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Monitoring Chemical Pollution in the Chenal's Waters of Cotonou

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Citation

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Abstract: The protection of estuarine aquatic ecosystems is essential to the ecological balance of fish species and to a healthy diet for local populations. The Cotonou Chenal in southern Benin is under the influence of several forms of pollution that result for most human activities. This work proposes to know the current state of chemical pollution of the aquatic ecosystem of the Chenal in order to limit the ecotoxicological risks. Monitoring indicators of physico-chemical quality (temperature, pH, conductivity, total dissolved solids, dissolved oxygen, transparency and depth) of organic pollution (COD) and total lead have been searched for in the different water and sediment samples of the channel. The inventory of the potential sources of chemical pollution of the Chenal, reveals that the garbage dumps littering the lagoon banks, the collectors and the drainage channels of the city of Cotonou, the road and maritime transport, and the dyers of Gbogbanou are the main sources. The physicochemical measurements of the Chenal water monitoring have shown that the values of the recorded temperature, pH, nitrate, nitrite and phosphate do not show statistically a sign of pollution of the studied area apart from some pockets of contamination like the mouth of the SOBEBRA and the Hotel du Lac at the time of wastewater rejection. Besides, the measured values reveal at the threshold of 5% a low transparency (0 to 0.875m), a low level of dissolved oxygen (0.00 to 4.33mg/L), a very high Chemical Oxygen Demand (COD) (669 ± 615 to 997 ± 337 mg O_2/L) and a high contamination of the water column with ammonium ion (6.84 ± 3.43 at 13.80 mg/L) at the mouth of the SOBEBRA (lake Hotel). In water, the average lead content is 0.258 ± 0.29 mg/L.

Keywords: Chemical Pollution, Water, Chenal, Monitoring

1. Introduction

Since the advent of science and technology, a frightful relationship has been developed between man and his environment [1]. One of the major problems facing modern societies today is environmental pollution [2]. Regardless of the compartment of the polluted environment and the type of pollution, the final destination of pollutants is mainly water resources through precipitation or direct discharges [3]. Levels of chemical contamination of aquatic environments have increased with the pace of technological development by the diversity of pollutants and/or their content (organic, inorganic, radioactive pollution, etc.). The phenomenon is more pronounced in terms of coastal water resources [4]. The West African coastline is rich in many surface water resources on what riverine populations are strongly dependent [5]. But the sad fact today is that we are witnessing advanced physical and chemical pollution of these aquatic ecosystems [6]. The causes are numerous and multiform, among which we can mention the proximity of the oceans which has favored the growth of coastal cities, the high industrial and human density of these cities, the lack of proper sanitation measures of the living environment, the ignorance for a long time of the environmental problems, the unconsciousness and the lack of public spirit of the townspeople [7]. All these regions are affected by the problems of water quality degradation, but at various levels.

Despite an embryonic industrial sector, Benin is facing today a persistent degradation of the fluvial and marine environment, with sedimentation and filling of water bodies, very advanced coastal erosions, pollution organic and inorganic chemicals [8]. Thus, the constant degradation of the quality of the water resources on which the riparian populations often depend, added to the growing difficulty to regenerate these resources, has progressively changed the consciousness both at the level of the national and international institutions and at the level of a fringe grassroots communities in the quest for everlasting measures to limit these threats to the human environment [9]. The taking of these measures must be guided by scientific knowledge which passes by the knowledge of the types of pollution, levels of contamination and/or degradation and the risks incurred by the various components of the environment. This study, entitled "Monitoring Chemical Pollution of the Cotonou Chenal Waters" aims to follow the spatio-temporal evolution of the contents of some physico-chemical parameters of water quality monitoring in order to assess the current quality of the water of this ecosystem.

Figure 1. *Map of the Cotonou Chenal with sampling sites.*

2. Material and Methods

2.1. Study Zone

The Chenal of Cotonou object of the present study is located in the South-East of the country, between the parallels 2026'30" and 2026'22" North and the meridians 6020'et 6023' East (figure 1). It is 4.5 km long and 300 m wide on average with an area of approximately 1,125 km^2. This chenal links Nokoué lake with the marine waters forming the lagoon complex Chenal of Cotonou-Nokoué lake-Porto-Novo lagoon. It plays an important role in the evolution of this complex, as its annual or multi-year opening and closing cycles influence the hydrodynamics of Lake Nokoué and the Porto-Novo lagoon through the channel of Totchè as well as the seasonal regime of continental inputs of Sô and Ouémé [5]. The Cotonou Chenal is bordered by the largest market in Benin Dantokpa and a large number of neighborhoods with a large population of the estimated population of more than 202,791 inhabitants from which it receives most of the pollution. Many resorts and industries also dump their wastewater. It is crossed by three bridges [10].

