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Research Article

STUDY OF THE WATER QUALITY OF THE YOPOUGON'S LAGOON BAY (ABIDJAN-CÔTE D'IVOIRE)

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Abstract

The demographic growth of the city of Abidjan is accompanied by an intensification of industrial and agricultural activities that are not correlated with the installation of efficient and adequate sanitation structures. Thus, most domestic, industrial and agricultural wastewater is discharged into the Ebrié Lagoon without any prior treatment. The objective of this study is to characterise the physico-chemical and bacteriological parameters of the waters of the lagoon bay in the commune of Yopougon. The framework of the methodology used to achieve this combines bibliographic research, laboratory analyses and semi-directive interviews. At the end of this methodology, the results showed a seasonal variability of the physico-chemical characteristics and the hydro-climate which condition the level of pollution of the waters of the lagoon bay of Yopougon. The values of salinity, pH, Nitrates, Nitrites and suspended solids remain within the limit authorised by the World Health Organisation for surface waters. On the other hand, the conductivity, phosphate, ammonium and dissolved oxygen levels are outside the standards set by the World Health Organisation. As for the bacteriological parameters, the strong presence of Total Coliforms, Clostridiums and Faecal Streptococci, indicate a strong bacterial contamination of faecal origin of the waters of this bay whose degree of pollution increases after the periods of rainy season..

Keywords: Parameter, Physico-chemical, Bacteriological, Bay, Lagoon, Yopougon.

INTRODUCTION

At the beginning of the 21st century, the protection of the environment has become a major issue because of polluting human activities. Human interventions, which are increasingly massive and highly concentrated in time, are likely to threaten and or interrupt natural cycles and lead to a threshold of irreversibility (Yemou, 2014). Water pollution undoubtedly represents one of the most worrying aspects of this degradation of the natural environment due to human intervention. Indeed, man has mistakenly thought that the ocean's immensity guaranteed him impunity from the apparently harmless act of dumping his waste into it. He has also asked too much of the brackish environments from many points of view (Dufour *et al.,* 1981). These brackish environments, which are lagoons and estuaries, represent varied natural spaces with a high degree of richness. They play an essential interface role as they are the seat of complex phenomena linked to exchanges between fresh and marine waters (Diagoné *et al.,* 2019). These environments are also ideal supply areas for food, energy resources and natural products. They also provide cultural services that benefit tourism, transport and other recreational activities. This explains the fact that most large African cities (Abidjan, Tunis, Lagos, Dakar) are located on the banks of estuaries, lagoons (Yao, 2009). The lagoons also play a role in many sectors as an element in the implementation of development strategies and policies in the fields of sanitation, agriculture and urban development. The importance of these lagoon environments in the ecosystem is therefore no longer open to discussion. However, most African lagoons have experienced an increased deterioration in their quality in recent decades. According to Yao *et al.* (2009), this deterioration is due to the enrichment of water bodies with various pollutants from domestic, industrial and agricultural waste without any treatment.

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In Côte d'Ivoire, the Ebrié Lagoon, which is the largest lagoon system in Africa, is not immune to this sad situation. This lagoon environment, located in the southern part of the coastline over a total area of about 1200 km2 , shows signs of pollution characterised by the phenomenon of eutrophication, strong odours of hydrogen sulphide and periodically by massive deaths of halieutic resources (Dufour *et al.,* 1981). The deterioration of the quality of its waters has become a complex problem, both in terms of ecological conditions and in terms of the socio-economic development of the city of Abidjan that it surrounds. The increase in urban populations, the installation of numerous industrial units and the emergence of peri-urban agriculture have resulted in the production of a large quantity of waste (solid or liquid) which is poorly managed. The city of Abidjan, one of the largest metropolises in West Africa, whose population has tripled (4 707 404 inhabitants) in the space of two decades, experiences this reality on a daily basis (INS, 2014). Indeed, wastewater collection is insufficient because sanitation has not kept pace with the expansion of the city. The sanitation system has a low household connection rate (29%) and malfunctions due to the deterioration of almost all the structures (stations and pipes) prevail (Soro *et al.,* 2010). This situation leads to the discharge of large quantities of wastewater from the sewerage systems. Furthermore, the collection rate of household waste is estimated at 55% of the total production estimated at more than one million tonnes. The uncollected waste, most of which is putrescible, ends up in gullies, shallows, water pipes and then in the lagoon after the rains. The bays of the Ebrié lagoon represent almost one fifth of the surface of the water body. They receive discharges of domestic and industrial wastewater with a high organic matter content, as well as runoff water that drains large masses of solid matter without prior treatment. In view of the low renewal of the water bodies, intensifying the degradation of the quality of the water in the lagoon bays, it is important to carry out a study to quantify these pollutants in order to determine the extent of this pollution. Numerous previous studies carried out on the Ebrié Lagoon have highlighted the state of its degradation. Already in 1980, according to Kouamé (2012), studies on the bacterial pollution of the Ebrié Lagoon showed that the state of pollution of the lagoon waters near Abidjan was worrying. Those of Yao (2009) on the bays of Bietry, Banco, Marcory, Cocody and the Bay of the Billionaires showed that these bays were heavily polluted. The study by Akpo *et al.* (2015) on M'badon Bay showed a very high level of faecal pollution and confirmed the advanced state of pollution of Cocody Bay. However, none of these studies, to our knowledge, has focused on the pollution level of the Yopougon lagoon bay, which is located in the most populated and industrialised commune of Abidjan. It is to bring our contribution to the understanding of this question that the present study concerns "Physicochemical and bacteriological characterization of the waters of the lagoon bay of Yopougon". The objective of this study is therefore to characterise the physico-chemical and bacteriological parameters of the waters of the Yopougon lagoon bay. Such a study is part of environmental geography and is part of the general framework of surface water monitoring in order to establish a database on the pollution of the waters of the Ebrié Lagoon.

