Bacteriological and Physico-Chemical Characteristics of the Bathing Waters of Agroville Town: A Case of Agnéby River and Moutcho River

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Abstract

BACKGROUND

The United Nations Sustainable Development Goals (SDG) aim to improve the health and well-being of the population, as well as the expansion of universal access to drinking water and sanitation by 2030. It is in this perspective that this study aimed to characterize the bathing waters of the rivers of Moutcho and those of Agneby in Agboville town.

MATERIALS AND METHODS

The methodology consisted of conducting eight water sampling campaigns during the twelve consecutive months from December 2017 to November 2018. On these samples, the classical physicochemical parameters were determined by electrochemical, and colourimetric methods and microbiological analysis was carried out by the membrane filtration technique.

RESULTS

The results showed a low level of chemical mineralization in these waters. River water was distinguished from the other by higher levels of turbidity, colour, sulphate, phosphate, sulphur, and phosphorus and low levels of conductivity, temperature, sodium, and magnesium. Microbiologically, the water of the Agnéby River was of 100% satisfactory quality as per the Ivorian standards. However, it was not in compliance with other international standards (Algerian, Canadian, American, WHO and European). The Moutcho River was more polluted than the Agnéby River and the water quality was inadequate for swimming.

CONCLUSION

The waters of the Moucho and Agneby rivers were unsuitable for bathing. Health surveillance must be carried out continuously in these waters to preserve the health of the community.

Keywords: *Bathing Water, Quality, Faecal Contamination, Physico-Chemistry*

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Introduction

Access to drinking water and improved sanitation is considered a human right [1]. Thus water is an essential resource for the basic needs of man and his environment [2,3]. Water is also used in agriculture, aquaculture, industry, crafts, and water sports including bathing [4]. Bathing is any part of surface waters intended to accommodate the public. There are different categories of bathing which are: bathing in fresh or inland water (river, lake, pond) and bathing in sea, ocean or coastal water [4,5]. However, bathing, although associated with moments of relaxation or play, presents physical risks, but also chemical or biological risks due to the poor quality of bathing water or the surrounding environment [6,7]. The town of Agboville located 79 km from the city of Abidjan has been identified as one of the areas at high risk of waterborne diseases [8]. It is served by the river "Agneby" commonly called river "Agbo" which is full of many bathing sites. However, few studies have looked at the quality of these waters. Since 1993, the Ivory Coast has had a decree setting hygiene standards in the context of the health surveillance of water basins open to the public [9]. From that date to this day, the health surveillance of wild bathing has not seen any start of execution. To assess the health risks incurred by the population who bathes there, the objective of this study was to characterize the bathing waters of the city of Agboville on the microbiological and physicochemical levels to assess the risks. to preserve public health.

Material and Methods

Location of the study area

The Agnéby watershed, covering an area of 4,693 km2, is located in a forested area between longitudes 340000 to 420,000 metres and latitudes 650000 to 770000 metres. It is drained by the Agnéby River (Figure 1) which flows into the Ebrié lagoon in the vicinity of the Atlantic Ocean in the south of Côte d'Ivoire (8). The Agnéby watershed is under the influence of the equatorial climate of transition marked by four seasons: a great dry season that starts (December to March) followed by a great rainy season, (April to July) and a small rainy season (October to November) which alternates with a small dry season (August to September). The unequal distribution of the seasons is due to the upward and downward movements of the FIT (Front Intertropical). The area’s annual rainfall often exceeds 2000 mm (9).

Equipment

The main equipment consisted of a Palintest photometer (Great Britain), a pH meter, a conductometer, a turbidimeter, and a membrane filtration device. Echantillonnage

Sampling took place during 12 (twelve) distinct campaigns from December 2017 to November 2018. Samples were taken in 1000 ml polyethylene flasks for physicochemical parameters and 500 ml for microbiological parameters.

The reagents

The reagents used were analytical grade. The chemical parameter measurement reagents were Palintest (Great Britain). The BIORAD brand Rapid E. coli 2® Agar, BEA (Bile Esculine Azide) agar and TSN (Tryptone Sulfite Neomycin) agar culture media were used to count faecal contamination markers.

