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Spatial and temporal variation of fecal contamination indicators in Grand-Lahou lagoon, Côte d'Ivoire

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ABSTRACT

Objective: To determine the level of bacterial pollution of the surface waters of the Grand Lahou lagoon using the fecal contamination indicators (thermotolerant coliforms, *Enterococci* and sulphite-reducing anaerobes).

Methodology and results: Thirty six (36) samplings were carried out during three annual cycles (May 2003 to April 2006) in ten (10) stations spread throughout the Grand-Lahou lagoon. Bacterial counts of thermotolerant coliforms, *Enterococcus* and sulphite reducing anaerobic bacteria were made together with the determination of physical and chemical parameters (temperature, salinity, pH, oxygen, turbidity, water transparency, NO_2^-, NH_4^+ and PO_4^{3-}). Temperature, salinity, pH, turbidity and transparency were characterized by a seasonal rhythm depending on oceanic and continental inputs. Water in the Grand-Lahou lagoon is turbid, and nutrients and hydrogen sulphide concentrations show that the milieu is eutrophic. The mean annual bacteria counts were between 1 and 5 log (CFU/ml) for thermotolerant coliforms, from 0 log to 4 log (CFU/100 ml) for *Enterococcus* and between 0 and 4 log (CFU/100 ml) for sulphite reducing anaerobic bacteria.

Conclusion and application of findings: In the study area the fecal bacterial loads are more abundant during the rainy season and least during the dry season. The area of the lagoon under continental influence and more subject to anthropogenic inputs and to more important hydrodynamic effects presents higher bacteria density than the area under oceanic influence. Further studies should be undertaken in order to compare these strains with those isolated in hospitals. Thus, it will be possible to determine the actual involvement of the lagoon waters in diarrheal epidemics that periodically appear in the city of Grand-Lahou and villages located on its bank. Meanwhile, some measures should be taken by the City of Grand-Lahou to take steps towards the building of some latrines in the villages and to educate the riverine population in order to minimize the fecal contamination.

INTRODUCTION

Coastal lagoons, representing nearly 13% of the world shoreline, are among the most productive aquatic ecosystems with great biodiversity. However, they are also intrinsically fragile and highly sensitive to external forces (Kierfve, 1994). These areas are usually prone to overloading with a variety of pollutants either through direct or indirect discharges. This situation may be worsened by the indiscriminate disposal of untreated wastes, which are often heavily laden with sewage into actively used waters. Sewage polluted waters carry microorganisms, some of which are human pathogens (Ogbodeminu, 1986;

Olayemi, 1994; Melo *et al.,* 1997; Lipp *et al.,* 2001).

The Grand- Lahou Lagoon is a part of the 1200 km²-coastal lagoon of Côte d'Ivoire and spreads over 50 km long with an area of 190 km² and an average depth of 3 m (Lae, 1982). Considered as a rural ecosystem and therefore less polluted, this lagoon is now subject to multiple human activities due to its proximity to the city of Grand Lahou and the presence of many fishing villages. Discharges of untreated sewage from coastal populations in the lagoon are likely to cause faecal contamination of the environment through the introduction of terrestrial microorganisms (Kouassi, 2005).

Poor bacteriological quality of the water is a health risk due to the presence of pathogenic micro-organisms including bacteria, viruses, fungi and protozoa. Given the wide variety of pathogens, it is difficult to systematically investigate their presence since most of the time their detection requires tiresome and costly research methods. It is the reason scientists generally prefer to use fecal contamination bacteria to assess water quality of an ecosystem. Indicator microorganisms are not pathogens themselves, but their close association with the intestinal tract means that their presence in water is indicative of bacterial pollution (Midigan *et al.,* 2000).

The purpose of this study was to determine the level of bacterial pollution of the surface waters of the Grand Lahou lagoon using the fecal contamination indicators (thermotolerant coliforms, *Enterococci* and sulphite-reducing anaerobes).

MATERIALS AND METHODS

Water sampling: Thirty six (36) samplings were undertaken during three annual cycles (twelve months per year and from May 2003 to April 2006) in ten (10) stations spread throughout the Grand-Lahou lagoon (Figure 1). Water samples were collected 20 cm below the surface and about 50 cm at the water / sediment interface using a Niskin bottle. The samples were preserved below 4 ° C in the dark until analyses. Water transparency was determined using a Secchi disk.

Physico-chemical analysis: Water temperature, salinity, pH and turbidity were measured in situ using a probe connected to a multiparameter TURO T-611 (Turo Technology 1996, Pty Ltd, Sandy Bay, Australia).

Bacterial counts: The isolation and enumeration of thermotolerant coliforms and *Enterococcus* was done by membrane filtration. The VRBL agar was used for thermotolerant coliforms after incubation at 44°C for 24 hours; while the KF medium was utilized for *Enterococcus* after incubation at 37°C for 48 hours (Il'in and Kasterskiĭ, 1966). Sulfite-reducing anaerobes density was determined using TSN agar with cultures incubated in an anaerobic jar at 46°C for 24 hours.

Hydroclimatic data: Rainfall and river flow data of the main tributaries were provided by the SODEXAM and the “Direction de l’eau du Ministère des Infrastructures Economiques” de Côte d’Ivoire”.

Statistical analysis: Bacterial counts were log (log_{10}) transformed. Bravais-Pearson correlations, Principal component (PCA) and Ascendant classification analyses were performed for data on all bacterial groups and physical parameters.

