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Fecal contamination level of Cotonou Lagoon waters (Benin, West Africa)

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Abstract

Surface waters are highly contaminated by solid and liquid wastes coming from anthropogenic activities. Wastewaters thrown out without purification contribute actively to microbiological pollution of these aquatic areas. In the current study, the fecal contamination level of Cotonou lagoon water has been assessed. Six stations have been sampled and fecal pollution indicator bacteria have been numbered using seeding method by incorporation in specific nutritious media. The registered mean bacterial loads were $3.14.10^3 \pm 2.12.10^3$ CFU/100 mL, $1.10.10^4 \pm 7.11.10^3$ CFU/100 mL, $4.03.10^3 \pm 3.82.10^3$ CFU/100 mL and $1.61.10^3 \pm 2.11.10^3$ CFU/100 mL for E. coli, total coliforms, fecal streptococci and anaerobic sulphite reducers respectively. These values have exceeded widely standards recommended for safe recreational waters. Therefore, Cotonou lagoon waters were highly contaminated owing to unchecked discharge of feces and urban effluents. It is urgent to strengthen basic sanitation facilities and undertake the purification of wastewaters before any pouring in order to reduce the fecal pollution level and consequently the hazards linked to public health.

Keywords: *Cotonou Lagoon; fecal pollution; wastewater; sanitation; people's health.*

Introduction

Surface waters receive commonly solid and liquid wastes coming from different anthropogenic activities practiced in their surrounding areas [1]. Thus, discharge of raw wastewaters able to contain alarming amounts of pathogenic microbial agents, represents one of contamination causes of these aquatic media strongly exploited for fishing, bathing and navigation. Such practices increase gradually the pollution level of these waterbodies and expose consequently users and riparian people to huge diseases hazards [2].

Water diseases are among those which increase the mortality rates in developing countries [3, 4]. These sicknesses due to pathogenic water germs have, for the most, epidemiological effects [5]. The numerous etiologic agents of such epidemics include salmonella causing recurrent water diseases such as typhoid fever, systemic salmonellosis, gastroenteritis and toxic infections, and *vibrio cholerae* responsible for cholera. In Benin, diarrhoeic diseases represent 2% of main causes of death and cholera is one of the more widespread potentially epidemic sicknesses [6].

The lack of hygiene and the non-attendance or insufficiency of basic sanitation infrastructures are some factors which contribute highly to the coming unexpectedly of these epidemics. In such conditions, wastes from anthropogenic activities are pouring into waterbodies mostly in sub-Saharan African towns built surroundings a river, a lake, an estuary or a lagoon [1]. The lagoon of Cotonou is the evident proof of this situation. Indeed, not only does it constitute the discharge point of huge amounts of strongly contaminated wastewaters [7] but it also receives solid and liquid wastes produced at its both banks.

The current study aims to assess the microbiological contamination of Cotonou lagoon waters by estimation of fecal pollution indicators in order to appreciate the hazards linked to public health.

Material and methods

Study area

The current study has been carried out on Cotonou lagoon in Benin. The lagoon is a channel looked North-South, 4.5 kilometers long with an average width of 300 meters and a depth of 5 to 10 meters, which connects Nokoué Lake to Atlantic Ocean [8] (Figure 1). It constitutes the outlet of several gutters and main sewers erected in the city, normally to canalize storm waters, but which receive permanently raw wastewaters coming from