Collection, transport and storage of samples

The samples were taken according to WHO/UNEP recommendations [10]. The samples were stored in a cooler protected from light at a temperature between 4°C and 8°C and transported to the laboratory while respecting the cold chain by ice accumulators. These were transported at room temperature taking into account the fragility at low temperatures.

Physico-chemical analyses

The physicochemical parameters were determined by the following methods:

- pH was measured with a HACH digital laboratory pH meter equipped with a combined electrode (Bioblock Scientific).
- Conductivity was measured using a HACH conductivity meter.
- Turbidity was determined through HACH-type nephelometry.
- titrimetry was used for the determination of the organic matter.
- The mineral salts and colour were determined by colourimetry using a Palintest 7100 SE
- Photometer with pre-programmed filters and calibration curves. Operational wavelengths range from 410 nm to 640 nm.
- The procedure followed was that of the manufacturer. The mineral salts sought

were potassium, nitrites, nitrates, fluorides, orthophosphates, iron, manganese, complete alkalimetric titre (TAC), total hydrotimetric degree (DHT), ammonium, aluminium, chlorides, sodium, Magnesium, calcium, sulphates, potassium, bicarbonate, sulphur, zinc, phosphorus, silicates and silica.

Microbiological analyses

Microbiological analyses have made it possible to identify and count total coliforms, thermotolerant coliforms, *E. coli, Enterococcus faecalis, salmonella, and Pseudomonas*. These microorganisms were identified and counted by filtering 100 ml homogeneous aliquots on a 0.45 µm pore diameter membrane. The membranes were then placed on selective culture media for 24 hours at 37°C in the thermal oven.

The following media were used: KF agar (Selective medium used for the isolation and enumeration of enterococci by the conventional Petri Dish Count Method) for faecal streptococci, Rapid *E. coli* 2® Agar (culture medium for the identification of Escherichia coli) for total coliforms, TSN (Tryptone Sulfite Neomycin) agar for Clostridium sulfito-reductor, SS (*Salmonella Shigelles*) agar for salmonella and shigelle, on pseudosalt or kettrimide medium for Pseudomonas.

Statistical analyses

The values of the physical and bacteriological parameters determined were the subject of a descriptive statistical analysis (mean, minimum and maximum) to present the observed data in tabular or graphical form, thus facilitating reading and understanding and inductive analysis. The analyses were carried out with the R software version.

Results

Bacteriological parameters

The results of the microbiology of the bathing waters of Agnéby and Moutcho d'Agboville showed three groups of sprouts (Table 1):

- Group 1, represented by the quasi-constant microorganisms of total coliform types, thermo-tolerant coliforms, *E. coli* and *E. faecalis*,
- Group 2, the inconstant microorganisms *Pseudomonas aeruginosa*, and ASR.
- Group 3, missing microorganisms: Salmonella, Shigella and Staphylococcus.

Coliforms and enterococci were higher at the Moutcho River than at the Agnéby River throughout the study period (Figure 2).

Table I:
Bacteriological Parameters of the Agneby and Moutcho Rivers

	Agneby			Moutcho		
Parameters	Min	Med	Max	Min	Med	Max
C T	3	100	1200	400	1600	27300
C TH	3	100	1200	400	1600	27300
E. coli	3	100	1000	400	1000	27300
E. *faecalis*	5	500	5400	11	2300	15800
ASR	0	0	4	0	3	14
Pseudomonas	0	1	19	0	0	9
S. aureus	0	0	0	0	0	0
Salmonella, Shigelle	0	0	0	0	0	0

Organoleptic and physicochemical parameters

The physicochemical results of the bathing waters of Agneby and Moutcho showed that these waters are heavily mineralized with averages of 82.3 mS/cm in Azuretti-village and Quartier France (Table 2).

Characterization of the two water sources

The analytical results presented for each of the two rivers in this study covered twenty-eight (28) chemical physico-parameters and thirteen (13) microbiological parameters analyzed regarding different standards in force.

