96 ± 2.67 NTU), it is lower than the range of normal values in unpolluted natural waters (10 - 50). The average values of chemical oxygen demand (<25 mg O_2/L) and biochemical oxygen demand (values < 5 mg of O_2/L) are slightly higher than the normal values in unpolluted natural waters which are respectively 20 and 2 mg/L of O_2. These COD and BOD_5 values show that the overall load of organic pollutants in this river is greater than in unpolluted natural waters during the dry season. Iron, manganese and aluminum have respective average contents of 1.45 mg/L, 0.06 mg/L and 0.33 mg/L are slightly higher than normal values in unpolluted natural waters (Table 2).

Table 2. Physicochemical characteristics of the waters of the Méné River in the dry season.

Parameters	Average values in dry season	Standard deviation	Minimum	Maximum	Normal values in unpolluted natural waters
T (˚C)	21.03	2.54	18.50	23.87	25[(1)]
pH	6.34	0.24	5.90	6.70	6 - 8.5[(4)]
Turbidity (UNT)	5.96	2.67	3.30	11.00	10 - 50[(1)]
Conductivity (µS/cm)	86.50	19.60	62.00	122.00	20 - 1200[(2)]
Cl^- (mg/L)	1.34	0.83	0.60	3.00	<25[(1)]
NO_3^- (mg/L)	0.25	0.11	<0.06	0.39	<44[(5)]
NO_2^- (mg/L)	<0.05		<0.05	<0.05	0.01[(1)]
PO_4^{3-} (mg/L)	0.08	0.00	<0.02	0.08	<0.2[(3)]
COD (mg/L d'O_2)	<25		<25	<25	20[(3)]
BOD_5 (mg/L d'O_2)	<5		<5	<5	2[(3)]
Fe (mg/L)	1.45	0.97	0.40	3.40	-
Mn (mg/L)	0.06	0.03	<0.02	0.11	<0.05[(1)]
Al (mg/L)	0.33	0.17	0.10	0.56	-

[(1)](Rodier *et al.*, 2009), [(2)](Loire Brittany water agency, 2006), [(3)](Chapman, 1992), [(4)](Chapman *et al.*, 1996), [(5)](Beau, 1998).

3.2. Water Quality of the Méné River in the Rainy Season

The average values of the physicochemical parameters of the eight (8) water

samples taken during the rainy season (June-September 2015) are grouped in Table 3. It appears from the measurements that: the average temperature obtained is 23.56˚C ± 0.42˚C, the average pH value is 6.87 ± 1.54, the average value of turbidity (44.64 ± 37.23 NTU) and electrical conductivity has an average of 86.50 ± 19.60 µS/cm conform to normal values in unpolluted natural waters. The concentrations of chlorides (average value 1.35 ± 0.48 mg/L), nitrates with an average content of 0.54 ± 0.33 mg/L, nitrites (contents < 0.05 mg/L) and phosphates with an average concentration of 0.08 ± 0.02 mg/L comply with normal values in unpolluted natural waters (see Table 3). The average value of COD (32.33 ± 4.73 mg/L of O_2) is higher than the normal value in unpolluted natural waters (20 mg/L of O_2). The average value of BOD_5 (value < 5 mg of O_2/L) is slightly higher than the normal values in unpolluted natural waters which is 2 mg/L of O_2. Iron, manganese and aluminum have respective average contents of 3.80 mg/L, 0.11 mg/L and 0.57 mg/L are slightly higher than normal values in unpolluted natural waters (Table 3) for identical reasons listed during the dry season.

Table 3. Physico-chemical characteristics of river water in the rainy season.

Parameters	Average values in dry season	Standard deviation	Minimum	Maximum	Normal values in unpolluted natural waters
T (˚C)	23.56	0.42	22.90	24.04	25[(1)]
pH	6.87	1.54	5.50	9.30	6 - 8.5[(4)]
Turbidité (NTU)	44.64	37.23	11.70	111.40	10 - 50[(1)]
Conductivité (µS/cm)	33.89	36.06	1.00	89.00	20 - 1200[(2)]
Cl^- (mg/L)	1.35	0.48	0.90	2.00	<25[(1)]
NO_3^- (mg/L)	0.54	0.033	0.17	0.84	<44[(5)]
NO_2^- (mg/L)	<0.05		<0.05	<0.05	0.01[(1)]
PO_4^{3-} (mg/L)	0.08	0.02	0.06	0.10	<0.2[(3)]
COD (mg/L d'O_2)	32.33	4.73	<25	36.00	20[(3)]
BOD_5 (mg/L d'O_2)	<5		<5	<5	2[(3)]
Fe (mg/L)	3.80	3.74	1.30	9.30	-
Mn (mg/L)	0.11	0.010	0.05	0.26	<0.05[(1)]
Al (mg/L)	0.57	0.38	0.24	0.97	-

[(1)](Rodier *et al.*, 2009), [(2)](Loire Brittany water agency, 2006), [(3)](Chapman, 1992), [(4)](Chapman *et al.*, 1996), [(5)](Beau, 1998).