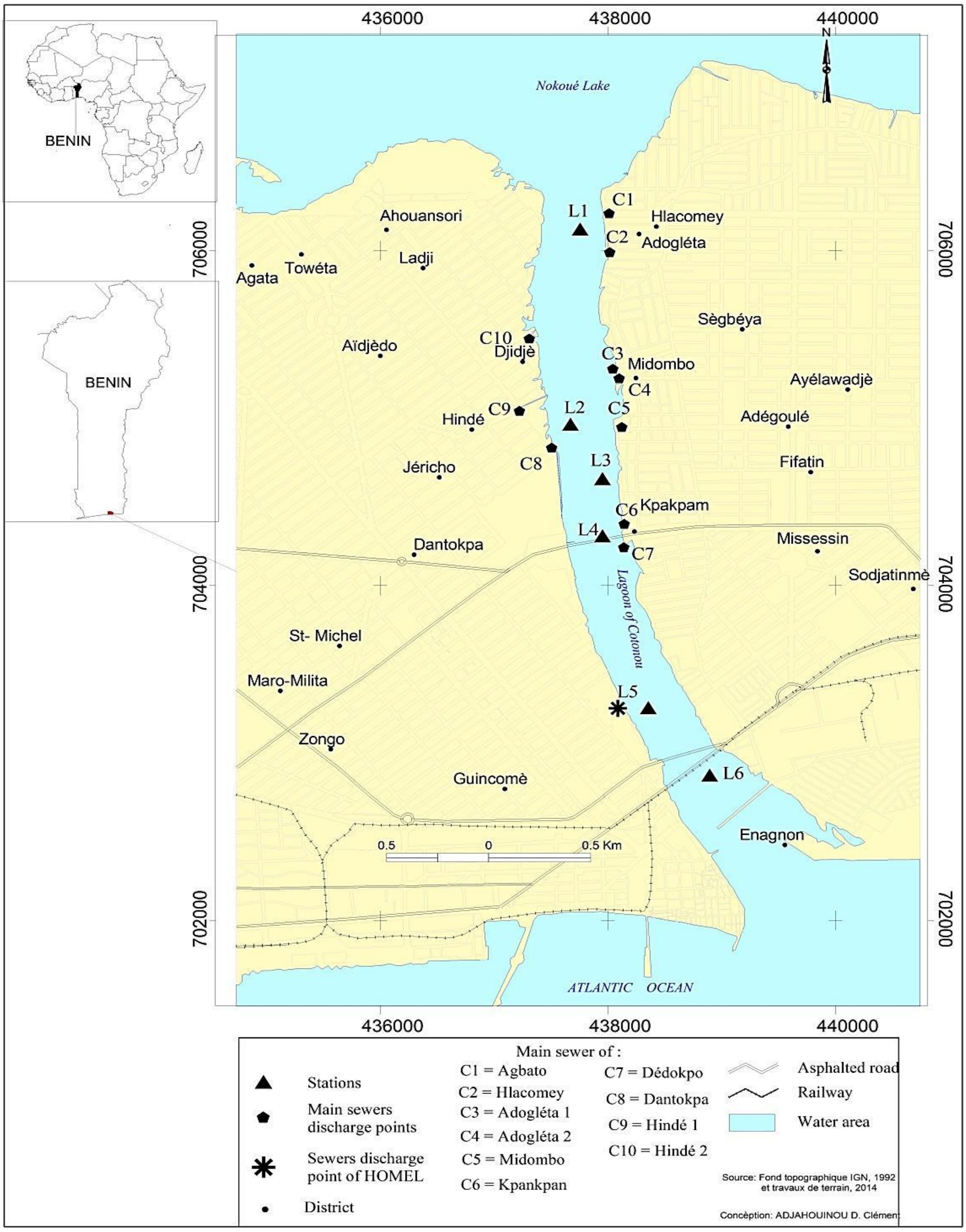

Fig.1 Map of Cotonou city showing the sampling stations on the studied lagoon and the discharge points of the mains sewers

human activities. Except these wastewaters, the lagoon receives others solid and liquid pollutants generated alongside its both banks. Indeed, on the right bank, some populations mostly fishermen live in precarious houses without basic sanitation systems. On the left bank, there are, Dantokpa international market including Gbogbanou market and the maternity hospital (Mother and Child Hospital “La lagune”).

The area study is subjected to subequatorial climate characterized by four seasons including a long dry season (LDS) from December to March, a long rainy season (LRS) from April to July, a short dry season (SDS) from August to September and a short rainy season (SRS) from October to November [9].

Sampling and analysis methods

The samplings have been carried out during LDS (from December 2013 to Mars 2014) while the main sewers discharge in the lagoon raw wastewaters only. Six stations (Table 1) were chosen in a way to cover all of the lagoon area (Figure 1). Each station, equidistant from the lagoon