2.2. Sampling Campaigns

Two sampling campaigns have been carried out; a first campaign in May 2012 during the dry season and a second one in November 2012 at the end of the small rainy season. PH, temperature, conductivity, and total dissolved solids have been measured in situ with a HANNA multiparameter. Dissolved oxygen has been measured in situ using the Winkler Kit. Transparency and depth have been measured using a Secchi disk. The water samples have been taken manually 10 cm below the flat surface of the water in amber bottles of two (02) liters capacity. Samples taken are labeled and stored in cold boxes with a cold accumulator and sent to the laboratory for analysis.

2.3. Methods of Analyzing Samples at the Laboratory

The levels of suspended solids have been determined using filter paper (WATTMAN) by weighing the filter before and after filtering the water and then drying at 105°C in an oven. The chemical oxygen demand (COD) in our water samples has been determined by acid reflux method of potassium dichromate using a COD reactor. The nitrites and the ammonium ions were analyzed respectively by the method of Zambelli and that of Nessler. Phosphates and nitrates were determined by the ammonium molybdate method and the sodium salicylate method respectively [11]. Spectrophometric measurements were performed with the DR-2500.

2.4. Data Analysis

Statistical analysis have been done with the Minitab 14 and R-2.15.3 software. The one-sample t-Student statistical test was used to verify the compliance of the average value of the different physico-chemical parameters with the corresponding standards. The equality of the averages of the parameters common to the two campaigns has been made by the Mann-Whitney statistical test. The Pearson statistical correlation test is used to verify the existence of possible links between the different physicochemical parameters. Principal Component Analysis (PCA) is done to describe the relationship between these parameters and the sampling points of the Cotonou Chenal. These different tests have been performed at the 5% significance level.

3. Results and Discussion

3.1. Spatio-temporal Variation of the Temperature

Figure 2 gives the spatio-temporal evolution of the temperature. From the analysis of the histograms, it is found that at all the sites, the temperatures vary from 24.8 to 26.7°C for the first campaign and from 29.2 to 30.4°C for the second. The averages of our temperature measurements corroborate with the work of [12], who found temperature values between 28 and 31°C for the Chenal waters. Temperature is one of the parameters that determines the life of ecosystems and the speeds of chemical processes that determine the physico-chemical quality of natural waters. The values taken by the temperature during this work do not allow to suspect a pollution. Statistically there is a link between ambient temperature and pH (P = 0.002).

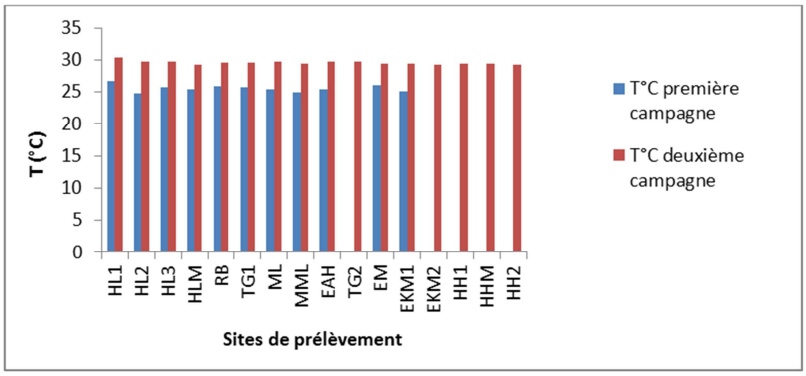

Figure 2. *Spatio-temporal variation of the water temperature of the chenal.*

3.2. pH Variation by Site and Sampling Campaign

The pH of a water is its acidity or alkalinity. Figure 3 shows the pH variation of the waters of the Cotonou Chenal for both seasons. The pH values obtained are between 7.80 and 9, for the month of May and vary between 6.92 and 9.40 for November. For all sites, the average pH values are 8.36 and 7.93 respectively in May and November. These two seasonal average pH values differ statistically at the 0.05 threshold (P=0.0005). pH values for November are comparable to those found by [8], whose pH valuesrecorded in the chenal ranged from 6.81 to 8.26. According to [13] the pH of surface waters varies between 6.0 and 8.5 (6.0 <pH <8.5). If the maximum recorded pH values fall outside this range, the average values obtained during the two campaigns are within this pH range and do not allow to suspect a chemical pollution inducing a noticeable variation of pH.

