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Physico-Chemical and Bacteriological Characteristics Of Comoé River Waters From Grand-Bassam To Kafolo (North-South Côte d'Ivoire)

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***Abstract*— The aim of the study carried out on the Comoé River was to assess the level of physico-chemical, bacteriological and chemical pollution of this body of water. Water samples were taken at eight (8) stations on the river. Bacteriological contamination indicators such as total coliforms, faecal streptococci and faecal coliforms were tested. Physico-chemical parameters such as temperature, pH, dissolved oxygen, nutrients (nitrate, nitrite, phosphorus and ammonium) and pesticides (fenuron and desisopropylatrazine) were also measured. The measurements revealed that water temperatures in the Comoé river varied between 27.1°C (C8F) and 34.8°C (C3S). The pH values showed that the water ranged from acidic to neutral. These values ranged from 6.02 (C2S) to 7.29 (C7S). Dissolved oxygen concentration was highest at the surface, with values ranging from 2.05mg/L (C7F) to 7.73mg/L (C7S). Nutrient levels varied between 0.8 mg/L (C6S) and 5.3 mg/L (C2F) for nitrate, 0.0035mg/L (C5S) and 0.08mg/L (C4S) for nitrite, 0.08mg/L (C3F) and 9.28mg/L (C1F) for phosphorus and 0.055 mg/L (C7M) and 0.39mg/L (C4F) for ammonium.**

Bacteriological analyses revealed the presence of total coliforms, faecal coliforms and faecal streptococci, with maximum average loads observed respectively at stations C8 (5.450 cfu/100mL), C2 (3.215 cfu/100mL) and C6 (3,085 cfu/100mL).The waters of the River Comoé showed high loads of micro-organism and physico-chemical pollutants. The CF/SF ratio showed that the water was contaminated in places by human, animal and mixed sources.

The waters of the Comoé River are likely to contain pathogenic micro-organisms and thus constitute a real public health problem.

***Index Terms*— Characteristics, physico-chemical, bacteriological, Comoé river, Kafolo.**

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I. INTRODUCTION

Contamination of aquatic ecosystems has been a real problem in recent decades throughout the world[1]-[3]. It remains a major concern[2] in African countries.

In Côte d'Ivoire, surface waters are subject to strong anthropogenic pressures caused by the development of uncontrolled agricultural, agro-industrial and domestic activities[4].

Effluents from these activities, which are not treated beforehand[5], are loaded with substances that are hazardous to water quality and lead to bioaccumulation of toxic pollutants in aquatic organisms.

In short, this contamination leads to a deterioration in the physico-chemical and bacteriological quality of these surface waters.

Some studies have shown that the waters of the Comoé river are contaminated in places[2],[6]. The high human pressure on the river's water poses a threat to its sanitary quality, and its use by the population could cause a public health problem[7].

This study was therefore carried out with the aim of obtaining factual data on the quality of the water in the Comoé River.

The general objective is to determine the level of pollution in the waters of the River Comoé. Specifically, the aim is to: (i) determine a number of physico-chemical parameters (pH, TSS, temperature, turbidity, salinity, dissolved oxygen and conductivity), (ii) determine nutrient salt levels (nitrate, nitrite, phosphorus, ammonium) and pesticide molecules (fenuron and desisopropylatrazine), (iii) determine the levels of bacterial contamination of the water by enumerating indicator germs of faecal contamination such as total coliforms, faecal coliforms and faecal Streptococci.

II. MATERIAL

A. Study material

The study material consisted of water samples taken from eight (8) stations on the Comoé River.

B. Sampling equipment

The sampling equipment consisted of 500mL sterile bottles (Pyrex bottle) used to collect the water samples and a cool box containing frozen carboglasses for transporting the samples under cold conditions (+4°C).

III. METHODS

A. PRESENTATION OF THE STUDY AREA

The Comoé River is 813 km long, 759 km of which are in Côte d'Ivoire, with a catchment area of 82,400 m². It is one of the major rivers crossing Côte d'Ivoire from north to south. It rises in Péni between Banfora and Bobo Dioulasso in Burkina Faso and flows into the Ebrié Lagoon in the town of Grand Bassam in Côte d'Ivoire[8] (Figure 1). Eight (08) stations have been sampled on this river. These are the stations of Grand-Bassam (C1), Bonoua (C2), Alépé (C3), Yakassé-Attobrou (C4), Anékouadiokro (C5), Groumania (C6), Gansé (C7) and Kafolo (C8) (Table 1). These towns were selected because of the activities found there, but also because of their areas of remarkable ecological influence.