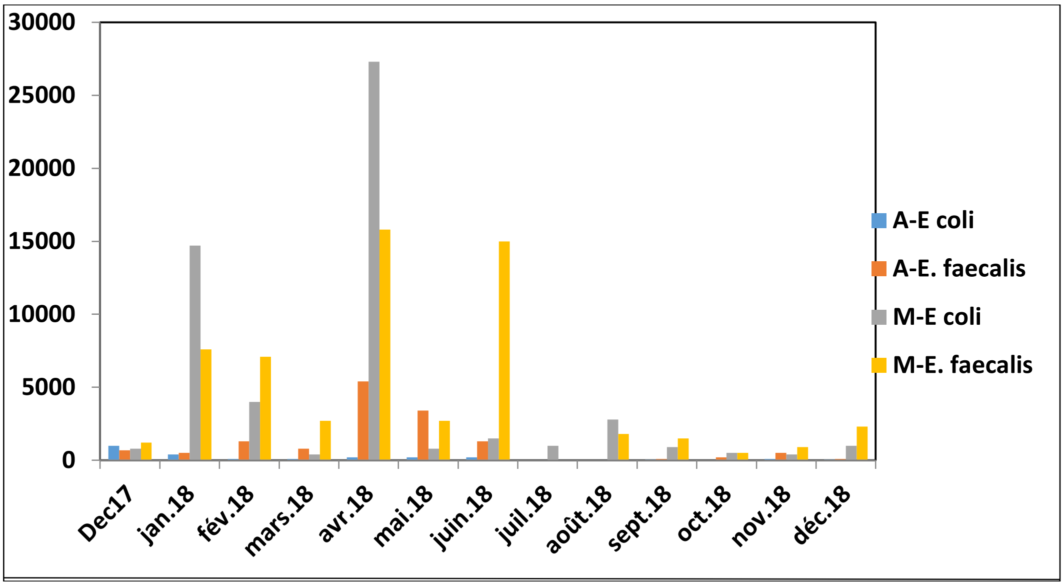

Figure 2:
Comparison of pathogen levels at the river level. **Key**: A_*E.coli* (*E. coli* in Agnéby), A_*E.faecalis* (*E. faecalis* in Agnéby), M_*E.coli* (*E. coli* in Moutcho), M_*E.faecalis* (*E. faecalis* in Moutcho).

Table II:
Physico-chemical parameters of the bathing waters of Agneby and Moutcho

	Agneby			Moutcho			Agneby Vs Moutcho	
Paramètres	Min	Med±ET	Max	Min	Med±ET	Max		
Turbidity (UTN)	7,18	14,3±7,896	37,6	25,1	43,9±12,051	67,5	37,6	67,5
Color: Pink (UCV)	20	220±100,756	310	35	330±228,190	680	310	680
Conductivity (µs/cm) Conductivity	6,04	212,6±85,115	294	35,8	82,5±37,779	175,5	294	175,5
pH	6,37	7,13±0,395	7,62	5,98	6,99±0,427	7,69	7,62	7,69
T (or C)	23,1	28,2±2,039	30,8	23,3	26,6±2,831	34,5	30,8	34,5
Fe (mg/L)	0,4	0,7±0,496	2,35	0,85	1,5±1,323	6,25	2,35	6,25
Cl (mg/L)	5,7	14±4,938	22	2,7	4,7±3,045	15	22	15
Al (mg/L)	0,01	0,1±0,059	0,23	0,05	0,17±0,081	0,29	0,23	0,29
Nitrite (mg/L) Nitrite	0,03	0,06±0,027	0,12	0,01	0,08±0,046	0,17	0,12	0,17
Nitrate (mg/L)	0,36	1±0,571	2,7	0,48	1,1±0,395	1,9	2,7	1,9
Ammonium (mg/L) or other	0,01	0,21±0,131	0,44	0,01	0,22±0,220	0,8	0,44	0,8
MO (mg/L)	0,72	11±5,593	19,09	0,87	11,09±4,855	19,79	19,09	19,79
Sulphate (mg/L)	0	8±3,846	10	11	17±3,294	22	10	22
Phosphate (mg/L)	10	14,7±77,523	306	6	38,8±56,239	241	306	241

The samples taken in the city of Agboville during the 12 months (December 2017 – November 2018) as part of the measurement campaigns are of instantaneous type. They are thus only a reflection of the characterization of water at a given moment.