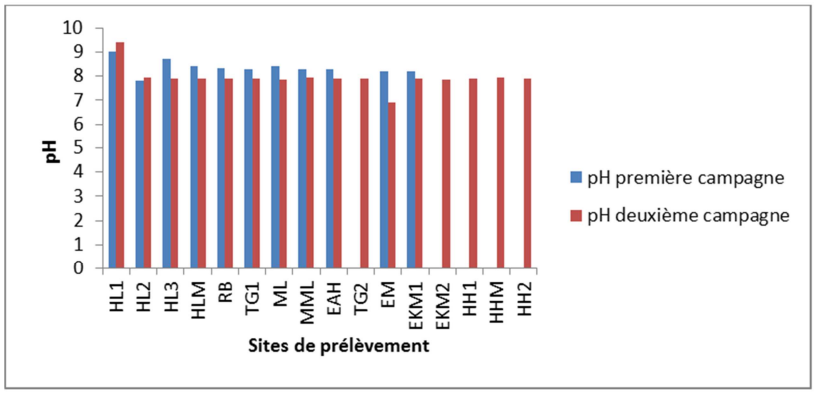

Figure 3. *Spatio-temporal variation of the pH of the chenal water.*

3.3. Variation of the Electrical Conductivity of the Chenal Waters

Table 1 presents the electrical conductivity values recorded during the second campaign. Values range from Not Determined (ND) to 47,500 µS/cm. All the conductivity values recorded in this study are high compared to the recommendations of the Beninese standard which set the Maximum Allowable Concentration of Electrical Conductivity at ≤ 2000 µS/cm for freshwater. The measured values vary from 18760 to 47500 µS/cm respectively for the Mahoulé pier and the Lake hotel with an average of (29904 ± 10138) µS/cm. The conductivity of water is a measure of its ability to conduct electrical current. The measurement of the conductivity allows to appreciate quickly but very approximately the mineralization of the water and to follow its evolution [14]. This average obtained indicates a very extensive mineralization of the channel waters. Comparison with the standard set by WHO (2000 µS/cm) reveals that at the 5% threshold it is significant (P=0.00). Similarly, the electrical conductivity values obtained are greater than those recorded by [8] which are between 685 and 1968 µS/cm with an average of 1485.00 µS/cm in the same ecosystem. The large difference observed between the extreme values of the electrical conductivity of the water of the environment is justified by two antagonistic hydrological phenomena, namely, the saline intrusion from the Atlantic Ocean responsible for the rise in value and the supply of the fresh waters of the Ouémé river which, on the other hand, reduce it. These two phenomena alternately make the channel water sometimes brackish or soft. This state of affairs contributes to the productivity of the water body for the benefit of the fishing activities of which live a good fringe of the local populations [5]. However, releases of solid waste and wastewater from the Dantokpa market would also influence the electrical conductivity in this aquatic environment. Statistically there is a link between the ambient temperature and the environmental conductivity of the Cotonou Chenal (P = 0.028) at the 5% threshold with correlation coefficients of 0.710 and 0.028, respectively. So an increase in temperature leads to an increase in conductivity and pH.

Table 1. *Variation of the electrical conductivity of the Cotonou Chenal water during the two sampling campaigns.*

Sites / settings	HL_1	HL_2	HL_3	HLM	RB	TG_1	ML	MML	EAH	TG_2	EM	EKM_1	EKM_2	HH1	HHM	HH2
Cond (ms/cm) 1st campaign	>2	>2	>2	>2	>2	>2	>2	>2	>2	ND	>2	>2	ND	ND	ND	ND
Cond (ms/cm) 2nd campaign	45.2	47.5	44	40.7	39.6	30.5	29.9	25.1	26.8	26	18.76	21.4	23	19.93	18.98	21.1