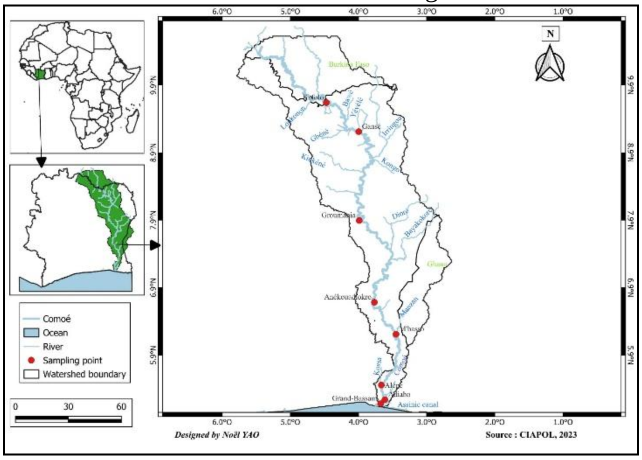

Figure 1 : Location of the study area and sampling stations on the River Comoé

B. SAMPLING

Two (2) sampling campaigns at three (3) levels of the water column were carried out every six months (June and December 2020) on the Comoé River. Samples were taken at 0.5 m from the surface, in the middle and at the bottom of the water using a Niskin bottle. A total of forty-eight (48) water samples were taken during the two campaigns at the eight (8) stations. These samples were placed in 500-mL sterile glass bottles (Pyrex bottle), then placed in a cool box (4°C) and transported to the central environmental laboratory of the Centre Ivoirien Antipollution (LCE, CIAPOL) for analysis.

Table I: Geographical location of sampling sites on the Comoé River

Stations	Codes	Latitude N	Longitude W
Grand-Basssam	C1	05°12.965’	003°43.225’
Bonoua	C2	05°17.186’	003°37.003’
Alépé	C3	05°30.164’	003°39.496’
Yakassé-Attobrou	C4	06°17.824’	003°28.678’
Anékouadiokro	C5	06°38.283’	003°42.796
Groumania	C6	07°54.872’	003°59.370’
Gansé	C7	08°36.912’	003°55.227’
Kafolo	C8	09°35.369’	004°18.508

C. METHODS OF ANALYSIS

1. C1. Physico-chemical analysis of the water

The physico-chemical parameters (temperature, pH, salinity, dissolved oxygen) were measured in situ using a WTW series 196 or YSI 620 M multiparameter probe (multifunction analyser) and turbidity using a turbidimeter. Suspended solids were analysed using the DR 6000 spectrophotometer method. Nutrients (nitrates, nitrites, phosphorus and ammonium) were analysed using the DR 6000 spectrophotometer assay method, while pesticides (fenuron and desisopropylatrazine) were measured using the GC-MS assay method.

2. C2. Microbiological analyses

3. Isolation and enumeration of total coliforms

Total coliforms were counted in accordance with standard NF ISO 4832 for human food products. Rapid-E. coli medium was used. The plating technique was membrane filtration with a porosity of 0.45µm. 1 mL of each sample and its 10^{-1}, 10^{-2} and 10^{-3} dilutions were taken and filtered on the membrane using a filtration ramp. Each membrane was then removed and placed in Petri dishes containing Rapid-E. coli agar and incubated at 37°C for 24 hours. Characteristic total coliform colonies appeared blue on the agar.

4. Isolation and enumeration of faecal coliforms

Faecal coliforms were counted according to the ISO 16140 protocol, using Rapid-E. coli medium. The plating technique was membrane filtration with a porosity of 0.45µm. 1 mL of each sample and its 10^{-1}, 10^{-2} and 10^{-3} dilutions were taken and filtered on the membrane using a filtration ramp. Each membrane was then removed and placed in Petri dishes containing Rapid-E. coli agar and incubated at 37°C for 24 hours. Characteristic colonies were pink to purple in colour.

5. Isolation and enumeration of faecal Streptococci

Faecal Streptococci were counted on Bile Esculin Azide (BEA) medium in accordance with ISO 7899-2. The inoculation technique is identical to that used for the enumeration of total Coliforms and E. coli. To do this, 5mL and 1mL of each sample and then 1mL of the 10-1 dilution of the sample were taken and filtered. Incubation was carried out at 37°C for 24 hours. After incubation, colonies surrounded by a black halo were counted.