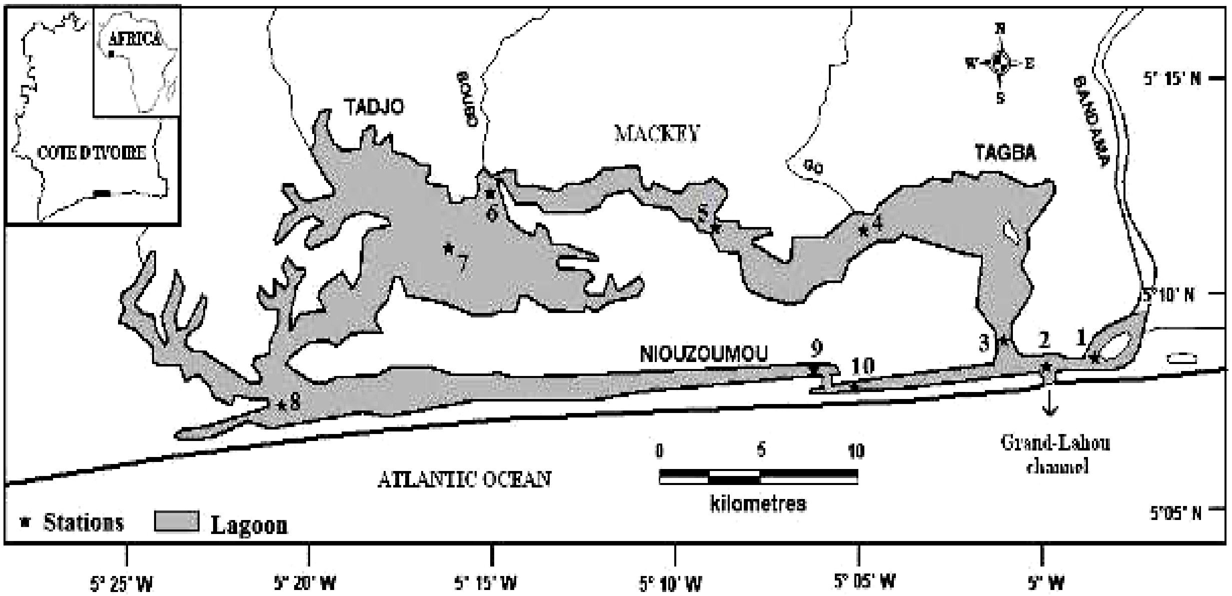


Figure 1: The sampling stations of the Grand-Lahou lagoon indicated by a star

RESULTS

The average temperature of the water in the Grand-Lahou lagoon varies between 25 and 28 ° C; salinity is between 4 and 19 % and mean pH is between 7.8 and 8.1 (table 1). The mean concentrations of PO_4^{3-}, NO_3^- and NO_2^- vary between 100 - 241 mg L, 14 - 215 µg / L, and 13 - 33 mg / L, respectively (table 2). The lagoon is characterized by a great nutrient variability linked to different bodies of water entering the lagoon. The nutrient loads are higher during the rainy (the lagoon is enriched with runoff) and the flood (the period where the lagoon is fed by the rivers flowing in to it) seasons. The water is poor in nutrient content during the dry and the upwelling seasons. The average concentration of dissolved oxygen is between 2.8 and 4.1 mg / L. Mean annual turbidity is between 36.5 and 52.9 NTU, and the highest turbidity is observed in October during the flood season and lowest during the dry season. Water transparency varies between 0.6 m and 1.3 m.

The mean annual thermotolerant coliforms density in the Grand Lahou lagoon surface water varied from 1 to 5 log cfu/100ml). The highest density was observed at stations 3 and 6 during the wet season while the lowest was during the upwelling season at stations 7 and 9. The coefficients of variability are relatively high (CV > 20%) in most of the stations and station 7 presents the lowest coefficient of variability (CV ≤ 5 ≤ 13). The amplitudes of spatial variation are between 0 and 5 log (cfu/100 ml) with maximum values at stations 3, 7 and 9. The rainy season is marked by the highest densities, followed by the flood, the upwelling and the dry season, in that order (table 3).

In general, the thermotolerant coliforms density decreased from May to February and increased from February to April, each year. The curves representing stations 2, 7 and 9 show a minimum in July (Figure 2).

The mean annual *Enterococcus* densities in the Grand Lahou lagoon surface waters varied from 0 to 4 log (cfu/100 ml). The coefficient of variability are very high in all stations (CV ≥ 44%) indicating a high variability of the population densities. The bacterial loads are more abundant during the rainy season, followed by the flood season for stations 1, 2, 3 and 10; and during the upwelling season for stations 4 to 9. The dry season has the least density of *Enterococcus* (table 4).

The variability in the population density of these organisms is dependent on rainfall and the river flow. During the great rainy seasons that coincide with the highest river flow, the bacterial loads are high and during low-flow season the loads reduce. Generally, all the curves present the same seasonal trend, and can be clustered into two groups of stations 1 to 6 and 7 to 10. In all the stations, at various periods of the year, *Enterococcus* was not detected. It was only in July that *Enterococcus* was not detected in stations 1 to 3 and in station 10. In the rest of the lagoon, *Enterococcus* was absent in the samples during several months (figure 3).

Table 1: Physico-chemical parameters of the water in the Grand-Lahou lagoon, Cote d' Ivoire.

Sampling station	Parameters	T (°C)	Salinity (‰)	pH	O_2 (mg/L)	Turbidity (NTU)	Transparency (m)
1	m	**27.1**	**7.4**	**7.9**	**2.9**	**52.9**	**0.9**
	cv	4	94	5	49	29	52
2	m	**25.2**	**14.4**	**8**	**3.2**	**47.9**	**1.2**
	cv	13	69	6	40	28	57
3	m	**28**	**11**	**8**	**3.3**	**45.5**	**0.8**
	cv	7	72	5	35	21	56
4	m	**28.4**	**8.5**	**7.9**	**3.1**	**44.1**	**0.7**
	cv	6	78	4	38	10	38
5	m	**28.3**	**6.9**	**7.8**	**2.9**	**46.1**	**0.7**
	cv	7	84	4	57	15	33
6	m	**28.1**	**4.8**	**7.9**	**3.1**	**48**	**0.6**
	cv	7	81	4	59	15	38
7	m	**28,2**	**6,9**	**8**	**4.1**	**41.4**	**0.8**
	cv	6	50	7	35	6	32
8	m	**28.6**	**10.5**	**8.1**	**4.1**	**41.4**	**0.7**
	cv	5	39	5	30	7	25
9	m	**28.1**	**18.6**	**8**	**2.8**	**37.1**	**1.3**
	cv	7	39	5	49	4	33
10	m	**28.1**	**18.2**	**8**	**3.4**	**36.5**	**1.3**
	cv	6	43	6	50	4	42

m = mean; cv = coefficient of variability

Table 2: Nutrient concentrations in water in the Grand-Lahou lagoon, Cote d'Ivoire.