Cond: conductivity

3.4. Spatio-temporal Variation of Solids Total Dissolved (TDS)

Table 2 summarizes the values recorded for Total Dissolved Solids (TDS) in both campaigns. The data analysis shows that it varies from ND to 1000 (ppt) in both campaigns. The trends of the first campaign are similar to those of the electrical conductivity discussed above. During

the 2nd campaign the values obtained in this medium are generally greater than 1000 mg/l except those of the sites EM, HH1 and HH2 with respective values of 619 ppt, 960 ppt and 922 ppt. These total dissolved solids (TDS) values are higher than the WHO guidelines for drinking water (TDS ≤ 500mg/l). These high levels of TDS are both related to the high conductivities recorded and to the pollution of the Cotonou Chenal by organic and/or inorganic loads dissolved in the aquatic environment resulting from inputs from inland waters and the various gutters leading into the chenal, direct discharges from the two Dantokpa and Gbogbanou markets and agro-food industries.

Table 2. *Variation of Total Dissolved Solids (TDS) in Cotonou Chenal water during two sampling campaigns.*

Settings \ Sites	HL_1	HL_2	HL_3	HLM	RB	TG_1	ML	MML	EAH	TG_2	EM	EKM_1	EKM_2	HH1	HHM	HH2
T D S (ppb) 1st campaign	>1	>1	>1	>1	>1	>1	>1	>1	>1	ND	>1	>1	ND	ND	ND	ND
TDS (ppb) 2nd campaign	>1	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.619	ND	ND	0.960	0.922	ND

3.5. Values of Depth and Transparency at Sampling Sites

Figures 4 and 5 shows the different depths and the evolution of transparency in the Cotonou Channel water during the month of November. The depth of the water is between 0 and 16.5m with an average value of 2.68 ± 4.11m. The greatest depth recorded during the present study is greater than that obtained by [15] and [8] which are respectively 5.64 m and 6 m. This discrepancy is linked to the fact that the Chenal has for some time been the subject of artisanal dredging by lacustrine for sampling the lagoon sand, whose trade is very flourishing following the ban on marine sand for various species building construction in coastal cities. The transparency of the water varies between 0 and 0.87m with an average value of 0.33±0.29 m. The smallest value recorded at the "Abokicodji pier", "Gbogbanou 2 dyers", "Mahoulé pier" and "Kpankpan 2 landing stage" sites can be explained by two phenomena that can be excluded. The first is the presence in the water column of a large load of suspended solids. The second, on the other hand, is the coloring of the water column by various rejects of dyes resulting from the activities that take place near the Chenal including the dyeing. The transparency values are smaller than those obtained by [12] (1,7±0.5 m) still in the same medium. This transparency instead of increasing, decreases during floods due to rainwater that carries the piles of filth piled up on the banks of the channel and the discharge of the waters of the Ouémé River loaded with organo-mineral elements leached on its course. The transparency of a water reflects the level of penetration of solar radiation essential to the photosynthetic activity of phytoplankton first link in the trophic chain. With this low transparency, photosynthetic activity may be drastically slowed down to the detriment of aerobic organisms if the water is not regularly renewed.

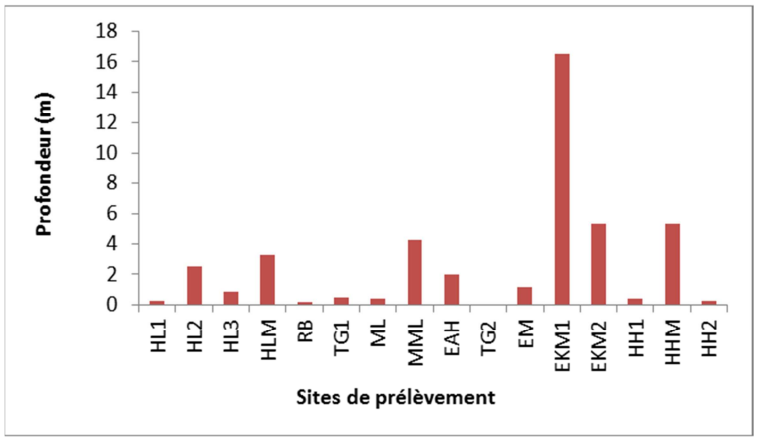

Figure 4. *Spatial variation of the water depth of the channel during the November campaign.*