6. Determination of bacterial load

The number N (CFU/mL) of microorganisms is calculated using the formula below :

$$N = \frac{\sum C}{V(n_1 + 0.1 n_2) \times d} \quad (1)$$

ΣC : sum of colonies counted on all plates retained from successive dilutions ;
V : volume of inoculum applied to each plate ;
N1 : number of plates retained for the first dilution ;
N2 : number of plates retained for the second dilution ;
D : dilution rate corresponding to the first dilution retained.

7. Determining the origin of the faecal contamination

Determination of the origin of faecal contamination is based on the criteria defined[9]. According to these authors, the contamination is of animal origin if the faecal coliform/faecal streptococci (FC/FS) ratio is less than 0.7 and of human origin if this ratio is greater than 4.

Table II: Criteria for determining the origin of faecal contamination

Ratio	Origin of pollution
R<0,7	strictly of animal origin
0,7<R<1	mixed, predominantly animal
1<R<2	uncertain origin
2<R<4	mixed, predominantly human
R>4	strictly of human origin

Source [9]

Results expression:

$$R = \frac{faecal\ coliform}{faecal\ streptococcus} \quad (2)$$

R= ratio

IV. RESULTS AND DISCUSSION

A.RESULTS

A1. Variation in physico-chemical parameters of water in the Comoé River

Figures 2, 3, 4, 5, 6, 7 and 8 show the variations in the physico-chemical parameters of the water at each station. The various temperatures (surface, middle and bottom) vary in the same order, with a peak observed at surface station C3. The pH varies between 6 and 7, with the highest observed at station C7S (7.29). The quantity of dissolved oxygen increases and reaches a peak at station C3S (6.44 mg/L), C4M and C4F (6.78 mg/L), then drops to station C5 and increases progressively to station C7 (S and M). Dissolved oxygen concentration is generally higher at the surface. Electrical conductivity and salinity, on the other hand, change in almost the same way. Generally speaking, the highest levels were recorded at stations C1 and C5.

Turbidity is higher at the bottom all along the river. Suspended solids are largely elevated in the environment. This parameter peaks at station C4M.

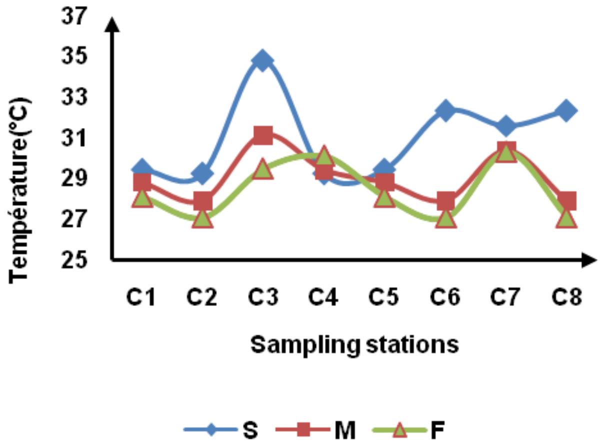

Figure 2: Variation in water temperature (°C) in the Comoé River according to sampling stations (surface (S), middle (M) and bottom (F))

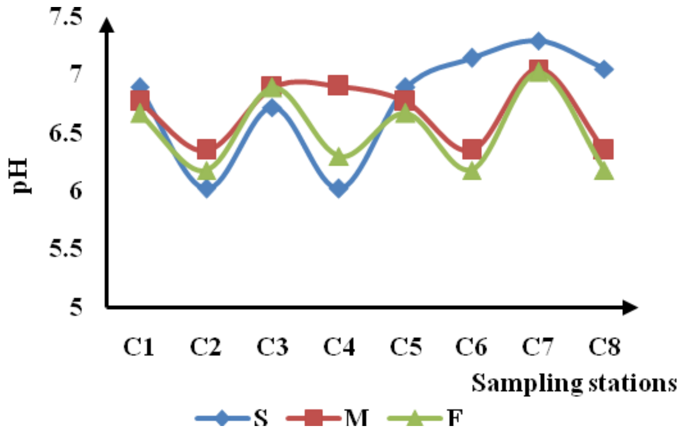

Figure 3: Changes in the pH of the waters of the River Comoé as a function of sampling stations (surface (S), middle (M) and bottom (F)))

