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Assessment of Bacterial Load in Urban Wastewater in Drainage Canals in the Cities of Abidjan, Bouake and Yamousoukro, Côte d'Ivoire

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Authors' contributions

This work was carried out in collaboration among all authors. Author CKJ designed the study, wrote the protocol and supervised the study. Authors DAS and YKE collected the samples in the field and made the laboratories analysis. Author DAS wrote the article with the assistance of author VNS and authors YKE and VNS runned the laboratories analysis and validated the results. Authors BI and GVC corrected the protocols and corrected the first draft of the articles. Authors CKJ, DAS and VNS managed literature research and references. Authors DM and DAJ validated the protocols, corrected the final draft of the article. All authors read and approved the final manuscript.

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ABSTRACT

The microbiological quality of urban wastewater presents important environmental, health and political challenges. The lack of a water treatment system leads to a lack of knowledge about the variability of the microbiological quality of wastewater in the major cities of Côte d'Ivoire.

Aims: The purpose of this study is to assess the level of microbiological pollution of urban wastewater in the drainage channels of the different agglomerations.

Methodology: Indicators of environmental pollution (mesophilic aerobic germs) and faecal contamination (fecal coliforms and intestinal enterococci) were analyzed at 14 upstream and downstream sites in cities of Abidjan, Bouaké, Yamoussoukro during rainy periods and in the dry season.

Results: Our results show an important pollution translated by the abundance of bacterial indicators of which the aerobic mesophilic germs can reach average loads going from $3x10^7$ cfu/100 mL to $7x10^9$ cfu/100 mL and the witnesses of fecal contaminations can reach average loads going from 3x105 cfu/100 mL to $7x10^7$ cfu/100 mL for the fecal coliforms and from $6x10^5$ cfu/100mL to $1x10^7$ cfu/100mL for the intestinal enterococci These average bacterial loads fluctuate according to the configuration of the sewerage systems and the hydrological conditions. In the rainy season, a significant dilution of certain indicators, precisely mesophilic aerobic germs and intestinal enterococcus, can be observed. The number of microorganisms encountered exceeds the values indicated by the WHO guidelines (WHO, 2017) and the standards in force for wastewater discharge.

Conclusion: Creation of strong treatment systems for wastewater to manage them before any discharge in waterbodies have to be a priority. This could reduce the risks of pollution from an environmental and health point of view. The microorganisms encountered can cause mild or serious infections.

Keywords: Wastewater; microbial pollution; water bodies; Côte d'Ivoire; urban; drainage channels.

1. INTRODUCTION

Inadequate sanitation and sewage services are at the root of many diseases affecting the world's population [1,2]. With industrial development, economic growth, rapid population growth and high density of urban areas, sewage discharges have become enormous. In the absence of treatment, this wastewater constitutes a growing danger to human health and the natural environment because of its toxic chemical loads and pathogenic microorganisms [3]. They therefore constitute permanent threats to both human and animal health [4]. Several studies of the impact of liquid effluents, particularly in Morocco, on groundwater quality have shown the discharge without treatment of wastewater [5].

According to the WHO, 80% of the diseases that affect the world's population are related to water pollution [2]. Indeed, most of the microorganisms that are at the origin of the great historical epidemics of water, have as their normal habitat the intestines of humans and some warm-blooded animals. Thus, the control and monitoring of water quality, particularly wastewater, was becoming increasingly essential.

Most wastewater disposal networks connected to mechanized wastewater treatment plants, set up after independence, are now non-functional and the raw wastewater produced is discharged to the shallows [6,7]. In response, many studies point to the negative health, environmental, and economic consequences of poor sanitation [8,9].