Sampling station	PO_4^{3-} (µg/L)			NO_3^- (µg/L)			NO_2^- (µg/L)			H_2S (µg/L)		
	m	s	cv	m	s	cv	m	s	cv	m	s	cv
1	165.8	108	65	215	288	134	22.3	15	69	395.2	214	54
2	157.1	119	76	130	154	118	23.0	24	105	82.2	75	91
3	151.1	90	60	65.1	60	93	19.6	12	59	210.0	270	98
4	197.9	100	51	63.3	81	128	20.4	14	68	232.3	230	99
5	241.0	134	55	36.2	41	114	21.2	10	49	387.4	98	25
6	222.1	113	51	45.2	39	87	32.5	23	72	221.3	144	65
7	152.7	161	95	26.3	32	120	26.8	21	79	408.9	276	67
8	130.7	131	94	14.3	19	130	24.3	17	69	621.6	283	46
9	114.1	103	91	25.7	31	122	12.8	12	92	255.4	249	97
10	100.5	109	96	32.3	34	106	17.2	14	83	391.9	262	67

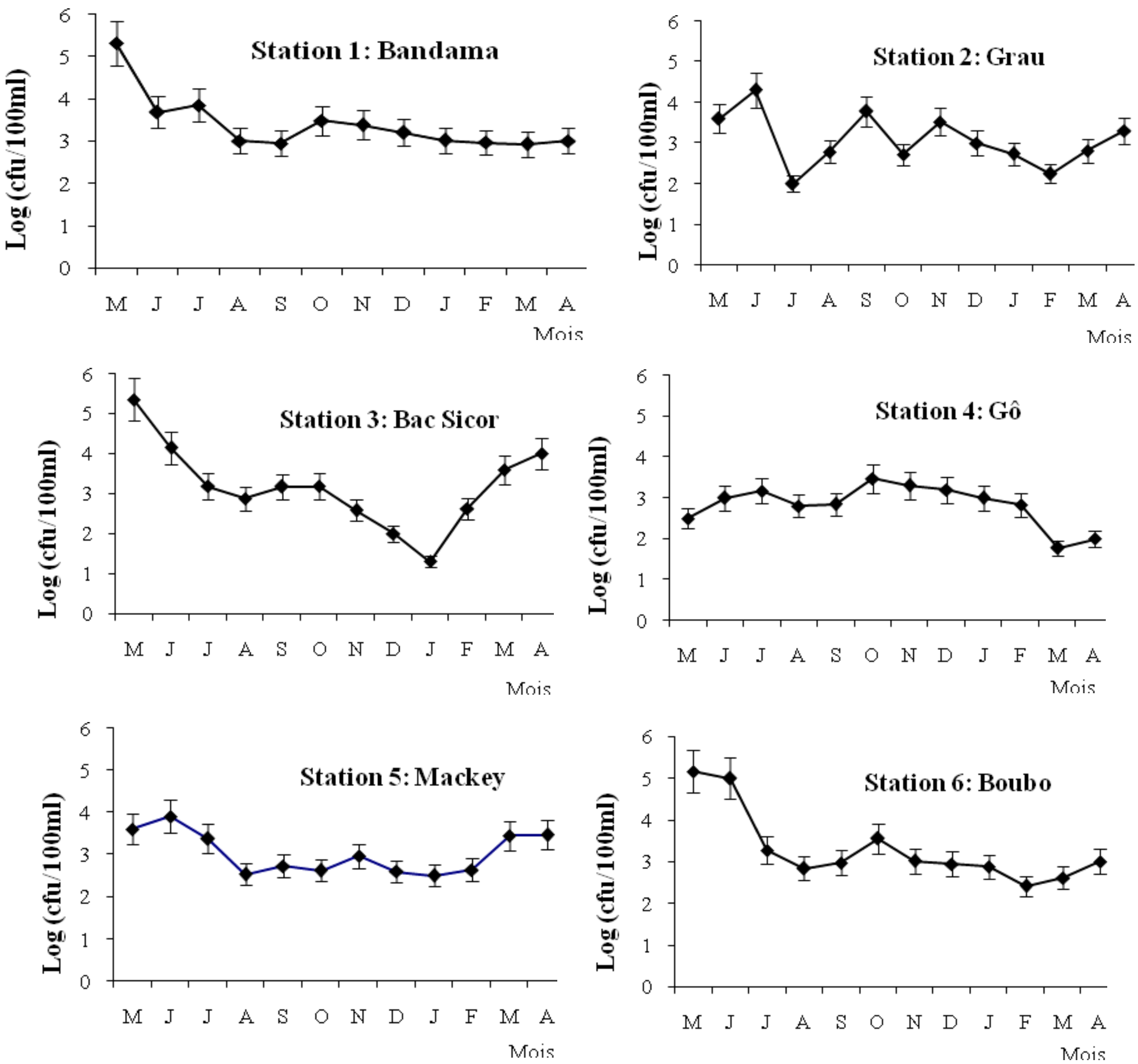
m = mean; s = standard deviation; cv = coefficient of variability

Table 3: Population density of thermotholerant coliforms in the Grand-Lahou lagoon (Cote d'Ivoire) during the four different seasons.

Sampling station	Great rainy season		Upwelling season		Flood season		Great dry season		Minimum –Maximum value
	m	cv	m	cv	m	cv	m	cv	min - max
1	4.00	119	3.42	60	3.27	28	3.03	12	[2.94 – 5.22]
2	3.68	43	2.39	55	3.34	56	2.70	32	[2.00 – 4.14]
3	4.50	75	3.03	22	2.98	34	2.38	98	[1.36 – 5.36]
4	2.50	50	2.99	26	3.21	33	2.70	63	[1.78 – 3.48]

5	3.66	22	2.96	60	2.77	17	2.80	44	[2.51 – 3.40]
6	4.39	121	3.06	31	3.19	32	2.72	25	[2.41 – 5.17]
7	2.85	176	1.68	237	3.03	53	2.42	33	[0.00 – 4.50]
8	2.98	31	2.44	5	2.40	9	2.34	13	[2.26 – 3.25]
9	3.53	65	1.21	171	2.51	23	2.31	12	[0.00 – 4.20]
10	3.53	55	3.16	97	2.29	33	2.64	51	[1.40 – 4.10]

Parameters are mean (m) and coefficient of variability (cv). Mean data are expressed in log (cfu/100 ml) and cv in %