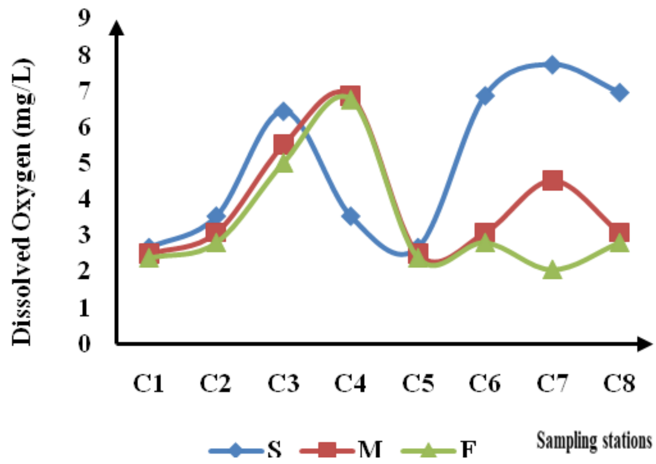

Figure 4: Changes in dissolved oxygen (mg/L) in the waters of the River Comoé as a function of sampling stations (surface (S), middle (M) and bottom (F))

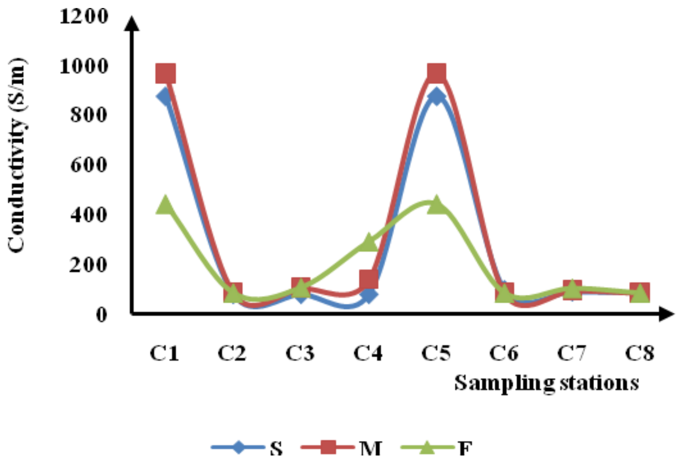

Figure 5: Changes in the conductivity (S/m) of water inthe River Comoé as a function of sampling stations (surface (S), middle (M) and bottom (F))

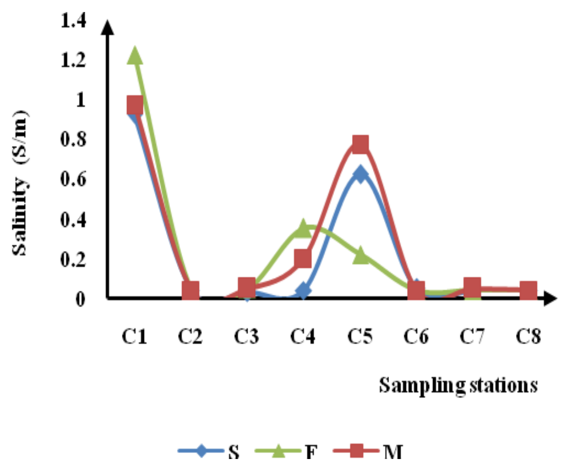

Figure 6: Changes in salinity (S/m) of the waters of the River Comoé as a function of sampling stations (surface (S), middle (M) and bottom (F))

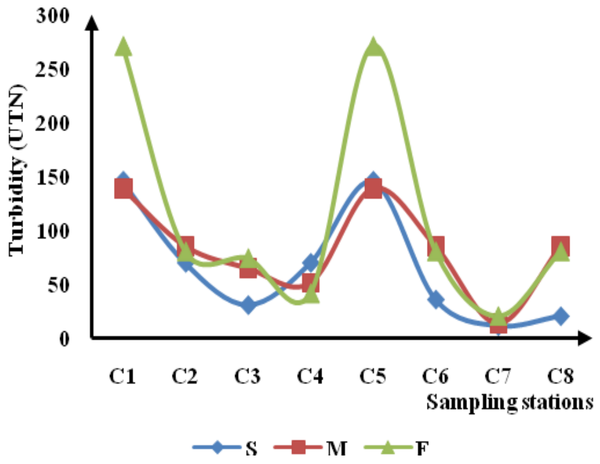

Figure 7: Evolution of Turbidity (UTN) in the waters of the Comoé River according to sampling stations (surface (S), middle (M) and bottom (F))