In Côte d'Ivoire, collective wastewater treatment is very uncommon in the country. In addition to Abidjan, it has an important collective sanitation heritage with a 40% rate of connection of users to the wastewater network in the District. The cities of Bouaké, Yamoussoukro and San-Pedro have some collective sanitation infrastructure. Liquid discharges represent one of the main environmental problems faced by these cities, given the extent of pollution generated by various liquid discharges (industrial and household) and its impact on surface and groundwater resources [10,11]. Domestic and industrial wastewater from the cities of Abidjan, Bouaké and Yamoussoukro is discharged without prior treatment into rainwater channels or natural effluents. The latter being open-air cross urban and peri-urban districts of these cities. During their passages, local residents use it on the one hand to evacuate waste (household waste and

evacuation of black water) and on the other hand for their daily activity such as irrigating cereal and fodder crops. These cities also experience significant industrial activity (oil mills, textiles, yeasters, traditional slaughterhouses, dairies, beverage factories, tanneries, etc.) which generates total pollution (generate contaminants exerting pressure on ecosystems, particularly water, modifying their functioning and impacting the dynamics of the microorganisms that compose them [12]. However, there are few detailed studies on the microbiological characterization of wastewater supplied to wastewater treatment plants; most published studies focus mainly on the removal performance of microorganisms by treatment plants, on contamination levels in surface water or on the structure and composition of microbial communities associated with activated sludge [13,14].

Coliforms and enterococci are indicator organisms used worldwide to monitor water quality [15,16]. The detection of these indicators in water means faecal pollution, which could have adverse effects on public health, the economy, ecological balance and functioning [17,18]. Public health risks associated with faecal pollution include the introduction of microbial pathogens [19,1] and antibiotic-resistant bacterial pathogen strains, which could result in the transfer of resistance to previously susceptible strains or species in aquatic environments [20,21].

Thus, as part of the prevention against infections, waterborne diseases and the reduction of the spread of antimicrobial resistance, a study on the bacteriological quality of raw wastewater from the cities of Abidjan, Bouaké and Yamoussoukro was carried out to assess the level of microbial pollution carried in drainage channels.

2. MATERIALS AND METHODS

2.1 Study Area

The sampling campaign of urban wastewater in the drainage network of the cities of Abidjan, Yamoussoukro and Bouaké, was carried out upstream and downstream of the various collectors before their natural outlet over the period of November 2019 and November 2020. A total of 14 sampling stations were selected from the sewerage network across large agglomerations based on different human activities, with urbanized areas with large populations having access to sewers (Fig. 1).

Fig. 1: The different sampling sites in the major cities of Abidjan, Bouaké and Yamoussoukro. The different sampling points chosen were characterized by technical data sheets describing the types of pollution encountered (domestic and or industrial), the water temperature and the surrounding activities. (Légende = Legend; District autonome d'Abidjan = Abidjan Autonomous District; District autonome de Yamoussoukro = Yamoussoukro Autonomous District; Grands Ponts = Great Bridges; Points de Prélèvements = Sampling Points; Subdivision Administratives = Administrative Subdivisions ; Cours d'Eau = Rivers)

2.1.1 Site of the city of Abidjan

The city of Abidjan has been divided into two zones including Abidjan North and Abidjan South for an assessment of pollution.

For the northern zone of Abidjan, the canal where the samples were taken is located on the Gourou basin. This basin, which covers an area of 28.6 km², covers the communes of Abobo, Adjamé, Cocody and Plateau. Three stations were selected along this primary channel and a fourth at one of its tributaries (Fig. 1):

- The Zoo-HMA station, located near a zoo and the military hospital of Abidjan, is characterized by a mixture of urban wastewater from the municipality of Abobo (mainly made up of popular habitats) and effluents from the hospital center.
- The Williamsville station is located downstream of the Zoo-HMA station and also receives urban wastewater from the municipality of Cocody.
- Fraternité station is located on a tributary of the main canal. It drains wastewater from affluent residential areas south of Cocody.
- The Corniche station is located in a reservoir located at the Indénié crossroads, which is the lowest point of the canal before its discharge into the Ébrié lagoon. The plant receives effluents and solid waste drained by the previous plants, to which are added discharges from other municipalities in the vicinity.