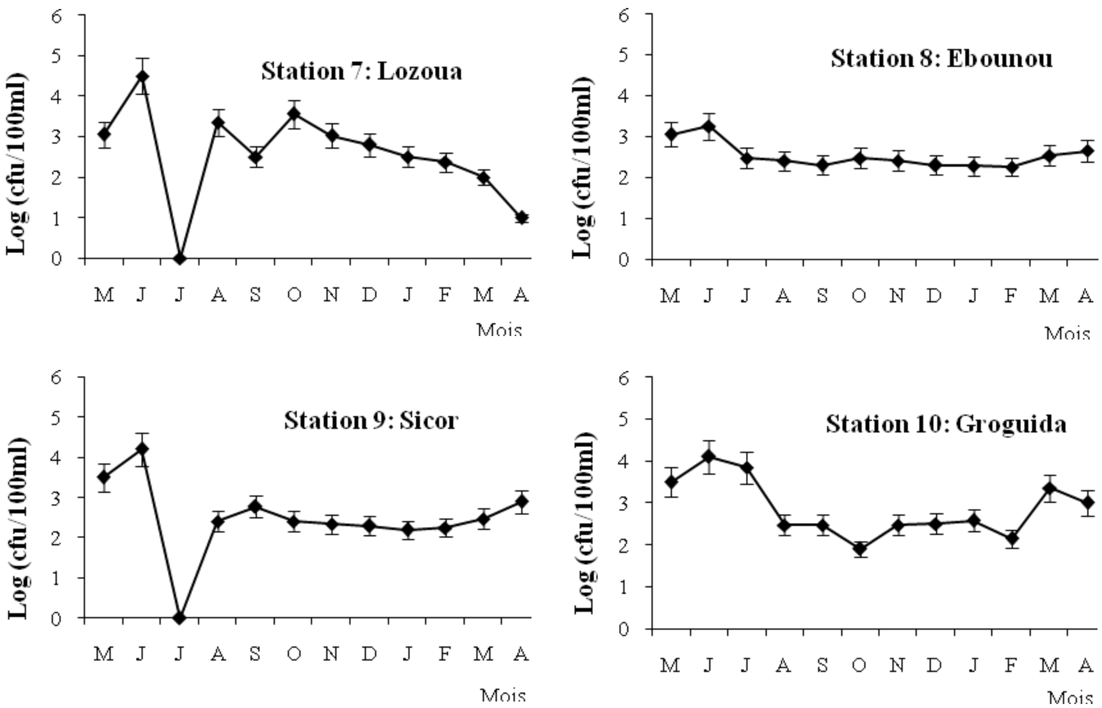


Figure 2: Seasonal variation of the population density of thermotolerant coliforms in the water of the Grand-Lahou lagoon (Cote d'Ivoire).
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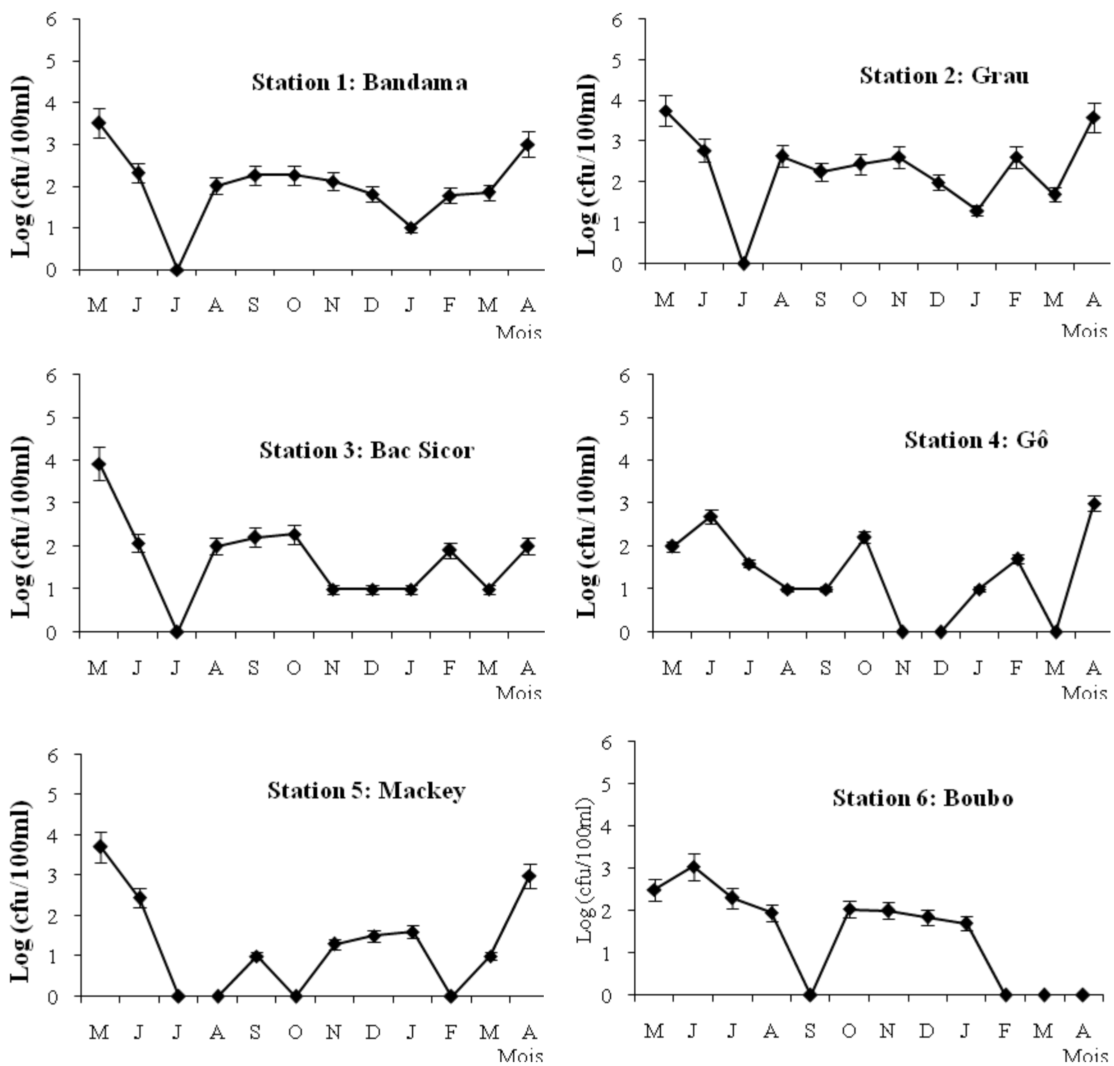
Table 4: Population density of *Enterococcus* in the water in the Grand-Lahou lagoon (Cote d'Ivoire) during four different seasons.