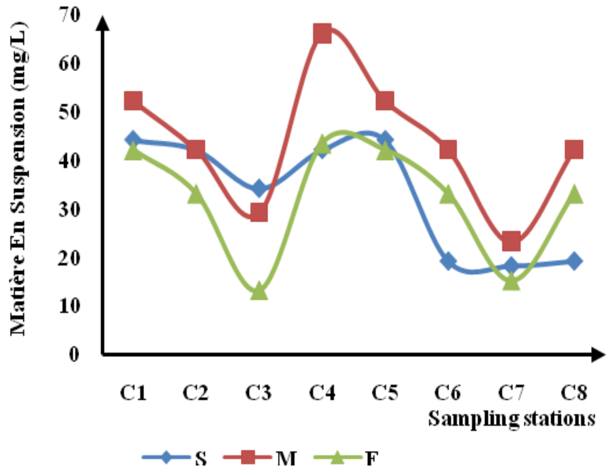

Figure 8: Changes in suspended solids (mg/L) in the waters of the River Comoé as a function of sampling stations (surface (S), middle (M) and bottom (F))

A2. Variation in nutrients in the waters of the River Comoé

Figures 9, 10, 11 and 12 show the organic characteristics of the water at the sampling stations. Nitrate levels vary from 0.8mg/L to 5.3mg/L. Nitrate levels were high at stations C2S, C2M and C2F, as well as C3S, C4S, C4M, C8M and C8F. Nitrite levels peaked at station C4S (0.08 mg/L). The maximum phosphorus value is at C1F, with a value of 9.28 mg/L. Phosphorus levels were also high at stations C4S and C7M. NH4 values range from 0.055 mg/L (C7M) to 0.39 mg/L (C4F), which is the maximum value.

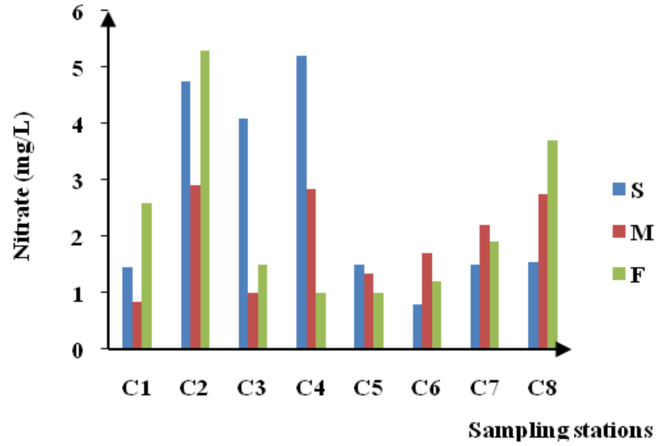

Figure 9: Variation in nitrate concentrations (mg/L) in the waters of the River Comoé according to sampling stations (surface (S), middle (M) and bottom (F))

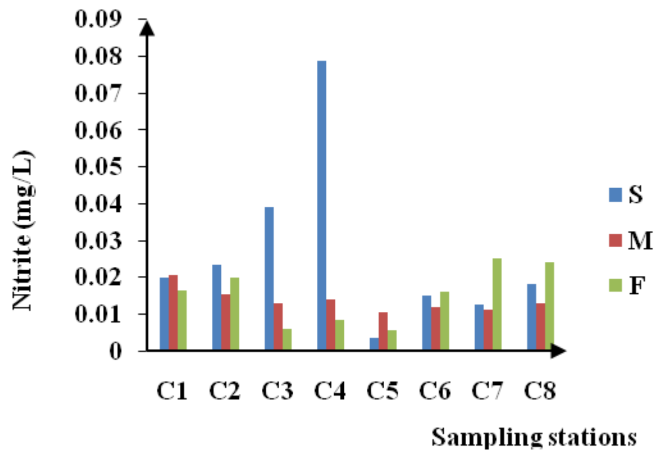

Figure 10: Variation in nitrite concentration (mg/L) in the waters of the River Comoé as a function of sampling stations (surface (S), middle (M) and bottom (F))

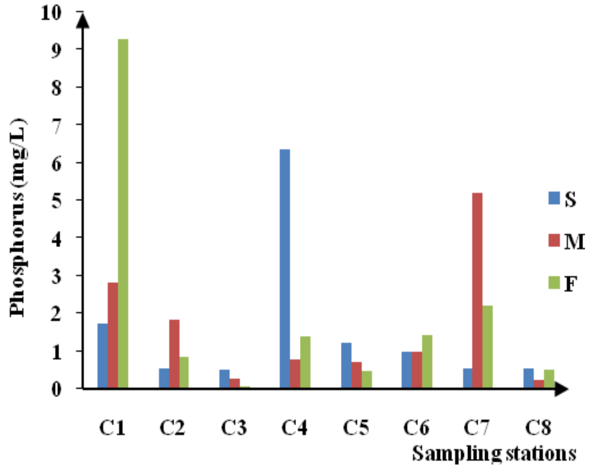

Figure 11: Variation in phosphorus concentration (mg/L) in the waters of the River Comoé as a function of sampling stations (surface (S), middle (M) and bottom (F)).