Physico-chemical analyses showed that the ten (10) parameters of turbidity, colour, conductivity, temperature, sodium, magnesium, sulphate, phosphate, sulphur, and phosphorus have made it possible to differentiate the waters of the Agnéby River from the Moutcho River. Of these results, some are similar to those of Kamara (2018) who worked on them. same waters in the period from December 2017 to April 2018 except for colour, temperature, sodium, magnesium, phosphate and phosphorus which were not significant between the two water sources [11].

A positive correlation was also found between coliforms and phosphates on the one hand and conductivity on the other. There was a negative correlation between coliforms and nitrates, turbidity, and colour (Figure 3).

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Discussion

Physico-chemical quality

Organoleptic parameters yielded turbidity values below the standard (37.6 UNT) for the Agneby River (50 UNT) and above the standard for the Moutcho River (67.5 UNT). The colour of the two bathing waters (310-680 UCV) is above the standard (15 UCV). Turbidity showed slightly turbid waters relative to the Bedjilali table [12].

Organic matter generally includes algae, protozoa and natural products from the decomposition of vegetation (humic substances, tannins, lignin). Soil leaching can also lead to less common organic acids. The conductivity of both waters showed relatively lower (294 µs/cm and 175.5 µs/cm) values than those obtained in a previous study [11].

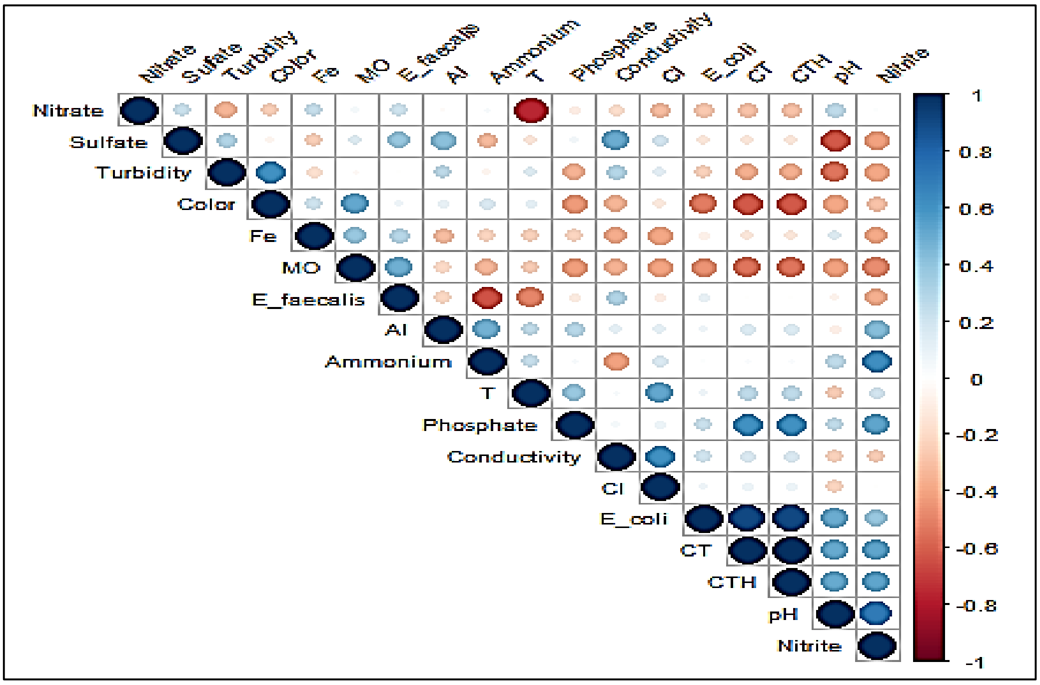

Figure 3:
Correlation between the values of the different bathing water parameters (Agneby Vs Moutcho).