Table 1 Standing, characteristics and geographic position of sampling stations

Stations	Standing and characteristics	Geographic coordinates	
		Latitude	Longitude
L1	Ladji - Agbato: junction area between Nokoué lake and Cotonou lagoon	06°23'16''N	002°26'11''E
L2	Hindé - Djidjè - Sègbeya: area directly affected by discharges of Sègbèya and Hindé main sewers and where the lagoon sand is manually extracted.	06°22'37''N	002°26'03''E
L3	Dantokpa - Midombo: area between the discharge points of Dantokpa and Midombo main sewers and highly exploited for conveyance of persons and goods by small boat towards Dantopka market.	06°22'28''N	002°26'15''E
L4	Kpankpan - Dédokpo: In the sphere of the Martin Luther King bridge where artisanal fishing is practiced and. This area is directly affected by discharges of Kpankpan and Dédokpo main sewers.	06°22'17''N	002°26'15''E
L5	Aboki codji - Tokpa hoho: area where wastewaters come from dyeing facilities and the maternity hospital named "La lagune" (HOMEL) were poured.	06°21'43''N	002°26'20''E
L6	Akpakpa Dodomey - Placondji: junction area between Cotonou lagoon and Atlantic ocean.	06°21'31''N	002°26'34''E

banks, has been sampled on board of a motorized small boat. Water samples have been monthly collected using 250 mL carefully labeled sterile glass bottles with screw corks according to the microbiological analysis recommendations [10]. The Sampling bottles were covered with a box equipped with rope in order to collect the samples from the bottom to the surface of the lagoon. At each station, composite samples were constituted by successive plunges at three different points. Water samples were conserved in frozen appropriate tanks until the analysis at laboratory six hours at most after the collection [11].

The counting of fecal pollution indicator bacteria were carried out by seeding of 1 mL of raw sample and two dilutions (1/2; 1/5) in molten nutritious media at 45°C [10]. Thus, Brilliance *E. coli*/coliform selective medium (Oxoid, CM 1046) was used for numbering total coliforms by simultaneous detection of *E. coli* (blue colonies) and others coliforms (red colonies) in Petri dishes, after incubation at 37°C for 24 hours. The fecal streptococci (red colonies) was detected and counted in Petri dishes by Slanetz and Bartley medium (Oxoid, CM 0377) after incubation at 37°C for 24 hours. Meat-Liver glucose agar (Oxoid, CM 0918) was used to enumerate anaerobic sulphite reducers'spores (colonies surrounded with a black halo) in test tubes after destruction of vegetative form at 80°C following by incubation at 37°C for 48 hours.

Statistical analysis

The mean values recorded for *E. coli*, total coliforms and fecal streptococci loads were compared at $P<0.05$ among sampling stations using one way analysis of variance (ANOVA1) after verifying both data normality and homogeneity of variance using "Shapiro-Wilk's test" and "Levene's test" respectively [12].

The normality condition has not been fulfilled, even after logarithmic transformation (Log_{10}), for anaerobic sulphite reducers' loads data. Kruskall-Wallis non-parametric test has been therefore performed to compare the mean values registered for this parameter among the sampling stations [12]. All statistical analysis was performed using the Mintitab14 statistical software.

Results

The average loads registered for the studied fecal bacteria at the sampled stations were represented by the Figures 2 to 5. No significant difference was noticed among the stations ($P>0.05$). However, the loads recorded for *E. coli* were included between $4.00.10^2$ UFC/100mL (L6) and $8.00.10^3$ UFC/100mL (L4) with an average of $3.14.10^3 \pm 2.12.10^3$ UFC/100mL. The concentration of total coliforms varied from $9.00.10^2$ UFC/100mL (L6) to $3.29.10^4$ UFC/100mL (L2) with a mean value of $1.10.10^4 \pm 7.11.10^3$ UFC/100mL. The densities of fecal streptococci varied from $4.00.10^2$ UFC/100mL (L6) to $1.72.10^4$ UFC/100mL (L2) with an average of $4.03.10^3 \pm 3.82.10^3$ UFC/100mL. The anaerobic sulphite reducers were the least abundant among the studied fecal germs with $4.00.10^2$ UFC/100mL (L3), 10^4 UFC/100mL (L6) and $1.61.10^3 \pm 2.11.10^3$ UFC/100mL for the minimal, maximal and mean concentrations respectively.

