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RESEARCH ARTICLE

SPATIO-TEMPORAL STUDY OF THE FECAL POLLUTION OF THE WATERS OF THE ONO LAGOON IN THE COMMUNE OF BONOUA (CÔTE D'IVOIRE)

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ABSTRACT

The objective of this study is to evaluate the bacteriological quality of the Ono lagoon. The bacteria sought are total coliforms, fecal coliforms, *E.coli,* Enterococci, *Clostridium perfringens*. For this purpose, surface water was collected by dipping 500 mL glass bottles previously sterilized for laboratory analysis. The water samples to be analyzed were spread on agar media without any trace of moisture. After incubation, the colonies that grew on the surface were counted. The results also showed the presence of the bacteria sought in the lagoon. These varied seasonally at six (6) stations. The bacteriological loads recorded are higher in the rainy season than in the low water and flood seasons. The fecal coliform loads recorded in the Ono lagoon at the different stations 1, 5 and 6 in the low water season, at stations 4, 5 and 6 in the rainy season and at station 4 in the flood season showed the poor quality of these waters at these stations. Seasonal variation showed that the average fecal coliform load recorded in flood season is $4.5 \pm 2.4x10^2$ CFU/100mL. On the other hand, those recorded in low water season is $1.7 \pm 1.3x10^3$ CFU/100mL and in rainy season is $3.4 \pm 1.9x10^3$ CFU/100mL. Compared to the values of the general grid of microbiological quality (SEEE, 2008) of Morocco, our results obtained allow us to say that the waters of the Ono lagoon are of good quality in flood season and average quality in low water and rainy seasons.

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INTRODUCTION

Lagoons represent about 13% of the length of the world's ocean coasts (Cromwell 1971 in Durfour 1984). They are ecosystems located between the continent and the sea (Issola *et al*., 2008). These lagoons communicate permanently or temporarily with the sea, but are isolated from it by a large barrier beach (Lankfort 1977; Laë 1992; Affian 2003). In Côte d'Ivoire, the hydrographic network includes an important lagoon system comprising the Ebrié, Grand Lahou and Aby lagoons (Amani 2012). Apart from these three (3) main lagoons, the western facade of Côte d'Ivoire, presents small continental lagoons such as the Ono Lagoon which is the subject of this study. Today, lagoons are subject to strong anthropic (Bloundi 2005) and natural (river inputs) pressures. Indeed, according to Gnohossou (2006), these coastal hydrosystems are sites of fishing, aquaculture, tourism and transport activities. They are also places of abusive discharge of domestic and agro-industrial wastewater, without prior treatment. This is the cause of strong contamination of these lagoons by microorganisms, some of which could prove dangerous to the health of users. The pollution of lagoons is therefore a serious threat given the epidemiological risks associated with it (Kambiré 2014).Because of its vital character, the water consumed must be of good sanitary quality in order to avoid the occurrence of waterborne diseases. Water from the lagoons in Côte d'Ivoire is often used for watering raw vegetables such as lettuce, cucumber, etc. There is some evidence that raw edible vegetables are a source of infection (Barak and Liang 2009; Carey and Migliaccio 2009). Unsafe water alone causes about four million child deaths per year from diarrhea (Larbi 2003). Diarrheal diseases are a major public health concern worldwide, especially in developing countries where they are second only to respiratory infections (UNICEF 2004). Figures published by the World Health Organization (WHO) in 2013 reveal that 1.7 billion cases of diarrhea are recorded each year worldwide. According to this organization, diarrhea is the second leading cause of death in children under five. In developing countries, these diarrheal diseases are the cause of death of several hundred thousand children per year (Chen and Frankel 2005). In the Ono lagoon, which is the subject of this study, there is a lack of data covering the microbiological aspect, which is very useful for the population living along the lagoon. The growing anthropic pressure around this lagoon could have a negative influence on the quality of these waters. Indeed, fishing, boating, and swimming activities are carried out in the Ono Lagoon. In addition, market gardening and pig breeding are practiced in the vicinity. It is also the main receptacle of agricultural wastewater from large industrial pineapple and rubber plantations. The water of this lagoon is therefore of doubtful quality. It is therefore necessary that a study be carried out in order to know the contribution of anthropic impacts on the bacteriological quality of this lagoon during the low water, rainfall and flood seasons.

MATERIAL AND METHODS

This study was done on the water of the Ono lagoon. The technical material used is composed of glassware and equipment. The Ono lagoon is located in the north of the commune of Bonoua, more precisely between longitudes 3°35'20.62" W - 3°32'57.55" W and latitudes 5°21'10.44" N - 5°23'34.30" N, with an area of approximately 6.1 km^2 (**Figure 1**).