MATERIALS AND METHODS

Synthetic presentation of the study area

The present study takes place in the commune of Yopougon located in the part of the city of Abidjan between 5 °20'6.698"N and 4 °4'32.721". This commune is bounded to the north by the commune of Abobo, to the south by the Ebrié lagoon, to the west by the commune of Songon and to the east by the commune of Attécoubé (Figure 1). The commune of Yopougon has an Attiean type climate, hot and humid, with a long rainy season (May-June-July), a short rainy season (October-November) and two dry seasons. A long and a short dry season, respectively from December to April and from August to September. The average annual rainfall varies from 1500 to 2000 mm. The average monthly peak is observed in June with a rainfall of nearly 610 mm. The temperature is almost always around 27°C. The humidity level reaches 80%. The commune of Yopougon is estimated to have 1071542 inhabitants with an area of 127.44 km², i.e. a density of 8408 in habitants/km² (INS-RGPH, 2014). It is characterised by a strong presence of informal economic activities.

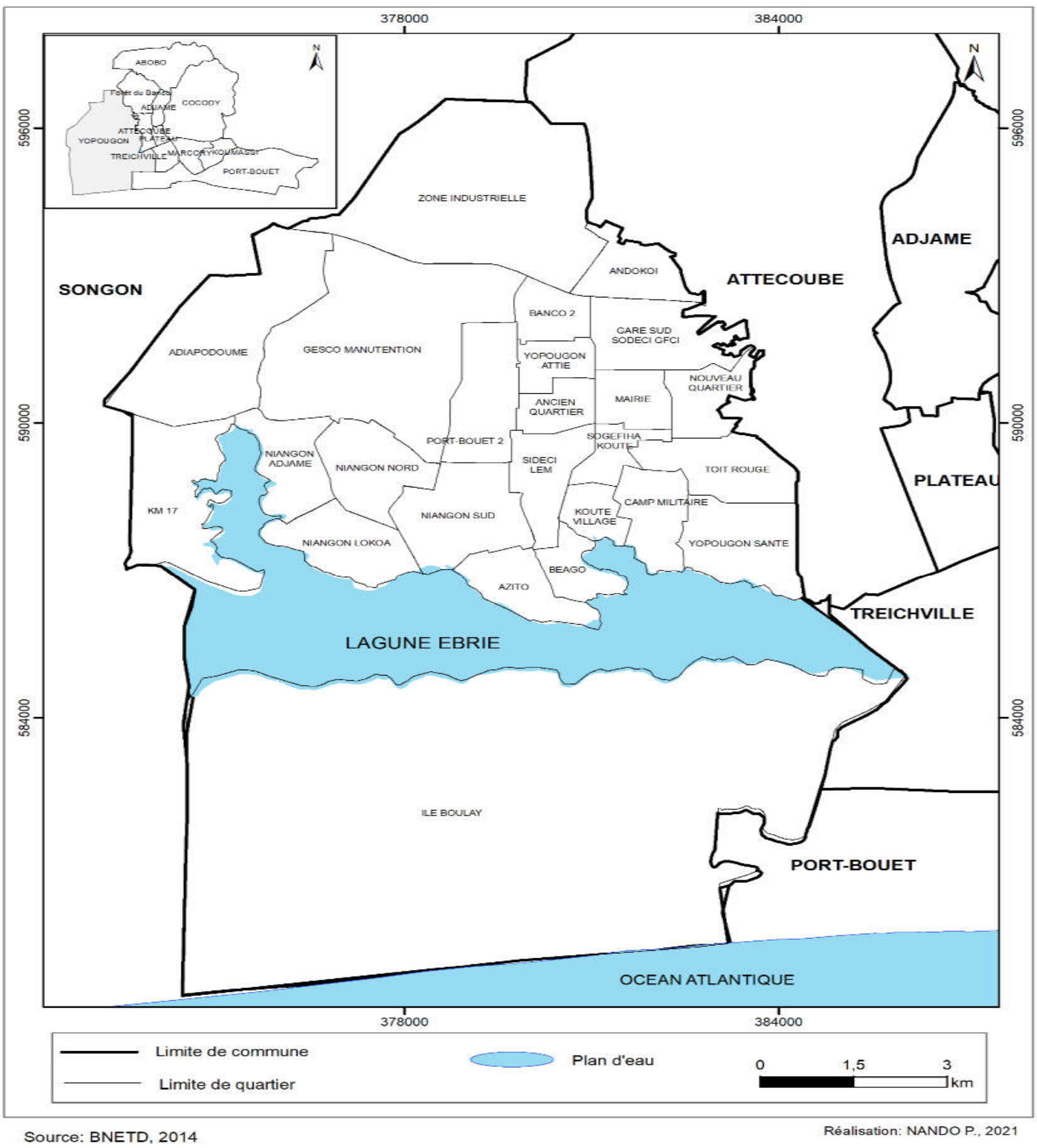

Figure 1. Presentation of the commune of Yopougon

It also represents an important centre of economic activities as it has the largest industrial zone in the city of Abidjan.

Materials used

All the equipment used in the framework of our work consists of

- A GPS model GARMIN to geo-reference the study area;
- A Niskin sampling bottle for water sampling at depth;
- A HACH multi-parameter for measuring physico-chemical parameters in situ;
- A digital camera for taking pictures.

Data collection method

Documentary research: The methodological equipment used for this purpose can be summarised in three fundamental stages: documentary research, field survey through the administration of a questionnaire and data processing. The bibliographical research on the subject, carried out in libraries and sometimes on websites, was directed towards documents likely to provide useful information. These are general works, dictionaries, theses, master's theses, scientific articles, reports of seminars, conferences and colloquia on the issue of urban transport. This documentation, which offers a global and theoretical view of the subject, has made it possible to measure the extent of the pollution of the Ebrié lagoon.