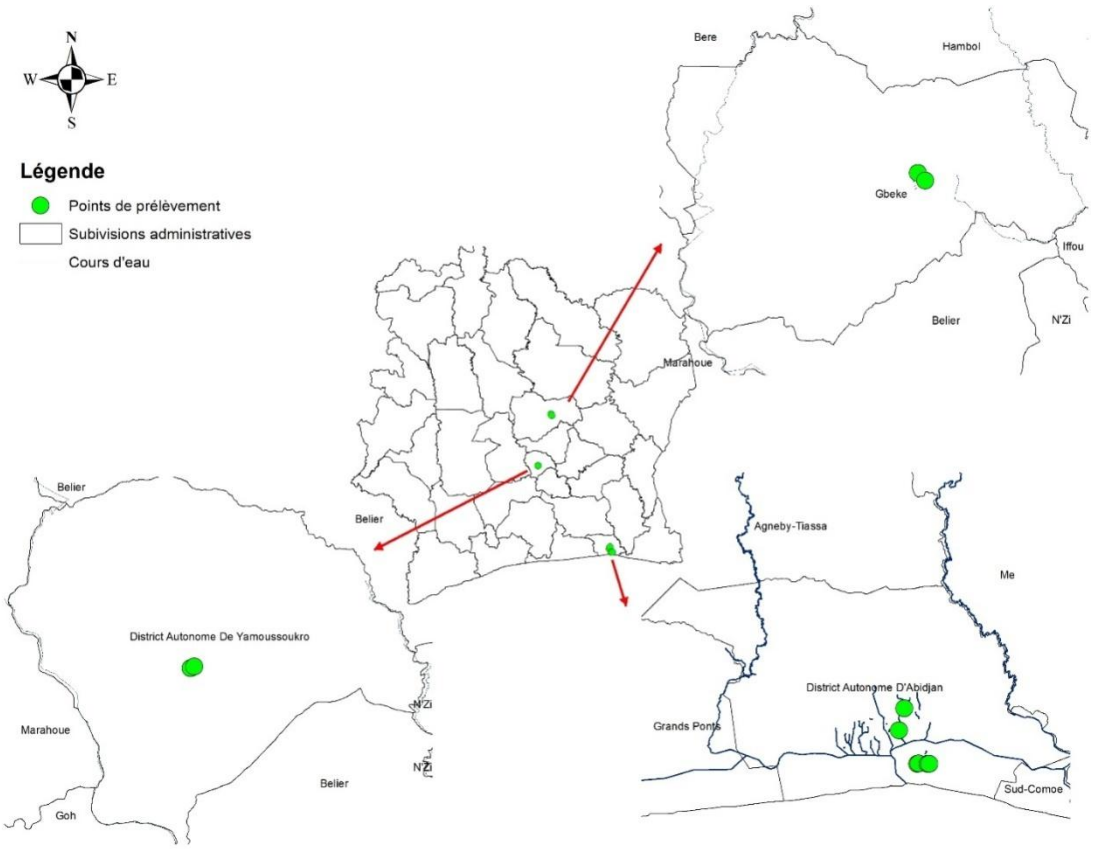

Fig. 1. Study area

For the southern zone of Abidjan, 3 separate channels were sampled. The 4 sampling stations are Saco, Marcory, Sicogi 1 and Sicogi 2 (Fig. 1).

- The Saco plant receives water of industrial origin (discharge from the Cacao Saco factory, textile industries and building and public works companies).
- The Marcory station, located 1km downstream from the Saco station, receives effluents from the municipality of Marcory which is distinguished by its residential areas, these many restaurants and shops.
- Sicogi stations 1 and 2 carry waters from the commune of Koumassi, dominated by an industrial zone and working-class districts.

The wastewater from these different channels will be discharged into the southern part of the Ebrié lagoon.

2.1.2 Sites of the city of Bouaké

In the city of Bouaké, the samples were collected in a canal along Lake Loka (Fig. 1). It crosses the CHU station adjacent to the University Hospital Center, before reaching the Diambrou station which concentrates mainly effluents from a working-class district. A second channel was sampled near the Gonfreville ink plant, so the Gonfreville station receives the discharges from this plant. Finally, Lake Loka, which supplies the city with drinking water, is the outlet for these two canals.

2.1.3 Sites of the city of Yamoussoukro

These samples correspond to a sampling of 3 different channels that flow into Cayman Lake: these are Yakro pharmacy, Yakro mosque and Yakro sheep (Fig. 1). These canals all receive urban wastewater from the popular district of Yamoussoukro.

2.2 Sampling

2.2.1 Sampling for the study

In order to assess the level of microbiological pollution of urban wastewater, the manual sampling for the bacteriological study is carried

out at the surface, in an area that is fairly agitated by the effluent flow, where the risk of sedimentation is very low.