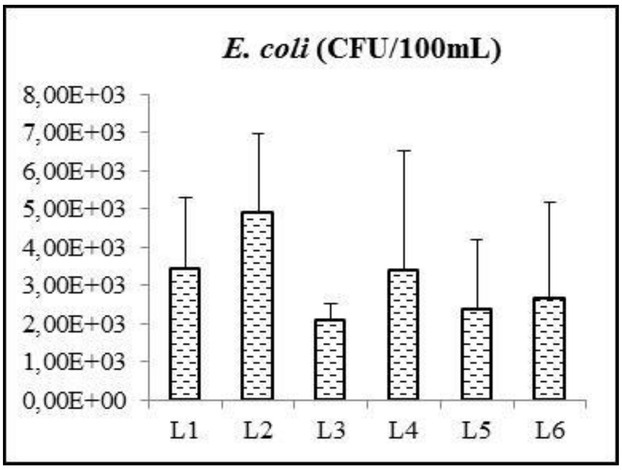

Fig.2 Density of *E. coli* in Cotonou lagoon waters (mean per station)

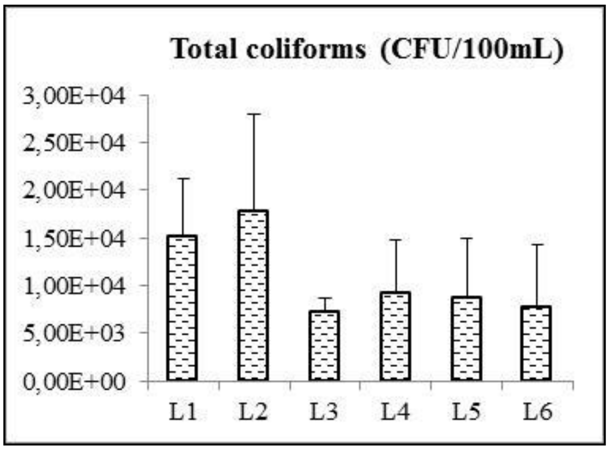

Fig.3 Density of fecal coliforms in Cotonou lagoon waters (mean per station)

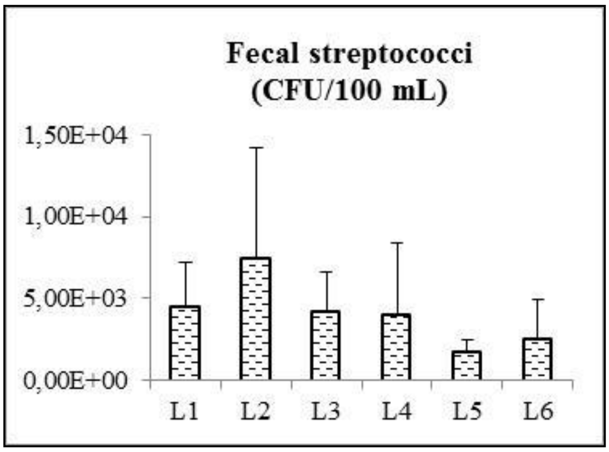

Fig.4 Density of fecal streptococci in Cotonou lagoon waters (mean per station)

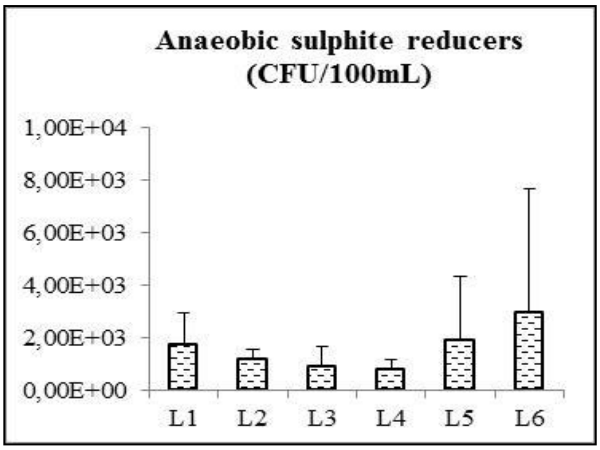

Fig.5 Density of anaerobic sulphite reducers in Cotonou lagoon waters (mean per station)

Discussion

The bacteriological analysis of Cotonou lagoon waters achieved in this study revealed high loads of fecal pollution indicator bacteria. Thus, the densities of *E. coli* and fecal streptococci in prospected waters exceeded widely the limit values recommended for recreational waters intended to bathing (126 CFU/100 mL and 500 CFU/100 mL respectively) [13,14]. These both enteric bacteria, considered as the main indicators of fecal contamination are closely associated to release of some pathologies including gastro-intestinal disorders and cutaneous, respiratory and auditory ways infections [13]. Several studies conducted, amount others, on Ebrié lagoon at Abidjan (Ivory Coast) [1], Orissa coastal water (India) [15] and Grand-Lahou lagoon (Ivory Coast) [16], have revealed positive correlations between fecal contamination and human pathogenic bacteria such as *Staphylococcus aureus*, *Pseudomonas aeuruginosa*, *salmonella sp.* This confirms that the aforementioned microorganisms were from fecal origin.