These waters are shown to be weakly mineralized. The levels obtained are comparable to those of the fresh surface waters of Côte d'Ivoire [13]. The pH of the two water sources was in virtually the same direction and was included in the standards (6-9). These values are in line with hygienic standards in the context of sanitary monitoring of swimming pools, swimming pools and swimming pools open to the public [10]. The pH of water representing its acidity or alkalinity, in terms of natural waters, is related to the nature of the terrain crossed [13,15]

Temperature averages ranging from 30.8°C to 34.5°C were recorded for the Agnéby River and Moutcho River, respectively, during the study period. Temperatures ranging from 27.3°C to 29.5°C were inversely proportional to those in Kamara (2018) [11]. According to Beldjilali, high-temperature values are not harmful to human health, but they play an important role in increasing the chemical activity of bacteria [12]. The phosphate concentrations obtained for the two rivers (306 mg/L and 241 mg/L) were above 0.5 mg/L [13]. This most often explains the problems of eutrophication in the waters. The levels of nitrites (0.12 mg/l and 0.17 mg/l) and nitrates (2.7 mg/l and 1.9 mg/l) in the waters were very low compared to the WHO (2004) standards of 2 mg/l and 50 mg/l, respectively [14].

River water was distinguished from river water by significant increases in the parametric values of turbidity, colour, sulphate, phosphate, sulphur, and phosphorus and significant decreases in conductivity, temperature, sodium, and magnesium.

Microbiological quality

The microbiological quality of the two bathing waters depended on the presence or absence of certain germs, the most frequently encountered of which were E. coli and Enterococcus faecalis. The Moutcho River is the most microbiologically polluted compared to the Agnéby River. This was observed in June, July, August and December 2018.

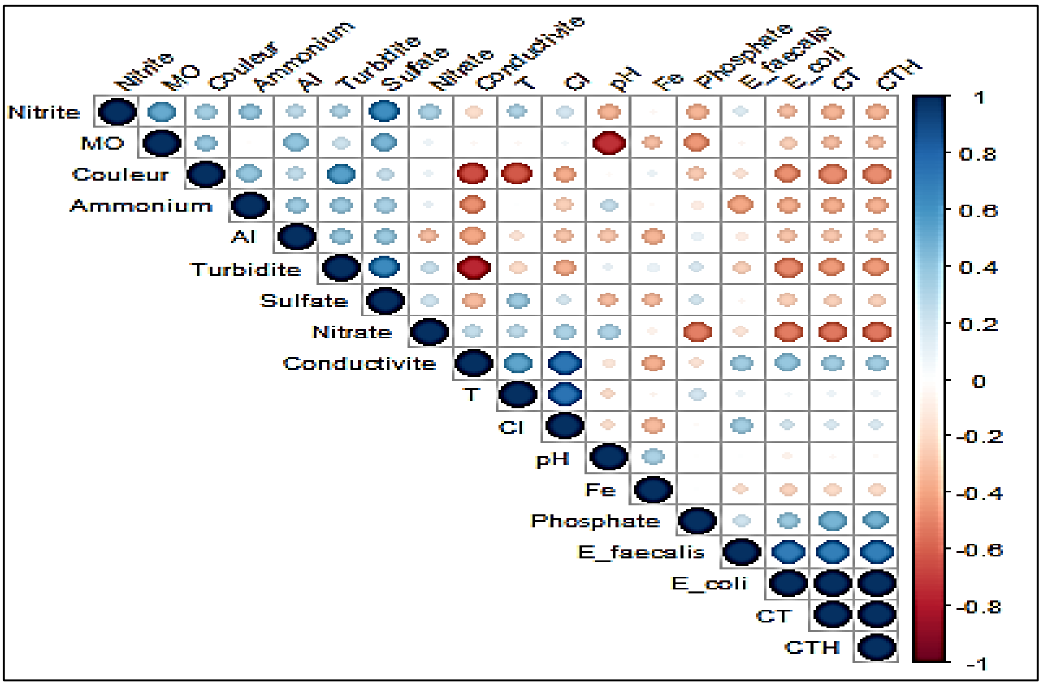

Figure 4:
Correlation between the values of the different Moutcho bathing water parameters