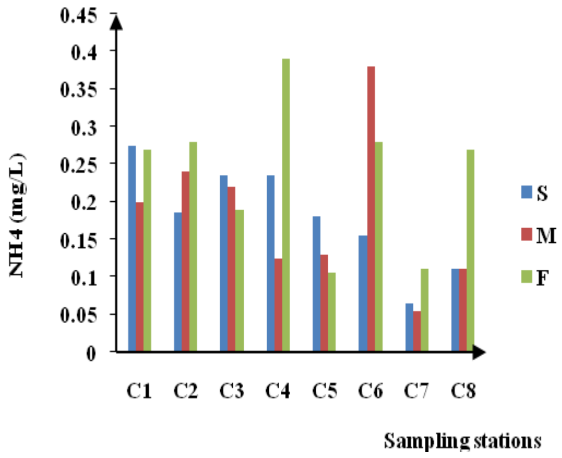

Figure 12: Variation in ammonium concentration (mg/L) in the waters of the Comoé River as a function of sampling stations (surface (S), middle (M) and bottom (F))

A3. Determination of levels of pesticide molecules in water from the River Comoé

The search for pesticides in water samples from the River Comoé revealed the presence of fenuron and desisopropylatrazine. The analysis showed the presence of fenuron molecules in almost all the water samples at variable levels, with a peak observed in the water from station C2 (0.9 mg/L). Only water from station C3 showed the presence of deisopropylatrazine at 0.051 mg/L (Figure 13).

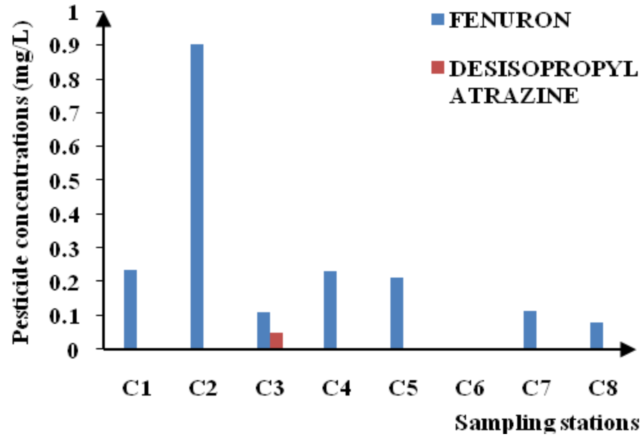

Figure 13: Concentrations of pesticide molecules (mg/L) in the waters of the River Comoé, by sampling station

A4. Enumeration of faecal contamination indicators in the waters of the River Comoé

Figures (14, 15, 16) show the variations in bacteriological loads in the waters of the River Comoé. Analysis revealed the presence of total coliforms, faecal coliforms and faecal streptococci in the water. Total coliform loads varied between 8350 (C2) and C8 (54750 cfu/100mL) (Figure 14). Stations C5 (46000 cfu/100mL) and C8 have the highest concentrations. Faecal coliform loads varied between 60 cfu/100mL and 3215 cfu/100mL (Figure 15). The highest level was recorded at station C2. The faecal streptococci level was recorded at station C6 (3085 cfu/100mL) (Figure 16).

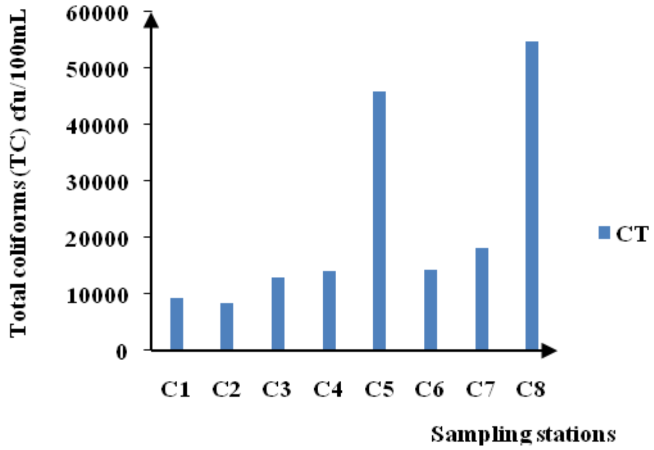

Figure 14: Variation in total coliforms (cfu/100mL) in the waters of the River Comoé according to sampling stations