2.2.2 Data collection time

The collection period was from November 2019 to November 2020, between 8:00 am and 1:00 pm of the sampling day. Urban wastewater samples were collected in dry and wet weather in duplicate with one monthly sample per station at each sampling site. The collected data were entered and processed using excel software.

2.2.3 Data collection procedures

Sterile polypropylene bottles were filled with 900 ml of wastewater and carefully labelled. These were stored in a cooler kept at a low temperature (4°c) and then immediately transported to the laboratory for processing within the day of collection.

2.3 Bacteriological Analysis

2.3.1 Fecal contamination indicator count (FCI), total culturable bacterial community (GAM)

The search for pollution indicator germs was carried out at the rate of successive dilutions of 10, from wastewater samples to dilution $1x10^{-7}$. For each sample collected, 1mL of each dilution of water was spread over the following culture media:

1) soy trypticase agar (ASD) for culturable bacterial community (GAM) count,
2) on Violet Red Bile Lactose Agar (VRBL) and bile-esculin-azide agar (BEA) which are used for the enumeration of fecal coliforms (CTT) and intestinal enterococci (EI), respectively.

ASD agar was incubated for 24h at 37°C, BEA agar for 24h at 37°C and VRBL agar for 24h at 44°C (this temperature selecting fecal coliforms).

2.4 Data Quality

Colonies were counted using a colony counter and counts were expressed as colony forming units (cfu) per unit volume.

All cfus were counted for mesophilic aerobic germs (mag).

For faecal coliforms, only purplish colonies with a diameter greater than or equal to 0.5 mm on the vrbl medium were counted.

For the search for intestinal enterococci on bea medium, the hydrolysis of esculin by the enterococci leaves fine colonies with a black halo (esculin positive).

2.5 Data Analysis

Data entry and statistical analyses were performed using excel 2016 and python software and libraries. the average loadings of the tested parameters were compared for the different sampling sites and by alternating seasons.

3. RESULTS AND DISCUSSION

3.1 Results

Thirteen (13) sampling campaigns were carried out on different dates in Abidjan and four joint campaigns for Bouaké and Yamoussoukro. A total of 76 samples were retained. The average bacterial concentrations of mesophilic aerobic germs, faecal coliforms and intestinal enterococci had respectively high loads of $7x10^9$ cfu/100mL, $7x10^7$ cfu/mL and $1x10^7$ cfu/mL in all sites.

3.1.1 Indicator of environmental pollution across these urban agglomerations

Average GAM loadings to wastewater across cities (Fig. 2) ranged from $3x10^7$ cfu/100 mL to $7x10^9$ cfu/100 mL. The seasonal variation for this indicator of environmental contamination in water was not very marked except for the city of Abidjan. In the rainy season, the highest average GAM loads were recorded, particularly in the city of Abidjan.

3.1.2 Indicators of faecal pollution across these urban agglomerations

The mean loads of faecal coliforms (Fig. 3) and enterococci (Fig. 4) in wastewater across cities ranged slightly from 10^5 cfu/100 mL to 10^7 cfu/100 mL.

The highest charges were recorded in the cities of Yamoussoukro and Abidjan. In these cities, fecal coliform loads were higher than those of enterococci. The seasonal variation for these two indicators of faecal contamination in this wastewater was very marked. Loads of 2x107, $1x10^6$ cfu/100 mL, $3x10^5$ cfu/100 mL and $7x10^7$,

$7x10^6$, $3x10^6$ were obtained in the rainy season and dry season for faecal coliforms, respectively. Average faecal coliform loads were higher in the dry season than in the rainy season. As for enterococci, the average loads were $1x10^7$ cfu/100mL, $6x10^6$, $6x10^5$ in the rainy season, $3x10^6$ cfu/100 mL, $6x10^5$ cfu/100ml in the dry season. Average loads of enterococci were significantly higher in the rainy season than in the dry season.