Sampling station	Great rainy season		Upwelling season		Flood season		Great dry season		Minimum –Maximum value
	m	cv	m	cv	m	cv	m	cv	min - max
1	2.93	60	1.00	141	2.21	8	1.61	40	[0.00 – 3.50]
2	3.38	52	1.32	187	2.44	18	1.90	55	[0.00 – 3.75]
3	2.67	109	1.00	141	1.83	72	1.23	45	[0.00 – 3.42]
4	2.57	51	1.30	43	1.07	110	0.67	83	[0.00 – 3.00]
5	3.05	63	0.00	0	0.77	68	1.03	73	[0.00 – 3.71]
6	1.85	162	2.3	25	1.35	117	0.89	103	[0.00 – 3.04]
7	2.18	204	0.80	113	0.33	58	0.25	50	[0.00 – 4.04]
8	3.05	51	0.65	92	0.00	0	0.83	57	[0.00 – 3.50]
9	0.75	130	1.80	28	0.43	75	0.69	81	[0.00 – 2.26]
10	2.17	189	1.02	144	2.12	81	1.95	42	[0.00 – 3.50]

Parameters are mean (m) and coefficient of variability (cv). Mean values are expressed in log (cfu per 100ml) and cv as %.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M J J A S O N D J F M A
Mois
Station 2: Grau
Log (cfu/100ml)
0 1 2 3 4 5 6
M J J A S O N D J F M A
Mois
Station 3: Bac Sicor
Log (cfu/100ml)
0 1 2 3 4 5 6
M J J A S O N D J F M A
Mois
Station 4: Gô
Log (cfu/100ml)
0 1 2 3 4 5 6
M J J A S O N D J F M A
Mois
Station 5: Mackey
Log (cfu/100ml)
0 1 2 3 4 5 6
M J J A S O N D J F M A
Mois
Station 6: Boubo
Log (cfu/100ml)
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M J J A S O N D J F M A
Mois

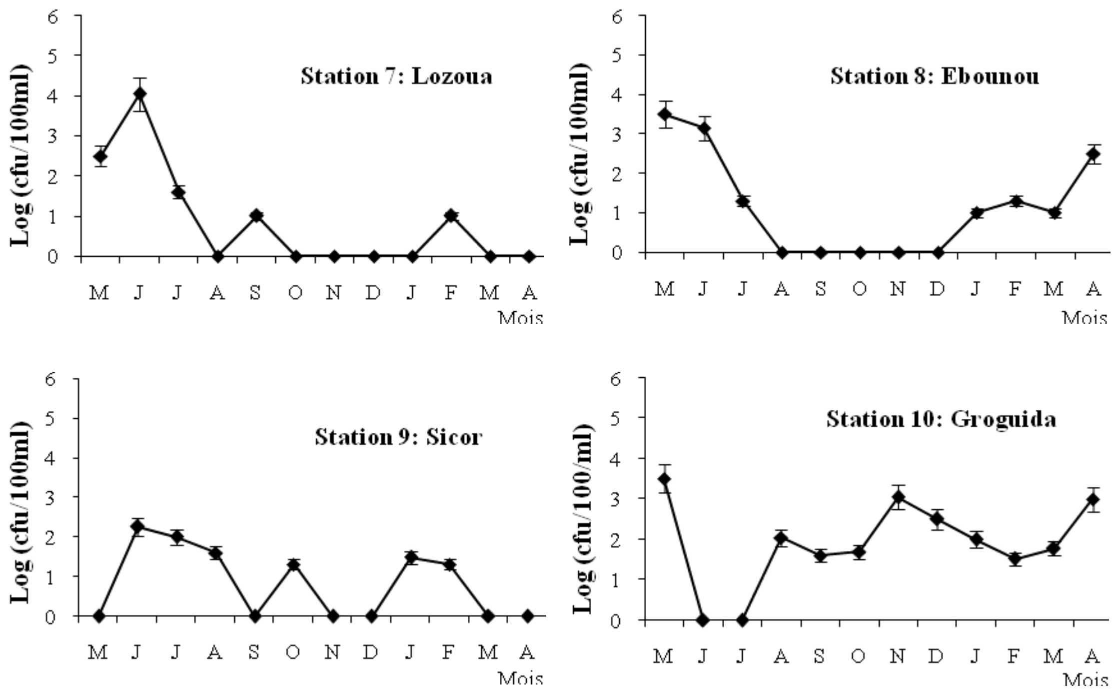


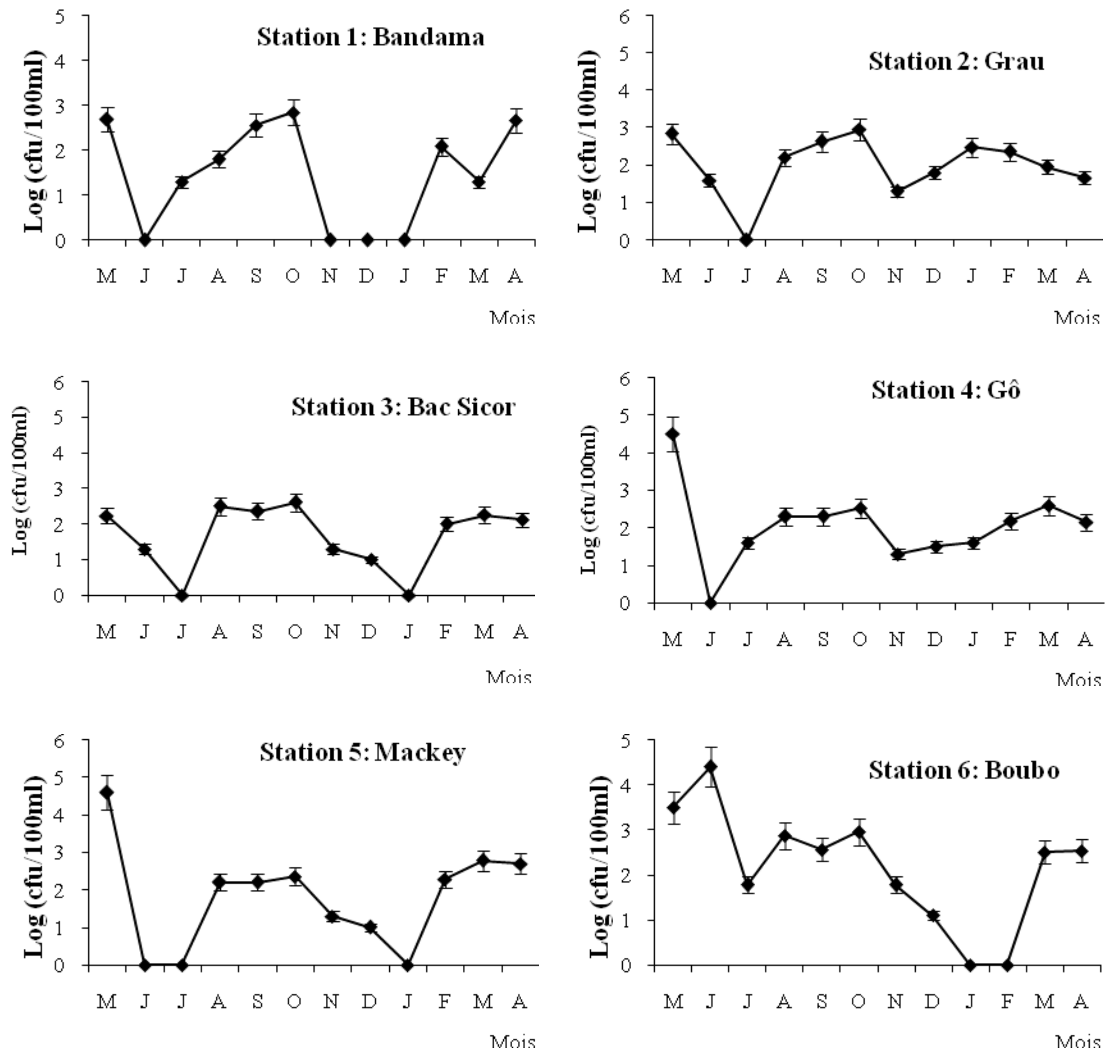
Figure 3: Seasonal variation in population density of *Enterococcus* sp.in the water of the Grand-Lahou lagoon, Côte d'Ivoire.