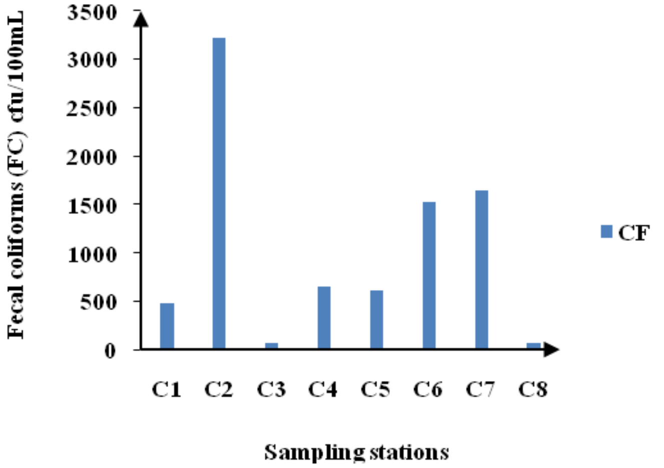

Figure 15: Variation in faecal coliforms (cfu/100mL) in the waters of the River Comoé according to sampling stations

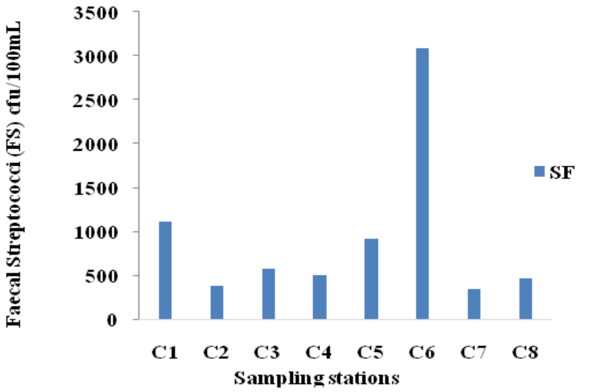

Figure 16: Variation in faecal streptococci (cfu/100mL) in the waters of the Comoé River according to sampling stations

A5. Determining the origin of bacteriological pollution

Table 3 shows the ratios of faecal coliforms to faecal streptococci in the water at the stations on the River Comoé, as well as the origin of the pollution at each site according to the ratios. Of the eight (8) stations studied to determine the origin of the pollution, five (5) were identified as being affected by pollution of animal origin. These were stations C1 (0.43), C3 (0.10), C5 (0.66), C6 (0.49) and C8 (0.13). Two are of human origin. These are stations C2 (8.35) and C7 (4.65). On the other hand, at station C4 (1.26), the pollution determined was of uncertain origin.

Table III: Origins of bacteriological pollution according to ratios

Sites	FC	FS	Ratio (FC/FS)	Origin of contamination
C1	480	1120	0,43	Animal
C2	3215	385	8,35	Human
C3	60	585	0,10	Animal
C4	650	515	1,26	Uncertain origin
C5	610	925	0,66	Animal
C6	1520	3085	0,49	Animal
C7	1650	355	4,65	Humain
C8	60	475	0,13	Animal

B. DISCUSSION

Analysis of water samples from the Comoé River revealed the presence of all the physico-chemical parameters sought. According to[10], the salinity and temperature of surface waters show spatio-temporal variations that are a function of freshwater inputs. Furthermore, the maximum temperature observed at station C3 (34.8°C) is thought to be due to the fact that this zone is subject to little river exchange with freshwater.

As a result, this shallow area receives direct sunlight. This helps to heat up the water more quickly. These data are in line with those[111], who shows that in inter-tropical Africa, average temperatures are high and most often above 20°C. As for salinity, the maximum value is recorded at station C1F (1.22 S/M). This peak could be explained by the influence of marine waters in the vicinity. This observation is in line with studies carried out by[12] on the Ebrié Lagoon in Côte d'Ivoire. This author revealed that the maximum average salinity values observed in the bays close to the Vridi canal (Biétri and milliardaires) can be explained by the effect of marine salt water. According to[13],tidal inputs, direct natural inputs from precipitation and sunshineimarine water salinity.