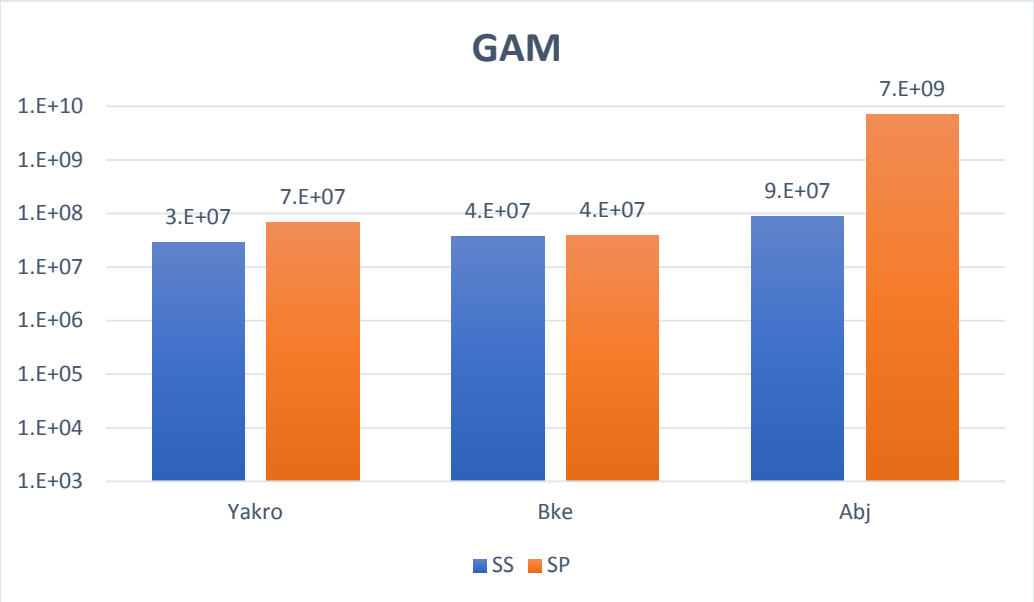

Fig. 2. Average load of the level of pollution of mesophilic aerobic germs according to the seasons (Dry (SS) and rainy (SP) seasons) in the urban agglomerations Abidjan (Abj), Bouaké (Bke) and Yamoussoukro (Yakro)

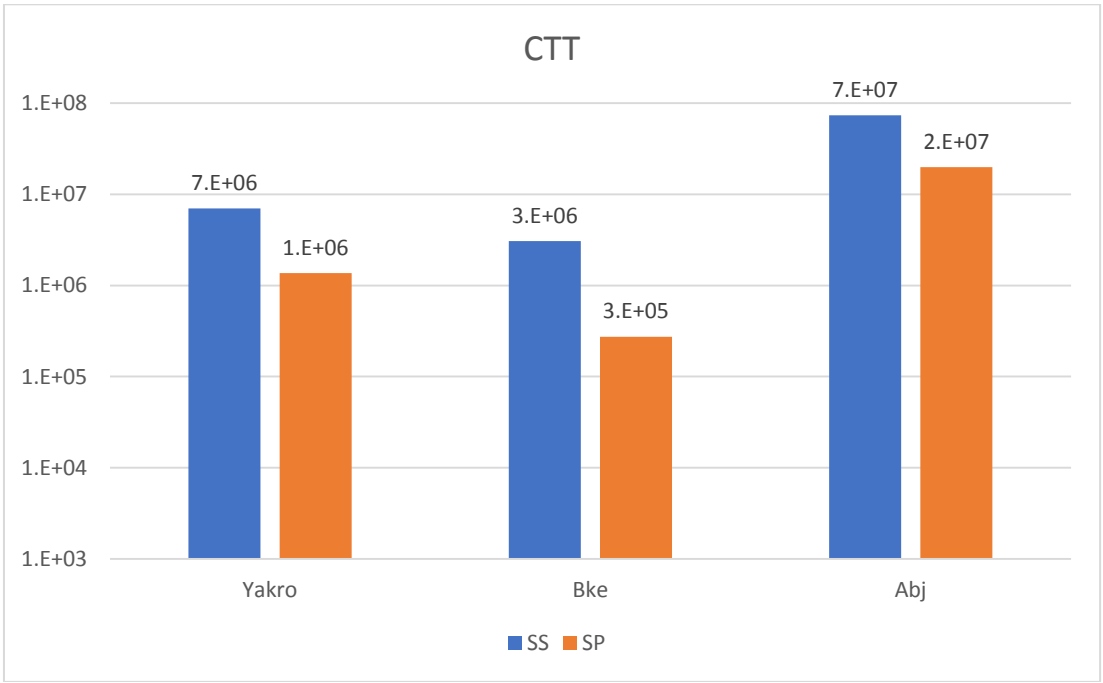

Fig. 3. Average load of faecal coliform pollution level by season (dry (SS) and rainy (SP) seasons) in urban agglomerations Abidjan (Abj), Bouaké (Bke) and Yamoussoukro (Yakro)