The annual population density of anaerobic sulfite-reducers is between 0 and 4 log (cfu/100 ml). The variation coefficients are very high (CV > 20%) at all seasons except during the upwelling season where the anaerobic bacteria were not detected (Table 5). The densities decreased from May to July, then increased until October and sharply fell in November, each year. From January to April, the density increased again (figure 4). The seasonal variations per station follow those of thermotolerant coliform and *Enterococcus.* The curves representing the stations 1 to 3 are between 1 and 6 log (cfu/100 ml; those of the stations 4 to 6 between 2 and 5 log (cfu/100 ml). Anaerobic sulfite-reducers were not detected in stations 7 and 9 in July during the entire period of the study (figure 4).

Table 5: population density of anaerobic sulfite reducers in the Grand-Lahou lagoon during four different seasons.

Sampling station	Great rainy season		Upwelling season		Flood season		Great dry season		Minimum –Maximum value
	m	cv	m	cv	m	cv	m	cv	m
1	1.79	155	1.55	35	1.80	164	0.85	103	[0.00 – 2.85]
2	2.03	70	1.10	156	2.30	85	2.15	32	[0.00 – 2.84]
3	1.88	51	1.25	177	2.09	85	1.31	103	[0.00 – 2.60]
4	2.22	225	1.95	49	2.04	65	1.97	51	[0.00 – 4.50]
5	2.43	231	1.10	156	1.96	72	1.51	126	[0.00 – 4.60]
6	3.48	93	2.32	77	2.43	94	0.90	119	[0.00 – 3.50]
7	2.44	149	0.92	130	1.97	77	1.52	22	[0.00 – 3.48]
8	2.01	46	0.00	0	1.36	103	0.98	78	[0.00 – 2.30]
9	1.71	154	1.26	178	2.15	75	1.18	24	[0.00 – 2.99]
10	2.12	200	2.11	72	2.22	100	134	43	[0.00 – 3.49]

Parameters are mean (m) and coefficient of variability (cv). Mean values are expressed in log (cfu/100ml) and cv in %.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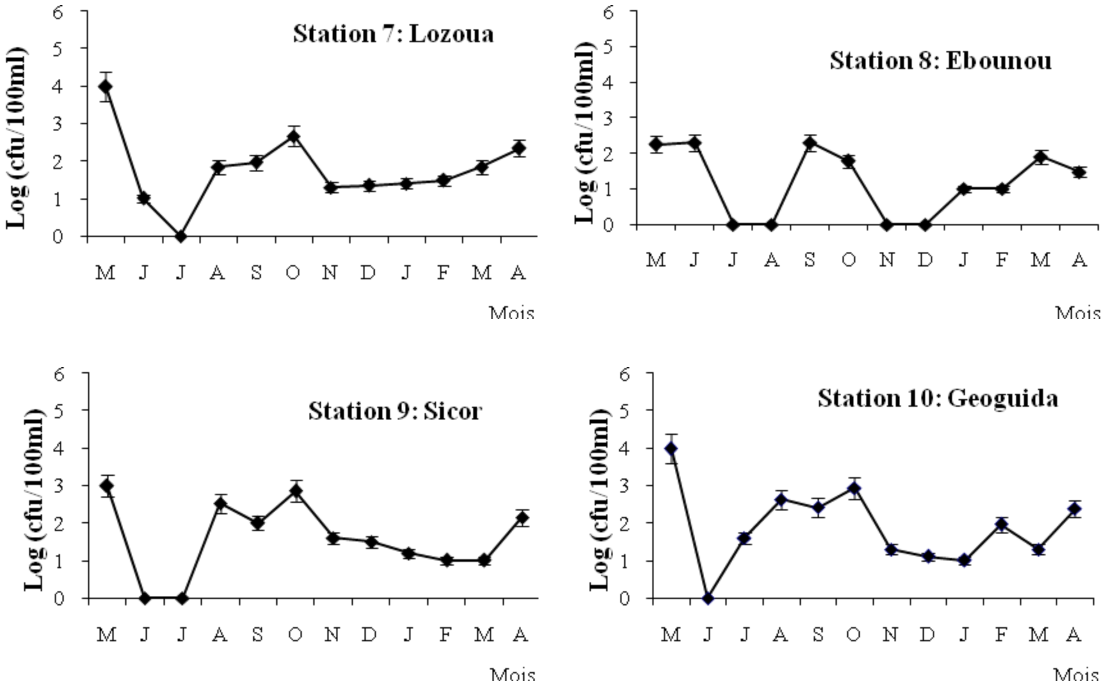

Figure 4: Seasonal variation of population density of suphite-reducing anaerobic bacteria in the water of the Grand-Lahou lagoon (Côte d'Ivoire).

The Pearson Bravais correlation matrix between salinity, turbidity, nutrients and of bacterial contamination indicators is presented in table 6.

Table 6: Correlation (Bravais Pearson) matrix between salinity, turbidity, nutrients and bacterial contamination indicators of the Grand Lahou lagoon waters, Cote d'Ivoire

Variables	Salinity	Turbidity	PO_4^{3-}	NO_3^-	NO_2^-	H_2S	CT	ENT	ASR
Salinity	1								
Turbidity	-0.66	1							
PO_4	-0.79	0.63	1						
NO_3	-0.15	0.77	0.10	1					
NO_2	-0.77	0.50	0.53	0.05	1				
H_2S	-0.20	-0.23	-0.17	-0.24	0.08	1			
CT	-0.41	0.82	0.51	0.67	0.35	-0.38	1		
ENT	0.14	0.51	-0.02	0.70	0.03	-0.42	0.71	1	
ASR	-0.13	0.11	0.46	-0.06	0.28	-0.69	0.33	0.24	1

(CT = Thermotolerant coliforms; ENT = Enterococcus; ASR = suphite-reducing anaerobic bacteria)
Data in bold are significantly different P = 0.05

The population density of thermotolerant coliforms and *Enterococci* was positively correlated with turbidity (r = 0.82 and 0.51, respectively) and nitrate (r = 0.67 and 0.70, respectively). Phosphates (PO_4^{3-}) were positively correlated with thermotolerant coliforms (r = 0.51). Hydrogen sulphide was negatively correlated to density of the three bacteria studied, with a high coefficient (r = -0.69).