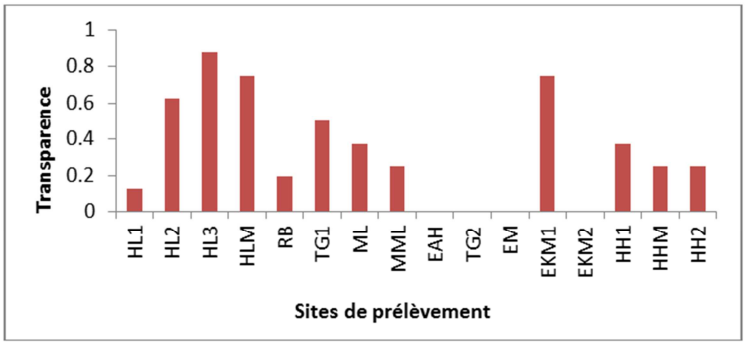

Figure 5. *Spatial variation of the transparency of the channel water during the November campaign.*

3.6. Spatiotemporal Variation of Suspended Solids (SS)

Suspended solids analysis provides information on the amount of undissolved material in a sample. Figure 6 shows the spatio-temporal variation of suspended Solids (SS) content in the water column of Cotonou Chenal. Levels range from 0.09 to 0.25 mg/L with an average of 1.16 mg/L in May while they range from 0.08 to 0.30 mg/L in November with an average value of of 0.16 mg/L. These average values are below the rejection standard in the Republic of Benin (500 mg/L). The suspended Solids (SS) values obtained are much lower than those found by [8] whose extreme values are 614 and 3615 mg/L and [12] for which 810 mg/L ≤ SS ≤ 3540 mg/L. This difference between the recorded values and those of the other authors can be interpreted as a period of calm between the two antagonistic hydrological phenomena justifying the variations of conductivity. Indeed these two antagonistic phenomena induce suspension of the sedimentary particles which are the main causes of the high values recorded. In a period of lull, the water column empties of SS hence our low values. The poor transparency of the water observed above in the field is also due to the two hydrological phenomena.

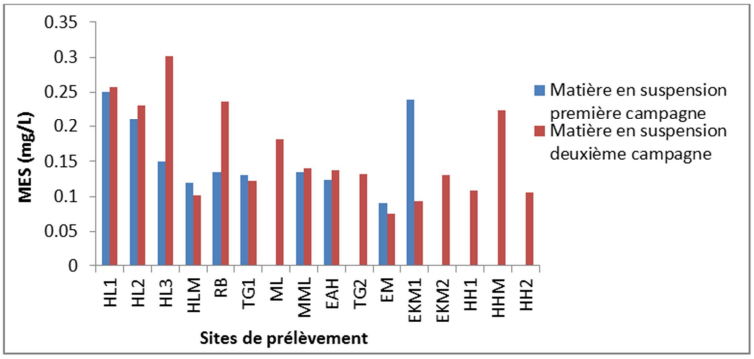

Figure 6. *Spatio-temporal variation of the SS content of the chenal water.*

3.7. Spatio-temporal Variation of Nutriments

3.7.1. Ammonium Ions

Figure 7 shows the variations of ammonium according to the chosen sites. Ammonium (NH_4^+) concentrations ranged from 1.03 mg/L to 13.80 mg/L at the Lagune maternity site and the SOBEBRA mouth with an average value of 6.836±3.432 mg/L. The WHO Guide Value (VG) for drinking water is 0.5 mg/L. The comparison of the average value of the ion NH_4^+ this WHO guideline value (0.5 mg/L) reveals, at the 5% threshold, that the Cotonou chenal is heavily contaminated with ammonium ions (P=0.000). On the other hand our values are lower than those found by [16] in a study carried out on the waters of Lake Nokoué. These high levels recorded in chenal waters are explained by the degradation of organic matter (animal or vegetable) and industrial discharges from SOBEBRA. In this form, nitrogen contributes to eutrophication of water bodies and intoxication of aquatic species. So the situation with regard to ammonium ion pollution in the Cotonou Chenal is alarming and deserves special attention. A comparison of the different concentrations of ammonium ion with the Beninese standard which recommends 0.5 mg/L for drinking water, makes it possible to say that the Cotonou chenal is heavily contaminated with ammonium ions during the second campaign whereas is not at the first. This state of affairs in the Chenal would be linked to the fact that in the second season, the rainwater of the North and those of the short season of the South have leached several agricultural and urban areas which end their races in the Atlantic Ocean through of the chenal they contaminate.