4. Discussion

The water temperatures studied (21.03˚C during the dry season and 23.56˚C

during the rainy season) are all lower than 25˚C which is the normal value for unpolluted natural waters. These results confirm those obtained by Iltis and Lévèque [7] in some rivers of Ivory Coast. According to their study, the temperature of Ivorian rivers very rarely drops below 25˚C; the lowest values are observed in the rivers of the north of the country during the cool season (December-January) and in mountain streams. This study showed that the waters of the Méné River are generally acidic whatever the season (pH = 6.34 during the dry season and pH = 6.87 during the rainy season). Similar results were obtained from work carried out on the waters of the Banco and the Mé in the Abidjan-Agboville region [11] on those of the mountainous West [5] and those of the Adiaké region [12]. In fact, these different authors concluded that all these waters were acidic. The study of turbidity showed that it complies with normal values in unpolluted natural waters during the rainy season. However, these values (5.96 ± 2.67 NTU) remain below the range of normal values in unpolluted natural waters (10 - 50) during the dry season, which would be favored by the dry season. In fact, during the dry season, there is almost no rain, meaning there is no runoff water. The river therefore does not receive animal or plant debris, much less dusty and colloidal materials, responsible for the cloudy nature of surface water. In addition, the value of turbidity observed during the rainy season (44.64 UNT) is characteristic of the significant rainfall in these months. The chemical oxygen demand (COD) in an unpolluted natural environment according to Chapman [13] should be less than 20 mg/L. This value is largely exceeded in all the waters studied, which reflects the importance of external contributions. Analysis of COD values reveals high pollution of waters with organic matter in rainy season. The importance of the organic pollutant load in the waters of the river could result from the limitation of the natural self-purification phenomena of the waters due to microorganisms. The conductivity values (86.50 µS/cm during the dry season and 33.89 µS/cm during the rainy season) conform to normal values in unpolluted natural waters. However, these values remain relatively low. This means that the waters of the Méné River are weakly mineralized, therefore less loaded with dissolved salts. This low mineralization is due to the geological composition of the lands crossed by these waters. These values are lower than those found by Ahoussi [5] in the spring waters of the mountainous west of Côte d'Ivoire (152.90 µS/cm) but higher than those obtained by Ahonon [14] in the surface waters of the mountainous areas of the southwest from Togo (23.84 µS/cm). In continental waters free of pollution, the concentration of chlorides rarely exceeds 25 mg/L according to Rodier *et al.* [10]. The chloride contents of the waters of the Méné River (1.34 mg/L) are below this value. Their presence would be linked to the nature of the geological formations crossed by the watercourse. The presence of phosphorus (PO_4^{3-}) and nitrogen (NO_3^- and NO_2^-) compounds in surface waters is natural. This study showed very low values of these nutrients in the Méné River; this is proof of a lower risk of eutrophication of this river. The work of Chapman *et al.* [13], showed that the natural

phosphate content in surface waters should not exceed 0.2 mg/L otherwise it could constitute an index of pollution. Méné waters have normal phosphate levels. Likewise, the analysis of nitrates shows values (0.25 mg/L in the dry season and 0.54 mg/L in the rainy season) all lower than 44 mg/L. According to Beau [15], a watercourse with a nitrate concentration lower than 44 mg/L can be considered to have good quality water. Thus, the waters of the Méné contain normally low nitrate values. These low nitrate values could explain the almost non-existence of nitrites (values < 0.05 mg/L) in these waters. Metallic elements are present in the waters of the Méné River. This presence is often attributed to their natural abundance in soils, sediments and bedrock. The average iron, manganese and aluminum contents of the Méné River are respectively 1.45 mg/L, 0.06 mg/L and 0.33 mg/L during the dry season and 3.80 mg/L, 0.11 mg/L and 0.57 mg/L during the rainy season. The analysis of these metallic elements shows characteristics similar to the surface waters of the Adiaké region studied by Eblin *et al.* [12]. These authors, as well as Ahoussi *et al.* [5], demonstrated that these elements come from geological formations in the region. Indeed, almost all of the soils in the Biankouma region belong to ferralitic soils which are heavily leached under high rainfall.

5. Conclusion

In this study, the water quality of the Méné River located in Ivory Coast was evaluated in both the dry and rainy seasons. The analyses were carried out using standardized Afnor methods. The values of the different physicochemical parameters measured were compared to normal values in unpolluted natural waters. The results of this study show that the waters of the Méné River generally retain their unpolluted natural water character whatever the season (rainy or dry) with the exception of a few parameters which experience a slight difference compared to the normal values for unpolluted natural resources established by several authors. The temperature is below 25˚C, the pH is slightly acidic, the nutrient elements (Cl^-, NO_2^-, NO_3^- et PO_4^{3-}) have values below standards. However, the chemical oxygen demand (COD) and manganese have values higher than the standards. Generally speaking, in view of the parameters analyzed, the waters of the Méné River are of satisfactory quality. Additional studies on the research for aquatic organisms and micro-organisms, indicators of more or less good water quality, are necessary. This could constitute interesting prospects for studies to be carried out on this river.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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