Collection of water samples: Water samples were taken at the surface (0.5m) and at depth (3.6m) in the waters of the bay using a Niskin bottle of 2 litres capacity. Thirty (30) samples were taken from February to December 2020.

Analysis of samples: The physico-chemical analyses carried out on the samples taken are grouped into two categories:

- Physical analyses carried out in situ ;
- Chemical analyses carried out in the laboratory.

In situ measurements: Five (05) physico-chemical parameters were evaluated in situ during this study. These were temperature, pH, conductivity, salinity and dissolved oxygen. The HACH multi-parameter apparatus has probes which, once immersed in the sample, allow the value of the parameter to be read directly on the apparatus.

Laboratory analyses: The laboratory analyses focused on five (05) physico-chemical parameters: nitrites, nitrates, ammonium, and orthophosphate were determined by spectrophotometry with the DR 6000 and four (04) bacteriological parameters (total Coliforms, faecal Coliforms, faecal Streptococci and Clostridiums).

Data processing: After the information collection process, which allowed for the collection of the necessary information and data through the different instruments or techniques chosen for this purpose, it is important to proceed with processing. This method of data processing consisted of organising and analysing the data in order to facilitate their interpretation and use. This processing was done manually and by using computer tools. It enabled figures to be produced. The methodology adopted enabled the present work to be structured firstly on the physico-chemical parameters and then on the bacteriological parameters.

RESULTS AND ANALYSIS

Physical parameters (pH, temperature, conductivity, salinity), organic pollution parameters (dissolved oxygen, suspended solids, ammonium, nitrates, nitrites and ortho-phosphates) and bacteriological parameters were measured to characterise the waters of Yopougon Bay.

Physico-chemical parameters beyond the norm

The temperature: The average temperature of the water is 29.07°C at the surface and 28.26°C at depth (figure 2). The maximum temperatures were observed in April during the dry season (31.16°C at the surface and 30.5°C at depth) and the minimum temperatures were observed during the rainy season in June (27.05°C at the surface and 27.1°C at depth). The surface water is warmer than the bottom water.