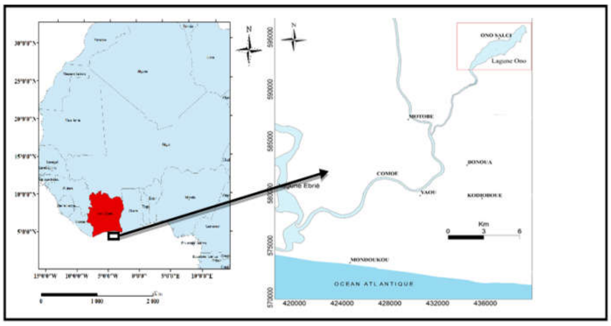

Figure 1. Geographic location of the study area

Sampling: Water samples for analysis were collected from the surface of the water body by dipping into previously sterilized 500 mL glass vials. These were kept at 4°C in coolers during transport to the laboratory. The water sampling was done on six (6) stations at each campaign (low water (April), rainy (August) and flood (November)) in 2017. That is, six (6) water samples per campaign (**Figure 2**). A total of eighteen (18) water samples were collected during the three lagoon seasons.

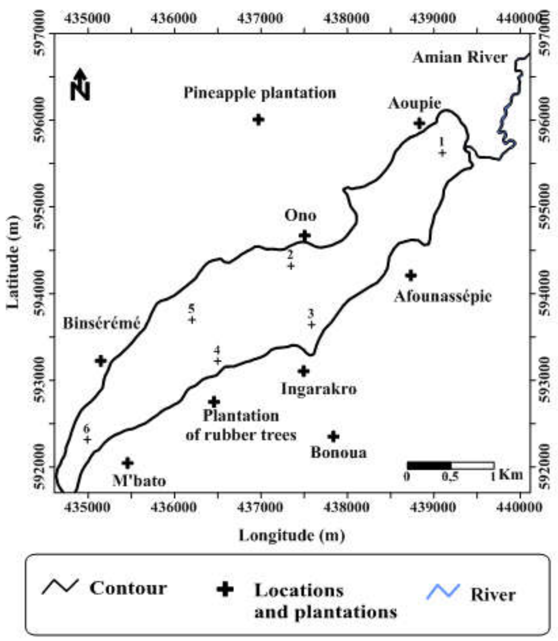

Figure 2. Sampling stations

Bacteriological analysis: The bacteriological analyses were carried out at the Ivorian Anti-Pollution Center. The analyses focused on the search for pollution indicator bacteria such as total coliforms, fecal coliforms, *Escherichia coli,* Enterococci and *Clostridium perfringens*. **Table 1** different methods used for the isolation of each bacterium. For enumeration, after plating, *Escherichia coli* appears pink to purple while other Coliforms such as Total Coliforms and Faecal Coliforms appear blue on the culture medium. Enterococci appear black and *Clostridium perfringens* appear as large black colonies in depth.

Statistical analysis: The data obtained were processed using Statistica 7.1 software. The statistical analysis of the differences was done using the parametric test (Turkey test). The differences were considered as not significant if $P > 0.05$.

DETERMINATION OF THE ORIGIN OF THE FECAL CONTAMINATION: It is based on the criteria defined by Borrego and Romero (1982) in Wognin (2014). According to these authors, the origin of the fecal contamination depends on the value of the ratio of fecal coliforms to fecal streptococci (Enterococci) (CF/SF) (**Table 2**).

EVALUATION OF THE BACTERIOLOGICAL QUALITY OF THE WATER: This system is extracted from the general microbiological quality grid used for surface water classification (SEEE, 2002) updated by DRPE (SEEE, 2008) (**Table 3**).

RESULTS

Spatial and temporal variation of contamination indicators in Ono Lagoon

Variation in total coliform (TC) loads: Total Coliform loads vary differently between seasons and stations. In the low water season, in Ono Lagoon, total coliform loads ranged from 2.7x10^3 CFU/100 mL to 9.9x10^3 CFU/100 mL with an average of 5.6 ± 3.1x10^3 CFU/100mL. The highest value was recorded at station 5. In the rainy season, these loads range from 1.4x10^3 CFU/100 mL to 6.1x10^4 CFU/100 mL for an average of 1.7±1.4x10^4 CFU/100mL. The highest load was observed at station 4. However, in the flood season, high loads are observed at stations 4 and 5. Loads ranged from 1.4x10^3 CFU/100 mL to 23.6x10^3 CFU/100 mL with an average of 7.9 ± 5.6x10^3 CFU/100mL (**Figure 3**). Statistical analysis indicates that there were no significant differences between stations ($P > 0.05$) but a significant difference was observed between low and high water seasons and between low and wet seasons ($P < 0.05$).