The three faecal contamination indicators were positively correlated among themselves with a strong correlation between thermotolerant coliforms and enterococci (r = 0.71).

Based on the hydrochemical and bacteriological data a Hierarchical Correlation Analysis (Analysis of Ascendant Classification) and a Principal Component Analysis (PCA) were conducted (figures 5 and 6). In figure 6, two major groups can be observed, i.e. the area A (stations 1 to 6) and area B (stations 7 to 10). Sector A corresponds to the continental zone and area B to the oceanic zone observed elsewhere from hydroclimatic and hydrochemical variations of the Grand-Lahou lagoon (Konan *et al*., 2008).

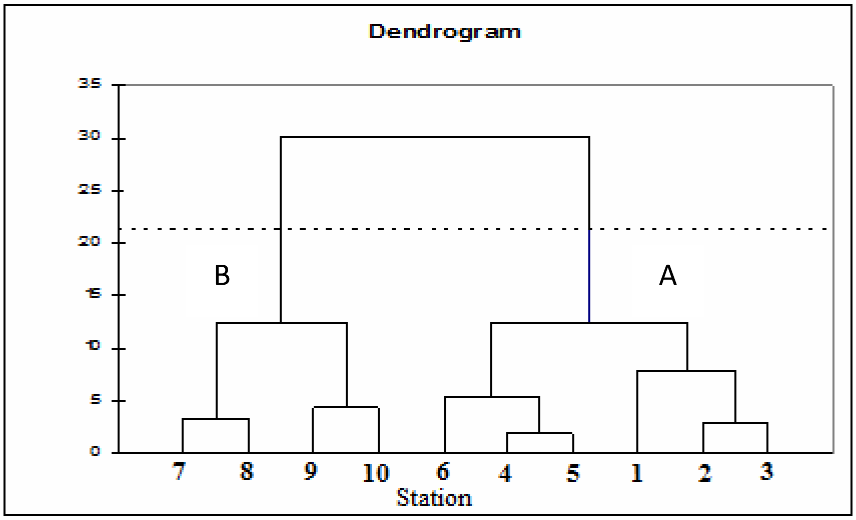

Figure 5: Dendrogram of the sampling stations in function physical and chemical parameters and fecal contamination loads of the Grand-Lahou lagoon waters.

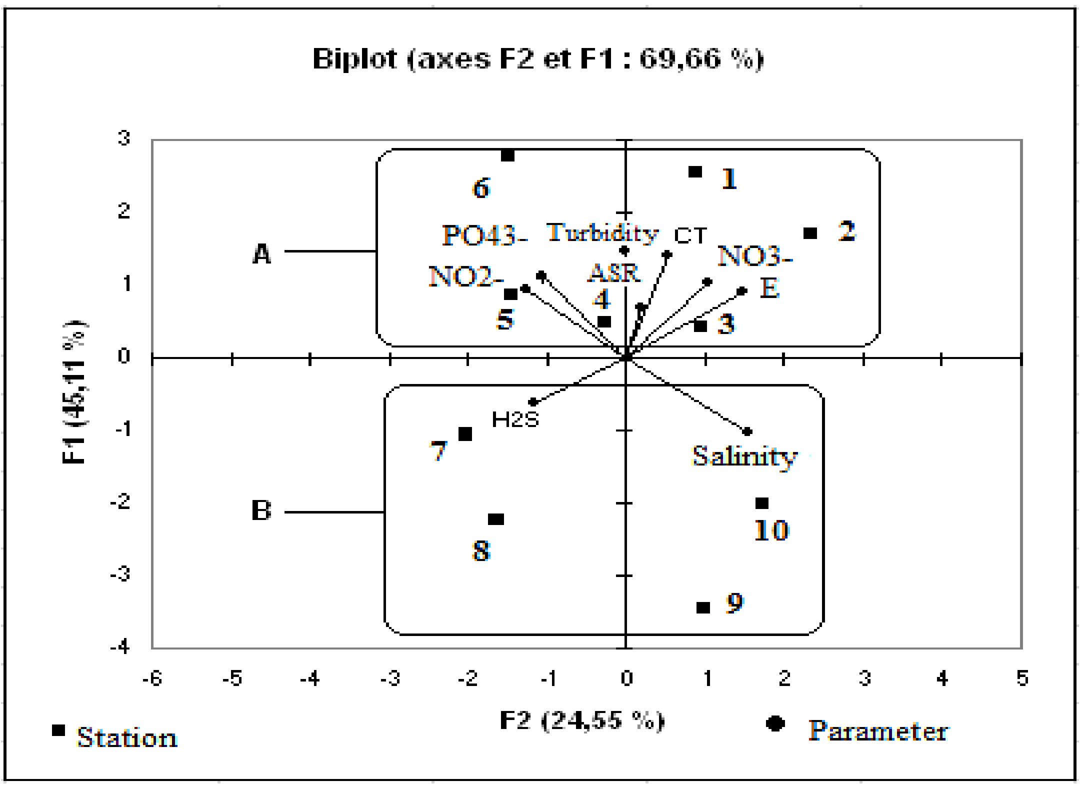

Figure 6: Principal Component Analysis (PCA) relating to the water sampling stations in the Grand-**Lahou** lagoon. Projection in the plane 1 – 2 of salinity, turbidity, nutrients and fecal contamination indicators (CT, ENT and ASR).

In Area A, the sub-sectors A1 (stations 1 to 3) are near the inlet and the mouth of the Bandama river, covering most of the lagoon TAGBA and correspond to the estuarine zone while sub-sector A2 (stations 4 to 6) correspond to the Mackey lagoon.

For the sector B, the sub-sector B1 (stations 7 and 8) are wider and therefore more oxygenated, these correspond to the Tadjo lagoon and the western part of the lagoon Niouzoumou. The B2 sub-sector (stations 9 and 10) are more stable (low hydrodynamism) and far from the influence of Bandama and other coastal rivers; these correspond to the Niouzoumou lagoon and western part of the TAGBA lagoon.