For enterococci, their maximum concentrations were approximately 5400 CFU/100 ml for the Agnéby River and 15800 CFU/100 ml for the Moutcho River. This increase is believed to be due to human and animal manure (open defecation), and the release of domestic and agricultural discharges without treatment, as indicated by Hounsou et al (2010) [15].

Detection of these germs indicates faecal contamination of the water and thus the possible presence of faecal pathogenic bacteria, viruses or protozoa. Similar observations were made by Dovonou at Lake Nokoué in Benin [13] and Merhabi et al (2019) [16]. The abundance of faecal germs during the rainy season may be mainly due to increased anthropogenic inputs through the leaching of soiled soils and the draining of sewers and runoff. [17].

The presence of these markers, which are indicators of faecal pollution, proves that the waters analysed are polluted.

Comparison with bathing water standards

The hygienic quality of bathing water is of paramount importance. The health risk associated with bathing water pollution is above all microbiological. Control is based primarily on the detection and counting of faecal pollution indicator bacteria such as E. coli, the best indicator of faecal contamination in freshwater.

Microbiological analyses of the Agnéby River and the Moutcho River in the city of Agboville provided results compared to Ivorian, Algerian, Canadian, and European standards and those of the American Environmental Protection Agency (US EPA) and the WHO. For bathing water of satisfactory quality, the Ivorian standard recommends that there is an absence of Salmonella, Vibrion, Shigella and less than 10000 CFU/100 ml of total coliforms and 2000 CFU/100 ml of faecal coliforms [11].

This standard showed that the Agnéby River could be of acceptable quality during the campaign period, compared to the Moutcho River, which could be classified as of unacceptable quality in June and August 2018. Compared to Algerian standards, water is of satisfactory quality when the total coliform levels, E. coli and E. faecalis are below 500, 100 and 100 CFU/100 ml respectively. Water is of acceptable quality and should be monitored when total coliform levels are below 10000 CFU/100 ml, E coli at 2000 CFU/100 ml and E. faecalis above 100 CFU/100 ml. From this standard, it emerges that the river water could be of acceptable quality compared to that of the river whose quality was not acceptable with an increased abundance of enterococci in June (15800 CFU/100ml) and a fairly high rate of E. coli in April (27300 CFU/100ml). These results are similar to those of Dosso (2017) on the bathing water of the Man waterfall. [20].

The comparison with the U.S. and Canadian standards is based on geometric means of parametric E. coli values for freshwater. Both waters were found to be unsatisfactory to American standards, but for Canadian standards, only the river met the specifications of this standard, and the quality of the river was inadequate for swimming.

Compared to European and WHO standards, the waters of the Agnéby and Moutcho rivers could be of poor quality for bathing because the 90th and 95th percentiles were higher than the values of class D. Indeed, class D (poor quality water) is water with percentiles (bacteria) greater than 1000. But we observe that compared to the European standard the river did not contain a sufficient amount of E. coli that could cause a microbiological risk.

In short, the significant presence throughout the campaign of indicator germs of faecal pollution such as E. coli, and E. faecalis proves that the waters of the river and the river are polluted. This pollution may be due to certain activities such as open defecation and the discharge of household waste into water [21,22].

Correlation between different parameters

The analysis of these two types of water indicates that there is a positive correlation between the indicator coliforms of faecal pollution and conductivity while these waters are weakly mineralized. According to Fouad (2013), [23] electrical conductivity reflects the degree of overall mineralization and provides information on salinity levels. As a result, salinity is a very important stressor for faecal pollution bacteria in a salt environment [24].