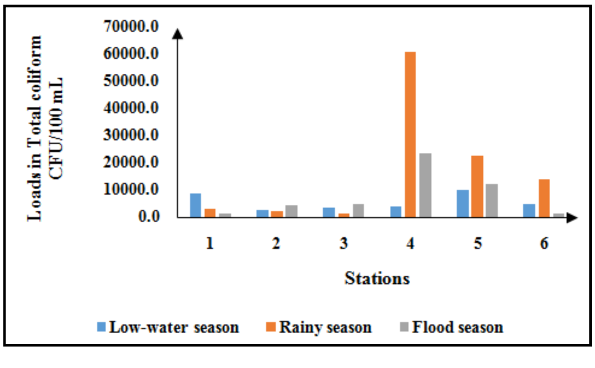

Figure 3. Spatial and Temporal Variation of Total Coliform Loads in Ono Lagoon

Variation in fecal coliform (FC) loads: Fecal coliform loads recorded in the low water season vary from 4x10^2 CFU/100mL to 5x10^3 CFU/100mL with an average of 1.7±1.3x10^3 CFU/100mL. The highest load was recorded at station 5. In the rainy season, these loads range from 1.3x10^2 CFU/100mL to 1.1x10^4 CFU/100mL with an average of 3.4 ± 1.9x10^3 CFU/100mL. The peak was reached at station 4. In the flood season, the highest load was measured at station 4. Loads ranged from 52 CFU/100mL to 1.4x10^3 CFU/100mL with an average of 4.5 ± 2.4x10^2 CFU/100mL (Figure 4). The increasing order of fecal Coliforms is as follows Flood < low water < rainy. There is no significant difference between stations ($P > 0.05$). The same is true for the seasons.

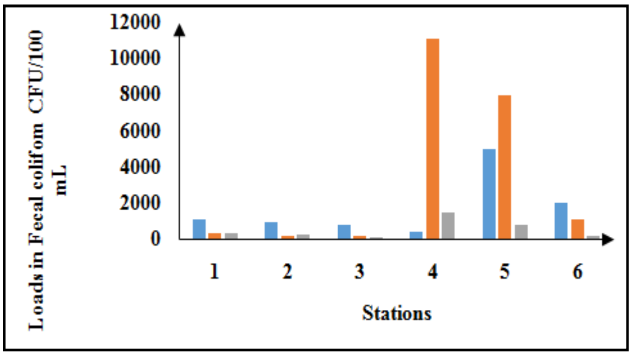

Figure 4. Spatial and Temporal Variation of Fecal Coliform Loads in Ono Lagoon

Variation in E. coli loads: During low water periods, *E. coli* are more concentrated at station 5, the low load was measured at station 4. These loads vary between $2x10^2$ CFU/100 mL and $2.2x10^3$ CFU/100mL with an average of $8.3 \pm 6.2x10^2$ CFU/100mL. In the rainy season, these colonies are abundant at stations 4 and 5. The loads vary from 10 CFU/100 mL to $3.4x10^3$ CFU/100mL with an average of $1.1 \pm 0.9x10^3$ CFU/100mL. On the other hand, in the flood season, *E. coli* were observed a lot at station 4. Loads ranged from 40 CFU/100mL to $3x10^2$ CFU/100mL for an average of $1.3 \pm 0.9x10^2$ CFU/100mL (Figure 5). The order of abundance is as follows: Flood < low water < rainy. No significant differences were indicated by statistical analysis between the different stations and between seasons (P > 0.05).