Figure 5 indicates that sector A is in the positive part of F2 and is under the influence of turbidity, phosphates, nitrates, nitrites and three faecal contamination indicators. This sector A is in contrast to sector B, which is located in the negative part of F2 and under the influence of salinity and hydrogen sulfide. These results show two (02) clusters: a cluster of "non-polluted sea, high salinity, low nutrient concentrations and fecal contamination indicators and a pole" continental - polluted, "rich in nutrients and fecal contamination.

The projection of the observations in the F1 and F2 (Figure 6) plane reflects the alternation of continental and oceanic influences that affect the seasonal variability of the waters of the Grand Lahou lagoon. To the periods of strong oceanic influence (with a surface water saltier, less eutrophic and lower bacterial contamination) follow the periods of flood and rainfall during which waters are of lagoonal type (less salty, high nutrient loaded and high level of bacterial contamination).

DISCUSSION

Temperature, salinity, pH, turbidity and transparency are characterized by a seasonal rhythm depending on oceanic and continental inputs. Water in the Grand-Lahou lagoon is turbid, and nutrients and hydrogen sulphide concentrations show that the milieu is eutrophic; which is mainly due to the continental, oceanic and anthropogenic inputs, the suspended sediments and the morphology of the lagoon (Konan *et al.,* 2008).

In general, the results of our study show that the waters of the Grand Lahou lagoon are unfit for any resort activities if one refers to the standards of the WHO / UNEP (1977). This pollution is dependent on anthropogenic inputs (Lanusse & Guiral, 1988; Kouassi et *al*., 1990 and 2005 and Guiral et *al.*, 1993).

The high increase of fecal pollution indicators in the Grand Lahou lagoon waters during the rainy and flood seasons is mainly due on one hand to a rise of anthropogenic inputs by leaching of contaminated soils and on the other hand due to other conditions that are more favorable to the vitality of these germs (period of continental influence, more rich nutrients and therefore more eutrophic). The weak bacterial contamination observed during the oceanic influence is due to the drastic decrease in the survival rate of the bacteria (Mitchell, 1968; Lanusse, 1987). This decrease in survival according to the salinity was initially interpreted as the result of a set of physical, chemical, biological and environmental factors. In particular, the effects of osmotic pressure the action of solar radiation (Gameson & Saxon, 1967), the toxicity of metals (Jones, 1963; 1964), interspecific competitiveness (Greensburg, 1956) and predation pressure (Mitchell and Morris, 1969; Sieburth, 1984) have successively been proposed to explain this decrease. Similar observations were made by Lanusse (1987), Lanusse and Guiral (1988), and Adingra et *al.*, (1998) and Kouassi (2005) for the Ebrie lagoon and in rivers and marine waters in Canada by Hunter (2003).

These interpretations were questioned by the work of Grimes and Colwell (1986) and Gauthier *et al.* (1987). These authors have shown that the disappearance of bacteria in the marine environment could be due to their entry into dormancy while transiting through a hostile environment, which may not be detected using standard selective culture media techniques. Thus, they proposed the use of new methods of more specific bacteria counting (epifluorescence, immunofluorescence, direct counting of viable cells by use of serum anti-Enterobacteriaceae). The classical method based on selective medium was used during this work in order to benefit from data obtained by previous research.

The bacterial loads indicated that the average density of thermotolerant coliforms is higher with low variability compared to that of faecal *Streptococci* (or *Enterococcus*) and *Clostridium perfringens*. These results show that thermotolerant coliforms are present throughout the year in more important proportions. Indeed, according to Leclerc (1981), thermotolerant coliforms are more abundant in faeces and therefore they are considered as preponderant indicator of the environment. The abundance of these germs reflects recent contamination and is due to lack of appropriate sanitary systems with people directly defecating in and or near the lagoon waters and its tributaries. The high variability of *Enterococcus* and suphite-reducing bacteria is certainly due to hydroclimate of the region.

In vivo studies conducted in the Ébrié lagoon (Lanusse, 1987) and in lake water and sewage treatment plants (Sinclair and Alexander, 1984) showed that survival of *Enterococcus* and sulphite reducing bacteria do not depend on water quality of the receiving environment. This may be in relation with the morphology but also with the structure of cell walls of these gram-positive cocci. Within the lagoon, the *Enterococci* densities are directly related to the rhythm of the continental and oceanic inputs and modulated by the movement of water masses. *Enterococci* are particularly an important indicator of estuarine fecal contamination. This group of species appears in fact less sensitive to nutritional stress and the levying of dormancy (if any) during cultivation on enriched media would limit the differences between viable and non cultivable bacteria. The cultivation on enriched media would thus allow a spontaneous revival of bacteria.

The continental zone which is subject to more anthropogenic inputs and hydrodynamic effects presents higher bacterial density than the area under oceanic influence. In addition to this, the villages on the banks of the mainland have population densities greater than those of the oceanic area.

Heavy bacterial contamination of the continental cluster can be related to the volume of household wastes that this sector receives compared to the oceanic sector. The presence of H_2S in the oceanic pole confirms the weak hydrodynamics of the area (the ocean is very weakly influenced by continental inputs).

The positive correlations observed between fecal contamination bacteria and turbidity and nutrient factors showed that rainfall and the arrival of coastal rivers flood are responsible for the "carriage" of the lagoon waters in the direction of the Ocean (Kouassi et *al.* 2005).

The existence of positive correlations between the three bacterial forms reflects the fact that the detection of a germ indicates a high probability of presence of the other two (Lanusse & Guiral, 1988; Kouassi et *al*. 1990; Guiral et *al*., 1993).

CONCLUSION

The Grand-Lahou waters are eutrophic, characterized by high bacterial densities and are thus unfit for any recreational activities. The pollution is mainly caused by anthropogenic inputs and the bacterial loads are largely dependent on the hydroclimate of the lagoon. The annual cycles of the fecal contamination indicators counts show high bacterial densities during the wet and the flood seasons; and lower densities during the dry and oceanic seasons. The area of the lagoon under continental influence is more polluted than the area under the oceanic influence. This bacteriological study, the first one undertaken in this coastal ecosystem, confirmed the high degree of faecal contamination of the lagoon of the Grand - Lahou waters. It is now important to find the real pathogenic bacteria (Vibrios, Aeromonas, etc.) by the utilization of more specific techniques and to compare these strains with those isolated in hospitals. In these additional studies, it will be possible to determine the actual involvement of the lagoon waters in diarrheal epidemics that periodically appear in the city of Grand-Lahou and villages located on its bank. Meanwhile, some measures should be taken by the City of Grand-Lahou to take steps towards the building of some latrines in the villages and to educate the riverine population in order to educate the riverine population in order to minimize the fecal contamination

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