Furthermore, it suits to notice that fecal streptococci concentration is slightly higher than *E. coli* concentration in studied waters. This may be due to the vulnerability of *E. coli* like any Gram negative bacterium in highly saline medium contrary to fecal streptococci, Gram positive bacteria, which are euryhaline and rustic owing to the structure of their membrane [16, 17]. Fecal streptococci are therefore the more accommodated indicators of estuary fecal contamination [14, 18] by reason of above-mentioned properties and behavioural similarity that they have with certain fecal pathogenic organisms [19].

The high load recorded for these fecal germs at all sampled stations indicate that the lagoon waters undergo a harsh microbiological pollution. At first sight, this alarming level of fecal contamination may be attributed, on the one hand, to the direct defecation by riparian in the lagoon from precarious latrines erected on pile, and on the other hand to fecal matter of animals especially wandering pigs. This direct pouring of feces in the lagoon seems the immediate cause of the heavy amount of *E. coli* and fecal streptococci. As a matter of fact, these germs living in the intestine of human and warm-blooded animals are therefore thrown out with the feces [20, 21].

Nevertheless, the open-air main sewers erected alongside of the lagoon, throwing out extremely fecal contaminated effluents [7]. Thus, they also participate undoubtedly to the high fecal load of the lagoon waters. Moreover, the manual dredging of sand on the lagoon could increase the availability of bacteria in the water by putting back those already trapped in the bottom sediments. The same factors have been mentioned among the contamination causes of Grand-Lahou and Aby lagoons (Ivory Coast) [16, 18, 22] although these waterbodies are less contaminated by *E. coli* and fecal streptococci than current studied waters.

The presence of total coliforms in water does not indicate ipso facto a fecal contamination. Indeed, total coliforms include, except certain enteric bacteria such as *E. coli* and *Klebsiella pneumoniae* [23], more others non-fecal coliforms. However, their detection in water may be, in some cases, an indicator of contamination by pathogenic agents causing waterborne epidemics [24]. The nutritive medium used in this study for the counting of the total coliforms distinguishes *E. coli* and the others coliform bacteria including for instance *Klebsiella pneumoniae* and *Enterobacter aerogenes* able to induce respiratory infections to bathers [25]. Total coliforms concentrations of the Cotonou lagoon were higher than those recorded for the Nokoué lake waters [26].

The load registered for anaerobic sulphite reducers were widely above values reported for Grand-Lahou lagoon water at Ivory Coast [16]; Khoumane and Boufekrane watercourses at Morocco [27, 28]. Like total coliforms, anaerobic sulphite reducers, are not specifically fecal pollution indicators since they are for the most earthly germs. Nevertheless, *Clostridium perfringens*, one of anaerobic sulphite reducer species, is often associated with feces of warm-blooded animals [29]. This bacterium is consequently considered as a fecal contamination indicator. Besides, the spores of anaerobic sulphite reducers have a persistence capacity in environment because of their resistance [30]. They are therefore an old pollution witnesses [10] (Rodier *et al*., 2009) and some indicators of likely occurrence of the most rustic pathogenic agents such as virus [31]. The wide amount of the numbered anaerobic sulphite reducers'spores testifies thus, that the studied lagoon is subject to non-punctual but permanent fecal pollution.

The established pollution of Cotonou lagoon waters presents therefore some evident hazards of water diseases (gastro-intestinal, respiratoiry) or skin's affections for users namely halieutic products consumers, fishers and bathers [32, 33].

Conclusions

This diagnostic study on fecal contamination level of Cotonou lagoon waters revealed some bacteria loads above the standards for recreational waters intended to bathing. The high densities registered for the detected fecal germs indicate a worrying fecal pollution which may be attributed to unchecked pouring of human and animal fecal matters and other wastes especially urban effluents. Moreover, they testify the likely occurrence of pathogenic microorganisms even the most resistant. It is thus urgent to strengthen basis sanitation infrastructures surroundings the lagoon and undertake purification of wastewaters before any throwing out in order to safeguard public health.

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