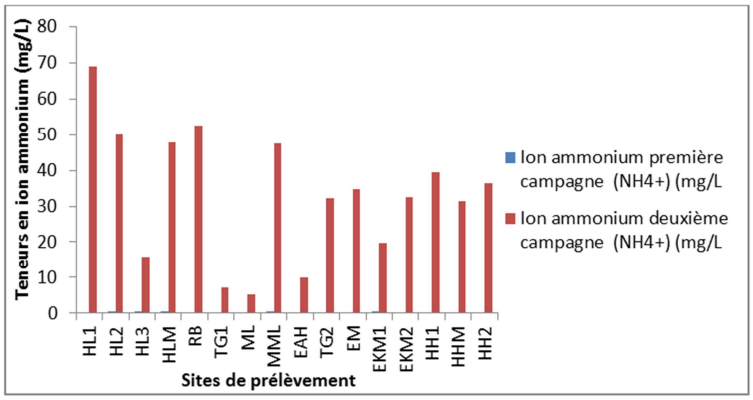

Figure 7. *Spatio-temporal variation of ammonium ion content in channel water.*

3.7.2. Spatio-temporal Variation of Phosphate Ions (PO_4^{3-})

Figure 8 shows the variation of the phosphate ion contents of the channel water. The values of the phosphate contents (PO_4^{3-}) observed vary from 0.12 mg/L to 3.1 mg/L. The overall average obtained is (0.75±0.722) and is low compared to the WHO standard (5 mg/L). All values recorded in this study are below this threshold. The comparison of the average log PO_4^{3-} value with the standard set by the WHO (log 5) reveals at the 5% threshold that the cotton channel or is not contaminated with phosphate ions (P=1). On the other hand, these values of orthophosphate contents are generally higher than those found by [12] and [17]. [18] before recorded at the same study area, orthophosphate average values (PO_4^{3-}) of the order of 4.1 mg/L, or 10 times higher. This suggests a possible self-purification by the ecosystem and a subsequent decrease in the sources of water pollution in the chenal. Household wastewater, fecal waste and runoff of fertilizer from watersheds are the main sources of phosphate input. To these we associate the wastewater discharges of SOBEBRA. This explains the high levels of 3.1 mg/L and 1.35 mg/L observed respectively at the mouth of the SOBEBRA and at the restaurant Berlin. Phosphate levels are generally lower than the standard set by the WHO (5mg/L), except in May at sites 1 and 2 of the Hotel du Lac which is the outlet of the wastewater of SOBEBRA and where high levels (5.25 mg/L and 5.39 mg/L respectively) were observed, a direct consequence of the company's releases.