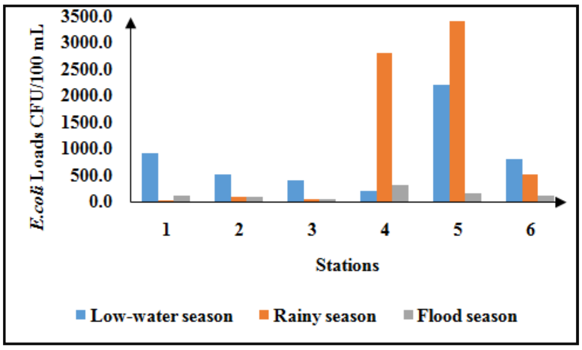

Figure 5. Spatial and temporal variation of *E.coli* loads in the Ono lagoon

Variation in Enterococci loads: During the low water season, these colonies are abundant at Station 5 and low at Station 6. Loads range from 10 CFU/100mL to $1.3x10^2$ CFU/100mL with an average of 35 ± 28 CFU/100mL. In the rainy season, these loads vary between 15 CFU/100mL and $2.2x10^2$ CFU/100mL for an average of 70 ± 55 CFU/100mL. Enterococci are concentrated at station 6. During the flood season, loads varied from 20 CFU/100mL to $2.7x10^2$ CFU/100mL with an average of $1.1 \pm 0.9x10^2$ CFU/100mL (Figure 6). The highest load was measured at station 4. The order of abundance was low water < rainy < flood. There were no significant differences between stations and between seasons (P > 0.05).

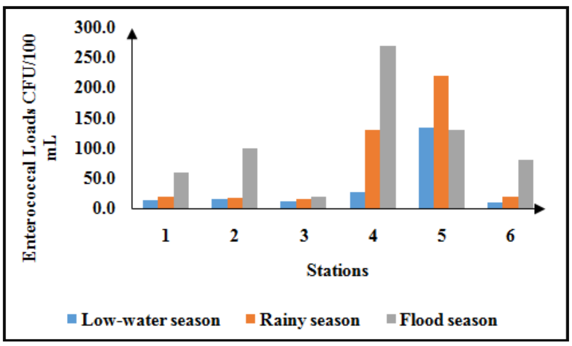

Figure 6. Spatial and temporal variation of Enterococci loads in the Ono Lagoon

Variation in Clostridium perfringens (CP) loads: Minimum and maximum loads ranged from 2 CFU/100mL to 20 CFU/100mL with an average of 9 ± 7 CFU/100mL. The highest load was recorded at station 4. In the rainy season, these loads vary from 0 CFU/100mL to $1.5x10^2$ CFU/100mL for an average of 17 ± 14 CFU/100mL. The highest load was recorded at station 5. In the flood season, these loads range from 0 CFU/100mL to 28 CFU/100 mL with an average of 13 ± 10 CFU/100mL. The highest load was recorded at station 4 but was absent at station 2 (Figure 7). The increasing order is as follows low water < flood< rainy. Statistical analysis indicated significant differences between stations 1 - 2; 1 - 5; 2 - 3; 2 - 4; 2 - 5; and 2 - 6 and between stations 3 and 5 (P < 0.05). No significant differences were observed at the seasonal level (P > 0.05).

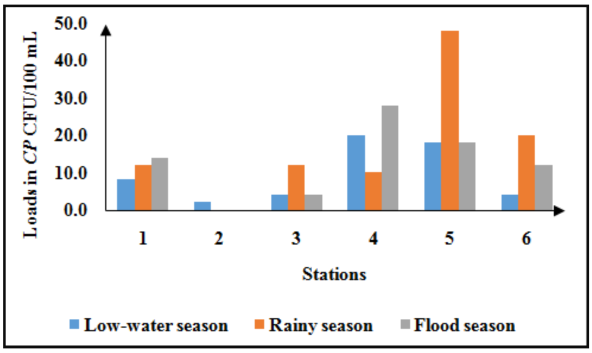

Figure 7. Spatial and temporal variation of *Clostridium perfringens* loads in the Ono Lagoon

Origin of the fecal contamination of the waters of the Ono lagoon: The fecal coliform to fecal streptococcus (enterococcus) ratio (FC/FS) value determining the origin of the fecal contamination in Ono lagoon is 26.034 CFU/100 mL (**Table 4**). Based on these values, the origin of the fecal contamination in Ono Lagoon is strictly human (CF/SF >4).