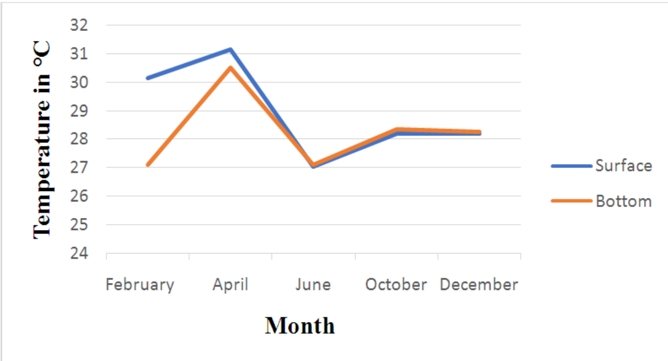

Figure 2. Monthly variation in temperature

PH: The analysis of the figure 3 shows that the pH of the surface water ranges from 7.54 to 6.65 with an average of 7.03. These values are relatively higher than those of the bottom, whose pH ranges from 7.24 to 6.52 with an average of 6.81. The pH decreases slightly from the surface to the bottom in all seasons. The water is basic (alkaline) during the dry season at the bottom as well as at the surface and then becomes slightly acidic during the rainy season.

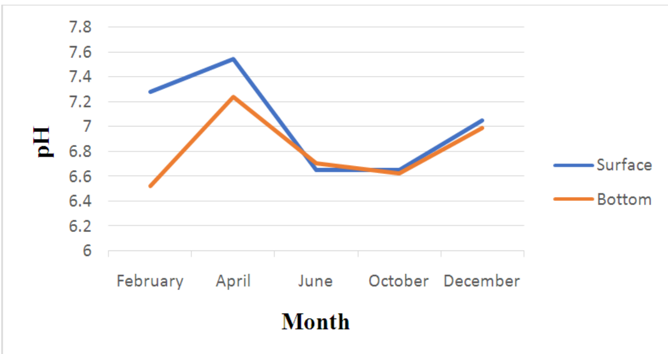

Figure 3. Monthly variation in pH values

Salinity: The analysis of the figure 4 indicates that the salinity of the waters of the bay ranges from 1.3 to 27.27‰ at the surface and from 1.5 ‰ to 28.11‰ at depth. The highest values of salinity are observed between February- April and December during the dry seasons. The lowest values are observed in June and October during the rainy and flood seasons of the various rivers flowing into the lagoon.

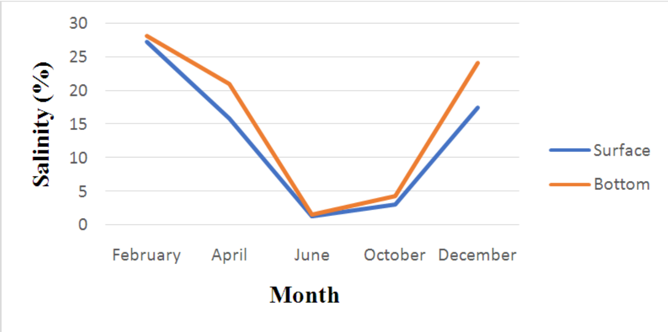

Figure 4. Monthly variation in salinity levels

Conductivity: Electrical conductivity shows a parallel evolution to that of salinity. Surface conductivity fluctuates between 2639 and 48826 µS/cm with an average of 22401.8 µS/cm and that at depth fluctuates between 3011 and 45035 µS/cm with an average of 12909 µS/cm (figure 5). The maximum values at depth and at the surface are observed during the dry season and the minimum values during the rainy season.

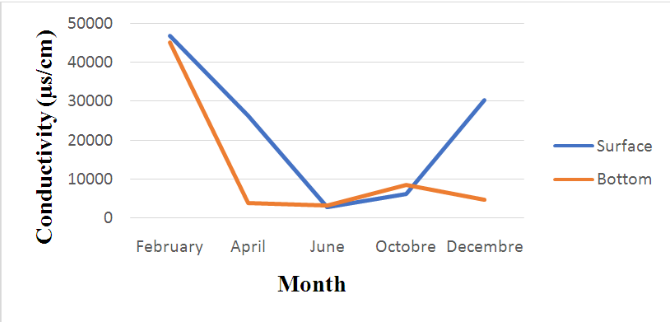

Figure 5. Monthly variation in conductivity levels

Dissolved oxygen: The analysis of the figure 6 shows that Dissolved oxygen values in the waters of the bay fluctuate between 1.9 mg/L and 4.68 mg/L at the surface and between 1.39 and 5.08 mg/L at depth. The minimum values are obtained in April during the dry season and the maximum values in October during the short rainy season.