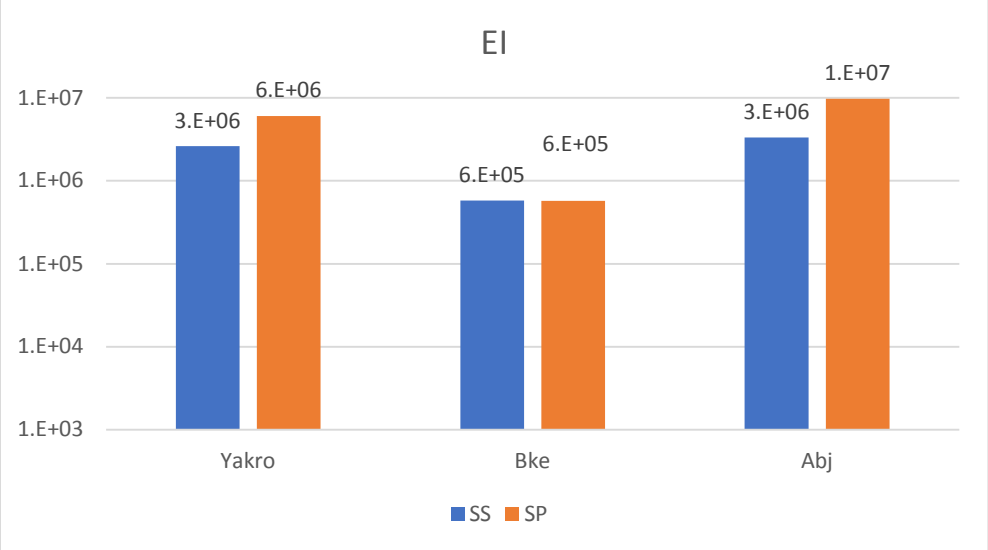

Fig. 4. Average load of intestinal enterococci pollution level by season (dry (SS) and rainy (SP) seasons) in urban agglomerations Abidjan (Abj), Bouaké (Bke) and Yamoussoukro (Yakro)

3.2 Discussion

The average quality of urban wastewater through the study of these three bacteriological parameters shows a high level of contamination. Indeed, the average loads of GAM in the cities varied from $3x10^7$ cfu/100mL to $7x10^9$ cfu/100ml in these wastewaters that end up in water bodies. These results are significantly higher than studies conducted in Africa, specifically in Morocco and Togo [22-25] on the quality of water showing rates of around 10^6 cfu/100ml. Fecal coliforms and enterococci were the two bacterial groups used in this study for the assessment of bacteriological quality of water. Fecal coliforms and intestinal enterococci showed high levels of high faecal contamination of these waters with values of $7x10^7$ cfu/100ml and $1x10^7$ cfu/100ml respectively. This characteristic of wastewater had also been made by other authors in Africa [3,26]. Indeed, the contaminations of these reservoirs were superposable to those obtained in urban wastewater as observed by [27,28] in Morocco. The same was true for the observations of [29]. These authors presented loads varying between 10^6 cfu/100mL and $1x10^8$ cfu/100mL for faecal coliforms and intestinal enterococci. This is also true for Tunisia according to the work of Eddabra [30]. The level of contamination observed in this study was higher than the rates obtained by Adjahouinou et al. [26] in Benin. These results far exceeded the WHO wastewater discharge guidelines of 10^6 cfu/100mL (WHO, 2017). Indeed, all samples had high levels of GAM, faecal coliforms and intestinal enterococci, above the wastewater discharge guidelines. According to the 2017 WHO guidelines on urban wastewater discharges, the allowable discharge standards for faecal coliforms and intestinal enterococci must be less than 10^6 CFU/ 1l of untreated wastewater. The values found in this study for the indicators of faecal contamination were well above 10^6 cfu/100 mL of untreated wastewater. Raw wastewater from the drainage networks of the cities of Abidjan, Bouaké and Yamoussoukro show unacceptable microbial counts [31,32]. This would be due to anthropic activities and anarchic connections along the canals. The wastewater from anarchic connections is of domestic origin, hospital, markets and traditional slaughterhouses installed along the canals [33].