DISCUSSION

Total Coliforms, Fecal Coliforms, *Escherichia coli*, Enterococci and *Clostridium perfringens* were the bacteria sought in this study to assess the bacteriological quality of the lagoon. The results showed variations in loads at the stations and seasons. This could be explained by the environment of this village characterized by the presence of garbage and the stagnation of wastewater in several places. The domestic discharges of the local populations and the washermen are sources of strong bacterial pollution and would also be at the origin. The fecal coliform loads recorded in Ono Lagoon at stations 1, 5 and 6 during the low water season, at stations 4, 5 and 6 during the rainy season and at station 4 during the flood season are higher than the Canadian Health Standard (2012) of 1000 CFU/100 mL used as an indicator of the general health of the surface water. These high values reflect the poor quality of the water at these stations. The recorded indicator loads of contamination could be due to anthropogenic actions. These bacteria in the water would come from animal and human waste. According to Traoré *et al*, (2012), runoff and winds carry animal waste directly into the lagoon or into the streams that feed it. The high loads of Enterococci and *Clostridium perfringens* recorded during the rainy and flood seasons could be due to the fact that heavy rainfall drains water from the watersheds, surrounding villages, and satellite streams containing animal feces and waste towards Ono Lagoon. Therefore, these bacteria could be derived from faeces and animal waste directly or indirectly discharged into the lagoon. The presence of animals such as reptiles, migratory birds, domestic animals (dogs...) can contribute to the fecal contamination of waters. The excreta of these animals are carried by runoff during the rainy season to these waters. The presence of *Clostridium perfringens* is evidence of past fecal contamination (Alvaro *et al.*, 2009). Ono Lagoon is prone to pollution, with high organic load and algal overgrowth observed in the water body. The high bacterial levels in Ono Lagoon may be explained by the fact that it is closer to the localities. In addition, the banks are less developed, which causes the proliferation of bacteria, the main source of which would come from human and animal faeces.

Table 1. Methods of bacteriological analysis

Bacteriaresearched	Methods	Culture medium	Standards	Incubation temperatures (°C)	Incubation time (h)
Total coliforms	By filtration	Rapid'E. coli 2 Agar	NF ISO 16649-2	37	24h
Fecalcoliforms	By filtration	Rapid'E. coli 2 Agar	NF ISO 16649-2	44	24h
E.coli	By filtration	Rapid'E. coli 2 Agar	NF ISO 16649-2	37	24h
Enterococci	By filtration	BEA Agar	ISO 7899	37	24h
Clostridium perfringens	Deepseeding or incorporation	TSN Agar	ISO 14189	46	24h

Table 2. Criteria for determining the origin of fecal contamination

Ratio CF/SF (R)	Source of contamination
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

Table 3. General Microbiological Quality Grid (SEEE, 2008)

	CLASS 1	CLASS 2	CLASS 3	CLASS 4	CLASS 5
Quality class	Excellent	Good	Average	Poor	Very Poor
Parameter unit					
Fecalcoliforms /100 mL	≤20	20-2000	2000-20000	20000-50000	-
Total coliforms /100 mL	≤50	50-5000	5000-50000	>50000	-
FecalStreptococci /100 mL	≤20	20-1000	1000-10000	>10000	-

Table 5. Origin of fecal contamination in Ono Lagoon

Lagoon / Germs	Ono
Fecal coliforms (FC) in CFU/100mL	1870.11
Enterococci (CF) in CFU/100mL	71.833
Ratio CF/SF (R)	26.034
Origin of the contamination	Strictly of humanorigin

The high loads of fecal coliforms recorded could be due to the proximity of animal pens (pigs), associated with the presence of fecal matter of human origin. In general, these bacteria are more important in the rainy season than in the flood and low water seasons, which could be explained by the fact that this period is favorable to the drainage of runoff water which brings in the water the waste of various kinds produced upstream. On the other hand, the low loads noted during the low water and flood seasons could be explained by the low runoff contributions due to the scarcity of rainfall. Seasonal variation shows that the average fecal coliform load recorded in Ono Lagoon during the flood season is below the Canadian Health Standard. This indicates that the water quality is good for recreation and water sports during this season. On the other hand, the average loads recorded during the low water and rainy seasons are higher than 1000 CFU/100 mL. This reflects the poor quality of these waters during these seasons. The proximity of the variables in the different factorial planes 1 and 2 would indicate a good correlation between them. This means that they have the same seasonal and temporal evolution. These different bacteria could come from the same source of contamination. Factors 1 and 2 would respectively reflect a pollution of fecal and old origin. According to the criterion for determining the origin of the fecal contamination, the value of the ratio of fecal coliforms to fecal streptococci (enterococci) calculated being greater than 4 (FC/FS > 4), the origin of the contamination of the waters of Ono lagoon is strictly human. This would be explained by the fact that human influence is very high in this environment. The general grid analysis (SEEE, 2008) indicates that the water quality of Ono Lagoon is good in the flood season and average in the low and wet seasons.

CONCLUSION

After analysis, it appears from this study that the Ono Lagoon is under strong anthropic pressure. The bacterial contamination of this water is of strictly human origin. The indicators of contamination in the lagoon are more concentrated in the rainy season than in the low water and flood seasons. Compared to the Canadian health standard, the lagoon is of good quality during the flood season for recreational and sports activities.

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