Figure 6. Monthly variation in dissolved oxygen levels

Suspended matter: The suspended matter content of the waters of the bay according to the month is shown in figure 7. It shows a clear stratification of the concentrations of suspended matter between the different measurement depths. The suspended matter values are higher at depth than at the surface. The surface values range from 10 to 51.2 mg/L with an average of 26.24 mg/L and those at the bottom from 18 to 121 mg/L with an average of 53.4 mg/L.

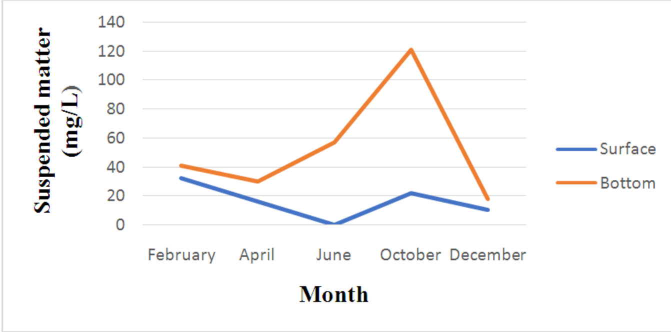

Figure 7. Monthly variation in suspended solids content

Nitrates: Figure 8 presents the nitrate concentrations obtained in the water column of Yopougon Bay according to the different months. The surface values vary between 0.1 and 2 mg/L with an average of 0.84 mg/L and between 0.1 and 1.4 mg/L with an average of 0.8 mg/L. It can be seen that nitrate concentrations evolve in a similar way in the water column. The lowest concentrations are observed in June and the highest in February.

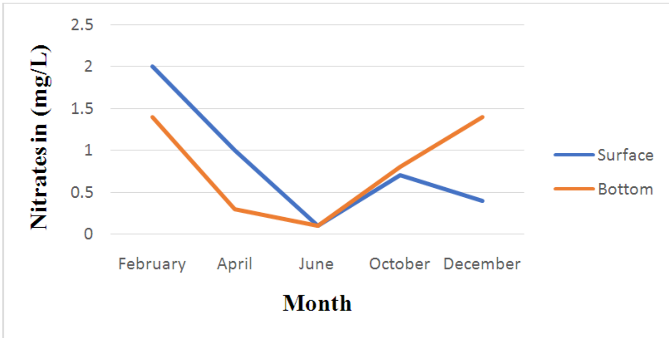

Figure 8. Monthly variation in Nitrate levels

Ammonium: Ammonium levels range from 0.3 to 2.18 mg/L in surface waters with an average level of 0.91 mg/L (figure 9). The maximum value is recorded in December. The ammonium content of the bottom waters ranges from 0.1 to 2.23 mg/L with an average of 0.8 mg/L.

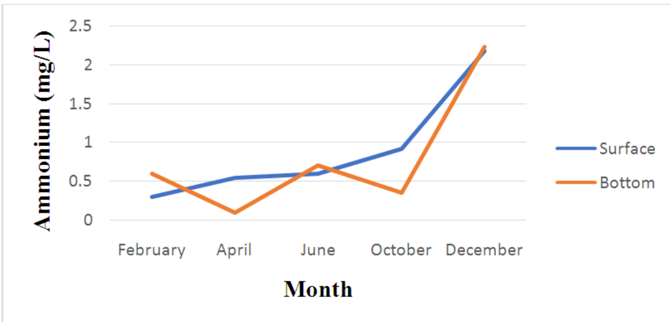

Figure 9. Monthly variation in ammonium levels

Nitrites: Nitrite levels range from 0.004 to 0.09 mg/L at the surface and from 0.004 to 0.036 mg/L at the bottom (figure 10). The maximum values are observed during the period from December to February and the minimum values in June.

Ortho-phosphates: Figure 11 shows the ortho-phosphate content of the waters of the Yopougon lagoon bay according to the different months. The values at the surface vary between 1.7 and 5.2 mg/L with an average of 3.43 mg/L and from 0.96 to 22.36 mg/L at the bottom. It is noted that the values of this parameter remain low during the dry seasons and then increase slightly during the rainy seasons. Phosphates in the water are generally more concentrated at the bottom than at the surface.