Conclusion

The study of the physicochemical and microbiological parameters made it possible to judge the quality of the waters of the Moutcho River and the Agnéby River in the town of Agboville. It appears from the physicochemical plane that these two waters are weakly mineralized. The water from the Moutcho River differed from the water from the Agneby River by the significant increase in the parametric values of turbidity, colour, total iron, aluminium, nitrites, sulphur, zinc, silica and silicate.

Microbiologically, the water in the river was of satisfactory microbiological quality compared to river water. Compared to Ivorian, Canadian, American, US-EPA, WHO, and European standards, these waters are of insufficient quality for swimming.

Health surveillance of these waters is necessary to ensure the health of the population engaged in this activity.

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Appendix:

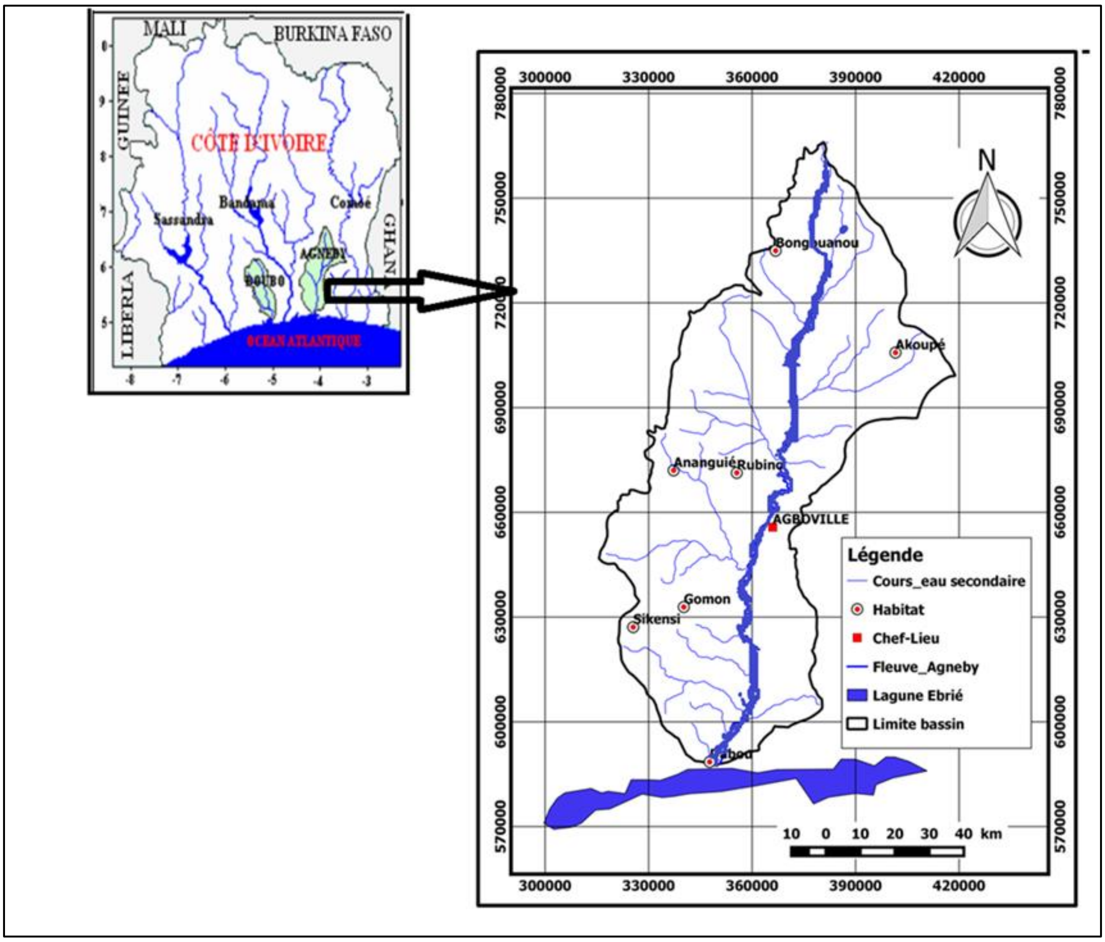

Figure 1:
Agneby Watershed Map