Conductivity is a measure of water mineralisation. Like salinity, it varies according to oceanic and continental inputs. This justifies the high conductivity observed in C1M (966 S/m). The high conductivity value observed in C5 (966 S/m) could be explained by the leaching of granitic zones in the centre-east, which carries large quantities of sediment into the Comoé river.

The pH values obtained during this study ranged from 6.02 (C2S) to 7.29 (C7S). These results show a slightly acidic to neutral pH. These different levels are linked to biological and physico-chemical reactions in the water and to the presence or absence of aquatic plants[14. According to[15], pH is a limiting factor in aquatic ecosystems. If the pH is below 4.5 or above 10, the environment becomes toxic for living organisms. As a result, the pH throughout the river is conducive to aquatic life.

Turbidity is determined by suspended solids. Suspended matter values confirm the observations made about water turbidity. The high content of suspended particles is linked to the nature of domestic and industrial waste and particles carried by run-off water[12].

A large amount of suspended matter leads to high turbidity. These parameters give the water a turbid appearance. Variations in the quantity of dissolved oxygen are influenced by factors such as water depth, current speed and the presence of reducing deposits [12]. According to[16], the origin of dissolved oxygen in natural environments is linked to the photosynthetic activity of aquatic plants, but also to dissolution from atmospheric oxygen.

According to[17], the gradual increase in nitrates in water is attributed solely to the presence of domestic and industrial wastewater discharges along the river. Thus, the quantities of nitrate and nitrite show that the river receives a large quantity of nutrients due to leaching from the surrounding areas, industrial waste and the use of fertilisers in the fields, which are transported to the watercourse. The excessive presence of the nitrogen compounds nitrates and nitrites in the river's waters could have serious consequences for human health and negative effects on ecosystems. As for ammonium (NH4), the peak of 0.39 mg/L (C4F) observed could be explained, partly, by nitrogenous reactions and leaching from agricultural land in the river's catchment area. In the presence of phosphorus, nitrogen compounds react and cause eutrophication, weakening the river's resilience, which is manifested by the presence of aquatic plants.

The high levels of phosphorus in stations C1F (9.28 mg/L), C4S (6.35 mg/L) and C7M (5.19 mg/L) are thought to be due to the use of fertilisers and pesticides in cash crop plantations in these different areas. The transfer of phosphorus from the plantations to the river is probably due to the leaching of the soil by run-off water.

According to[18], a total phosphorus concentration greater than 0.015 mg/L would cause algal blooms in the aquatic environment.

Analyses carried out on water samples from the River Comoé revealed the presence of high bacterial loads (total coliforms, faecal coliforms and faecal streptococci) in the water. This result could be explained by the frequent discharge of household wastewater into the river catchment, which is a major source of bacteriological contamination. According to MEDD (Ministère de l'Environnement et du Développement Durable du Canada) and Canada Water Agency standards, the average faecal coliform load in a watercourse must not exceed 3.3 log CFU/100 mL for the water to be considered bacteriologically satisfactory. According to[19], human activity remains the main cause of the deterioration in natural water quality. This explains the large quantities of faecal coliforms and faecal streptococci observed at stations C2 and C6.

The large quantity of faecal streptococci is thought to be due to activities such as traditional livestock farming in the vicinity of the river and the free access of animals to the river. Fecal streptococci are abundant in faeces and are the predominant environmental indicators[20].

According to[21], faecal coliforms are generally more abundant in human faeces than faecal streptococci. The latter are thought to be more important than faecal coliforms in animal faeces.

The ratios of faecal coliforms to faecal streptococci are either of animal, human or uncertain origin. These characteristics could be linked to the inputs of faeces and untreated wastewater that are directly or indirectly discharged into the river.

The observation of exclusively animal contamination [C1 (0.43), C3 (0.10), C5 (0.66), C6 (0.49) and C8 (0.13)] is thought to be due to the development of livestock farming activities in the vicinity of the stations and sometimes the direct discharge of abattoir effluent into the river.

V.CONCLUSION

This study enabled us to determine the level of pollution in the waters of the River Comoé. We found that the water contained high levels of physico-chemical parameters, showing that the river Comoé is rich in nutrients. These waters also show high levels of bacteria indicative of faecal pollution. The loads of these faecal pollution indicator bacteria are above the microbiological standards set by the Ministry of the Environment for surface water quality. The CF/SF ratio report revealed that bacterial pollution of the waters of the Comoé river is of human, animal or uncertain origin. The search for pesticides in water samples from the River Comoé revealed the presence of fenuron molecules in places and desisopropylatrazine in almost all the area studied.

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