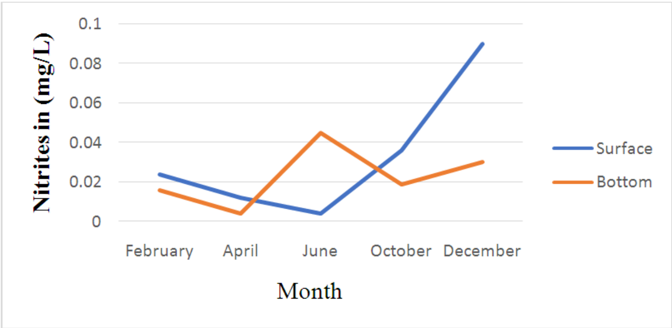

Figure 10. Monthly variation in Nitrite levels

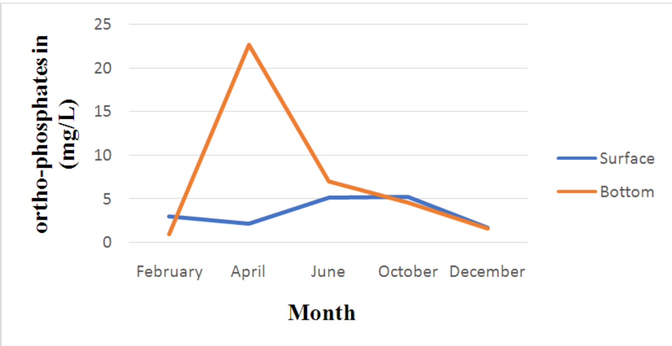

Figure 11 . Monthly variation in Ortho-phosphate content

Bacteriological parameters

Total coliforms: Figure 12 shows the total coliform content of the water in the bay. They range from 330 to 11300000 CFU/100 ml at the surface and from 330 to 11300000 CFU/100 ml at depth. The characteristic colonies of total coliforms are very high at the surface and at the bottom throughout the seasons. However, a significant drop is observed in June. This decrease is followed by an increase, with the maximum value recorded in October.

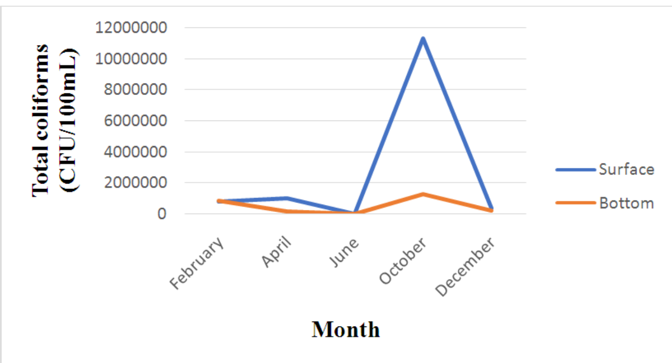

Figure 12. Monthly variation in total coliform levels

Fecal coliforms: The distribution of faecal coliform values in the lagoon waters of Yopougon Bay according to the months and at different depths is illustrated in figure 13. It can be seen that the values of these bacteria in the water of the surface layer are higher than those of the bottom. The values range from 300 to 910000 CFU/100 ml in the surface and from 3000 to 200000 CFU/100 ml in the bottom. It is noted that these values are very high in all months except for the month of June, which corresponds to the rainy season, when they are low.

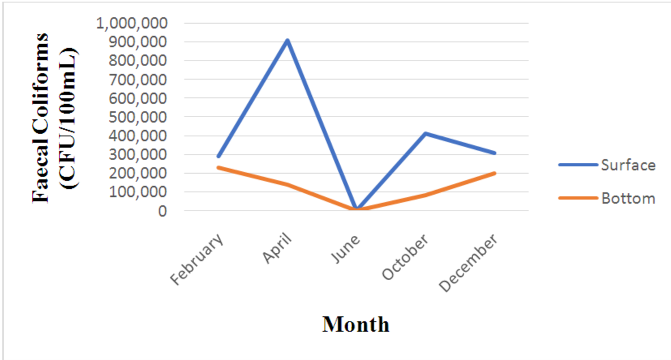

Figure 13. Monthly variation in faecal coliform levels

Faecal Streptococci: The values of the characteristic colonies of faecal Streptococci evolve in the same order as those of coliforms. The levels fluctuate between 50 and 445103 CFU/100 ml at the surface and between 50 and 15700 CFU/100 ml at depth (figure 14). The minimum and maximum values at the bottom and at the surface are recorded in June and October respectively.

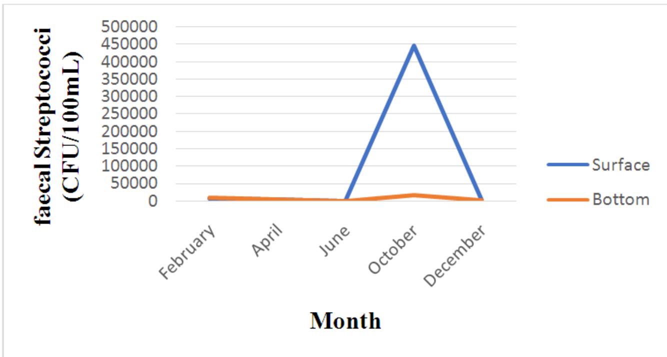

Figure 14. Monthly variation in faecal Streptococci content

Clostridium: Clostridium levels vary between 308 and 5520 CFU/100 ml at the surface and between 552 and 2293.3 CFU/100 ml at the bottom. Unlike Coliforms and Streptococci, the minimum Clostridium levels are recorded in April during the dry season.