The diagnosis of domestic wastewater management in the cities of Abidjan, Yamoussoukro and Bouaké reveals many sanitation problems. Domestic wastewater is frequently discharged untreated into yards, public roads, gutters and open spaces in neighbourhoods. Indeed, some households use septic tanks and lost wells to evacuate their gray water against the majority of households who evacuate this water in an anarchic way. These uncontrolled discharges of wastewater are widely encountered in Africa [34,35,6,36,37]. In these cities, these anarchic discharges could be due to the economic activities of households (manufacture of attiéké, traditional abbey ...). The lack of conventional sanitation infrastructure in the urbanization process gives free rein to the

population in the choice of its wastewater disposal methods [38]. These problems of uncontrolled dumping were discussed by Wandan et al (2014) in their study of perceptions of environmental problems [35]. Once discharged, this wastewater has as its final destination the water bodies (lakes, lagoons, rivers ...) of the various cities. These uncontrolled spills contribute to the pollution of these water bodies [39,40,9]. It should be noted, however, that Abidjan appears to be the most polluted city with high levels ranging from $9x10^9$ufc/100ml for GAM, fecal coliforms $7x10^7$ufc/100ml and intestinal enterococci $1x10^7$UFC/100ml. Indeed, the strong population growth in Abidjan is 4,707,404 against respectively 310,056 for Yamoussoukro and 680,694 for Bouaké [41]. according to the National Institute of Statistics [42]. Abidjan's urban water drainage system is carried out according to a gravity-type flow through sewer networks and rainwater drainage channels. The wastewater and rainwater drainage network of the Abidjan communes was built of concrete only upstream. The shortcomings observed in the construction of water drainage networks have two notable consequences: i) the exacerbation of soil erosion downstream, particularly during the rainy season; ii) the various water bodies (located downstream) are the receptacle of all wastewater and stormwater discharges from watersheds [43]. Indeed, domestic discharges (wastewater, garbage and faeces) are discharged directly into water bodies [28] and their tributaries. Faecal discharges from livestock are spread on the many agricultural plots or discarded into the environment. This waste is found in effluents during rains [28]. Reports continued to link faecal pollution and waterborne diseases to heavy rainfall [13,44]. In the rainy season, mesophilic aerobic germs and intestinal enterococci have higher rates than in the dry season in the cities of Bouaké, Abidjan and Yamoussoukro. This would be explained by a lower temperature of these waters in the rainy season. Meteorite waters tend to drop the temperature of these waters in drainage channels. This temperature below 30°C would be close to the ideal growth temperature of these germs especially GAM and intestinal enterococci. In the dry season, high levels of faecal coliforms are thought to be due in part to the high temperatures of these waters, which are close to their optimum growth temperature. Cities in Côte d'Ivoire are increasingly confronted with the deterioration of their environment, particularly because of untreated wastewater discharged into aquatic environments [45-47].

4. CONCLUSION

The high net levels of bacterial indicators in untreated wastewater carried through the drainage network of cities reveal the deterioration of water quality and reflect the degrading impact of human settlements and activities on the pollution of this runoff. Our results indicate that the microbial composition of urban wastewater is poor and leads to the imposition of health restrictions and constraints in view of the high levels of faecal and environmental pollution indicator germs. The high net levels of bacterial indicators in untreated wastewater conveyed through the urban drainage system reveal the deterioration of water quality and reflect the degrading impact of settlements and anthropogenic activities on the pollution of these runoff waters. Our results indicate that the microbial composition of urban wastewater is poor and leads to the imposition of health restrictions and constraints in view of the high levels of indicator germs of faecal and environmental pollution. Moreover, bacterial pollution was very high and almost permanent in the wells studied during the whole duration of our study with a contamination of a more or less important density by aerobic mesophilic germs, faecal coliforms, and intestinal enterococci. This result is consistent with the literature on the bacteriological quality of urban wastewater. It appears necessary to create treatment systems for this wastewater before it is discharged into the environment. This could reduce the risks of environmental and health pollution.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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