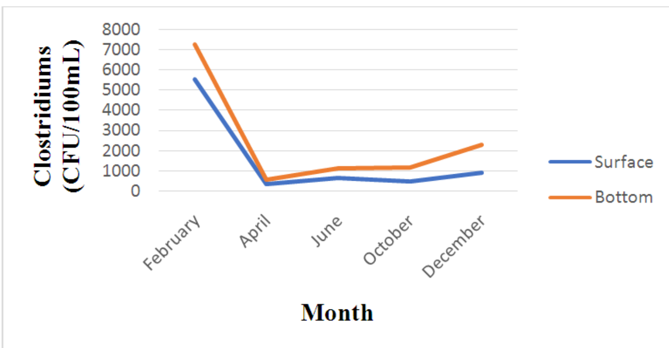

Figure 15. Monthly variation in Clostridium levels

DISCUSSION

Physico-chemical parameters beyond the norm

The temperature of the waters of the Yopougon lagoon bay averages 29.07°C at the surface and 28.26°C at depth. This is slightly lower than the values observed in the waters of the Aghien lagoon, which range from 30 to 32°C. This average confirms a well-known physical feature of the waters of the Ivorian lagoons, which reach their maximum values of 30 to 32°C according to Traoré *et al.* (2012). The maximum levels observed in the dry season are due to the fact that in the dry season, the ambient air temperature is high, which leads to a warming of the surface water layers. The low temperatures recorded during the rainy season are attributable to runoff and precipitation water that favours mixing between the surface and underlying water layers, thus creating a homogenisation of the entire water column in the bay. These temperatures exceed the World Health Organisation's recommended temperature of 25°C for surface waters. These high temperatures could stimulate the growth of harmful microorganisms that can cause unpleasant odours and tastes and even make the water unhealthy. The average pH of the surface waters of the bay for this study is 7.03 and 6.81 for the bottom waters. These values are roughly equal to those recorded by Kambiré, (2014, p.89) in the Aby lagoon which range from 6.96 to 7.8. These surface and depth values are in line with those reported by the World Health Organization (6.5-8.5).

The alkaline character during the dry season could be explained by the preponderance of basic marine water entering Yopougon Bay through the Vridi Channel (Soro *et al.,* 2009). On the other hand, during the rainy seasons, the waters of the bays are renewed by weakly acidic continental waters with the passage of the floods of the rivers and streams. This would explain the drop in pH (acid). Indeed, the arrival of the first more acidic waters of the Comoé in the lagoon, mixed with the first rains, contributes to lowering the pH (Bakary *et al.,* 2009). Examination of the average conductivity values reveals that these waters are highly mineralised. These values are much higher than those recorded by Koné S. (2011) in the bay of the Tiagba lagoon, which range from 1790 to 6610 µS/cm, and lower than those measured by Amani *et al.* (2019) in the bay of Biétry (47991 and 48510 µS/cm). The high values obtained during the dry season could be related to the evaporation of the mineralization brought in the rainy season by the runoff water containing fertilizers used by the market gardening crops located at the edge of the bay. Indeed, the pronounced evaporation and decomposition of organic matter cause an accumulation of ions in the environment. On the other hand, in the rainy season, heavy rainfall dilutes the water, thus causing a drop in conductivity. These values are above the standard set by the World Health Organisation, which is 3000 µS/cm. Salinity is a marker of the origin of the water. Seasonal variations are linked to the hydro-climate. According to Soro *et al.* (2009), the waters of Bietry Bay, Banco and Yopougon are more subject to marine influences, which would explain the high salinity rate. On the other hand, the drop in salinity recorded during the rainy season can be explained by the freshwater inflows that dilute the water in the bay. The drop in salinity favours the proliferation of aquatic species, more specifically water hyacinths, which, by developing, prevent the penetration of sunlight into the water and contribute to the rarefaction of water aeration, which is a threat to fish. The dissolved oxygen levels obtained throughout the campaign are very low. They vary between 3.18 and 2.31mg/L. These values are lower than those determined by (Kambiré, 2014), in the Aby lagoon which are between 4.4 and 8.2mg/L and those of Issola Y. et al, (2008, p. 376) in the Fresco lagoon (4.66 and 5.5 mg/L) and then higher than those of Tohouri *et al,* (2007) which is 1.1 and 4.4 mg/L in the Ono lagoon and Potou. Hypoxia, i.e. oxygen values below 3 mg/L, observed in the bay reflect the effects of high loads of organic matter brought into the lagoon by domestic wastewater discharges with low photosynthetic activity. Microorganisms use dissolved oxygen for the degradation of organic matter. Totally anoxic waters are characterised by anaerobic fermentation with the release of hydrogen sulphide, a source of nauseating odours. The average values of suspended solids (26.24 and 53.4 mg/L) are slightly higher than those obtained by Issola et al. (2008) in the Fresco lagoon, which vary between 26.4 and 45.69 mg/L. According to Rodier (2009) the abundance of suspended solids in surface waters depends on the season and the nature of the discharges. In this case study, the high values recorded during the rainy season are the result of the presence of uncontrolled rubbish dumps located at the edge of the bay or those discharged into the stormwater and wastewater drainage channels. These average values of suspended solids are below those accepted by the World Health Organisation. However, the suspended solids drained into the aquatic environment during the rainy season could limit the penetration of light into the water, which would reflect a decrease in photosynthesis of phytoplankton underwater, resulting in a reduction in dissolved oxygen in the aquatic environment. The average nitrate content (0.84 mg/L at the surface and 0.8 mg/L at depth) and nitrite content (0.033 mg/L and 0.022 mg/L) are well below the levels indicated by the World Health Organisation, which are 50 and 0.1 mg/L respectively. On the other hand, phosphate (3.43 mg/L 7.36 mg/L) and ammonium (0.91 mg/L at the surface and 0.8 mg/L at the bottom) levels are higher than the World Health Organization's guideline of 0.5 mg/L. These levels are the result of domestic and, above all, agricultural wastewater discharges. The interview with farmers located on the edge of the bay revealed that they use urea, composed of nitrogen, phosphorus and potassium, as chemical fertiliser. Thus, during rainfall, runoff from agricultural land (market gardening) carries these fertilisers spread on the soil to the waters of the bay, increasing the level of these nutrients.

Bacteriological parameters

The microbiological analysis of the waters of Yopougon Bay revealed the presence of high levels of coliform bacteria, streptococci and clostridium. These values are well above the threshold set by the World Health Organisation, which is 1000 CFU/100ml for bathing water. These bacteria are the most specific indicators of faecal pollution. They clearly indicate contamination of the bay water by faecal germs and therefore bacterial pollution. The densities observed are slightly higher than those found in the Abidjan lagoon area, particularly in the bays of Cocody, Banco and Biétry. According to Bamba et al, (2008) in June 2006, high densities of faecal coliforms and total coliforms were observed in these bays with, respectively, 630000 and 112000 total coliforms in the surface waters of Banco and Cocody bays. In these same bays, densities of 570000 and 103000 faecal coliforms were recorded. The abundance of faecal germs is essentially due to an increase in anthropic inputs through the leaching of soiled soils and run-off water, as well as the use of the banks of water bodies as latrines by the population, which constitute the main source of contamination inventoried in the study area. Indeed, domestic wastewater and runoff enter the bay without any treatment. Some sanitary installations located on the edge of the bay discharge their water through pipes connected directly to the bay or to the stormwater drain. However, the low levels of these fecal bacteria during the rainy season could be due to the abundance of rainfall recorded in June which dilutes the water in the bay. Thus, after receiving large amounts of organic matter during the rainy seasons through runoff, bacterial activity is increased during the dry seasons in the bay, resulting in a proliferation of these germs.

Conclusion

The present study has made it possible to assess the level of pollution in Yopougon Bay through physico-chemical and bacteriological characterisation. After analysis of the water samples, the results showed a seasonal variability of the physico-chemical characteristics and the hydro-climate which condition the level of pollution of the waters of the Yopougon lagoon bay. The values of salinity, pH, Nitrates, Nitrites and suspended solids remain within the limit authorised by the World Health Organisation for surface waters. On the other hand, conductivity, phosphate, ammonium and dissolved oxygen levels are outside the standards set by the World Health Organisation. According to these criteria, the analysis of the bacteriological parameters showed that the water in the bay is in a worrying state. The average loads of these faecal pollution indicator parameters (Total Coliforms, Total Coliforms, Clostridiums and Faecal Streptococci) indicate a high level of bacterial contamination of faecal origin in the waters of this bay, the degree of pollution of which increases after the rainy season due to the leaching of soiled soils and anthropic activities (black water discharge).

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