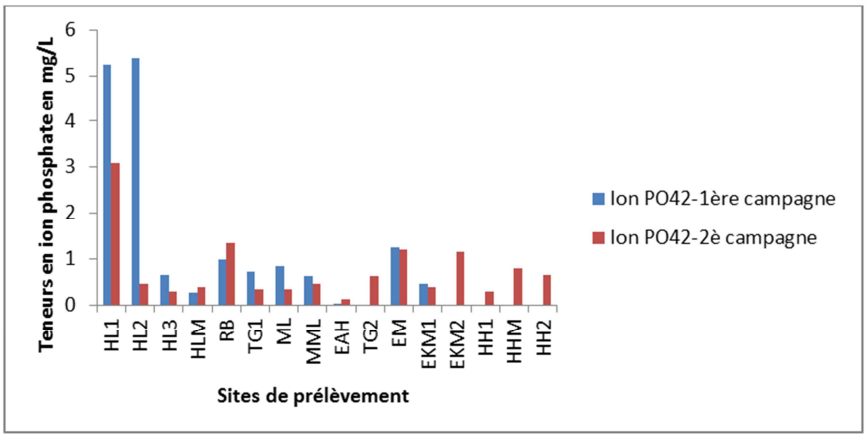

Figure 8. *Spatiotemporal variation of orthophosphate content in Chenal water.*

3.7.3. Spatio-temporal Variation of Nitrate and Nitrite Ions

Figures 9 and 10 respectively show the variations of the nitrate and nitrite content in the water at the different sampling sites on the Cotonou Chenal. Nitrate levels (NO_3^-) ranged from 3.52 mg/L to 20.68 mg/L respectively at the Hotel Hounzampie sites and Berlin restaurants with an average of 7.70±5.28 mg/L. The Guiding Value and the Maximum Permissible Concentration for drinking water prescribed by the Beninese standards are respectively 25 mg/L and 45 mg/L. WHO recommends 50 mg/L. The recorded values are well below the national and international recommendations while they are generally higher than those found in the waters of Lake Nokoué by [16] which vary from 3 to 15 mg/L. The comparison of the mean log NO_3^- value with the standard set by the WHO (log50) reveals at the 5% threshold that the Cotonou Chenal is not contaminated with NO_3^- (P = 1). In addition, the link between the nitrate ion content and the transparency of the medium is highly significant (P = 0.005) at the 5% threshold with a correlation coefficient of 0.670. As a result, as the nitrate content increases, so does the transparency. The nitrite ion NO_2^- content in the waters of the Cotonou Chenal ranges from 0.00 to 0.05 mg/L with an average of 0.01563±0.01209 mg/L. These values are much lower than those found by [8] in the waters of the Cotonou Chenal and Nokoué Lake where the minimum and maximum are respectively 0.018 mg/L and 3.6 mg/L with an average of 0.62±3.2 mg/L. The Guide Value and the Maximum Permissible Concentration for drinking water prescribed by Beninese standards are 0.05 mg/L and 0.1 mg/L, respectively. The 5% comparison of the average nitrite ion value with the WHO standard (0.1 mg/L) reveals that the water in the Cotonou Chenal is not contaminated with nitrite ions (P = 1). With the exception of the second dyeing site in Gbogbanou, all the other stations have a nitrite concentration lower than the guideline value and therefore well below the allowable limit corresponding to the lower threshold of the range of acute toxicity [19]. Therefore the pollution of the water of the Cotonou Chenal by nitrite is not alarming.

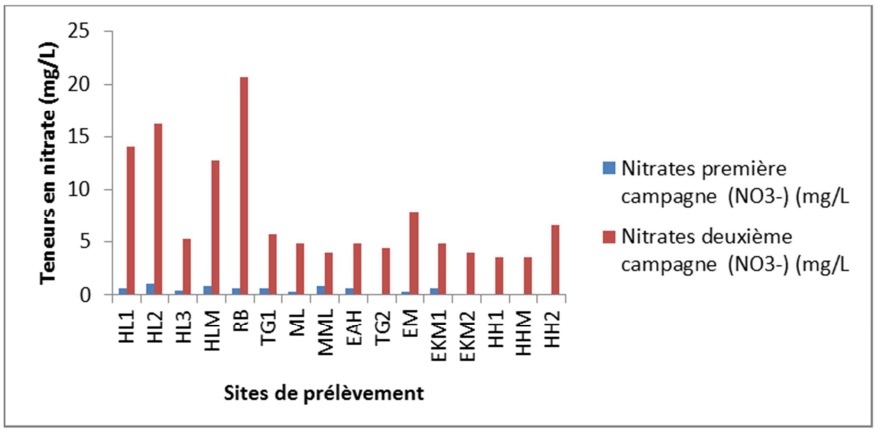

Figure 9. *Spatio-temporal variation of the nitrate content in the chenal water.*

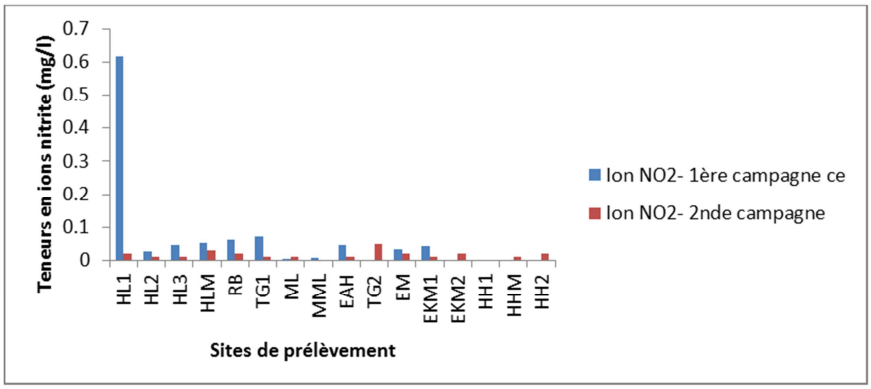

Figure 10. *Spatio-temporal variation of nitrite content in Chenal waters.*

3.8. Disolved Oxygen

The dissolved oxygen content provides information on the metabolic activities of the environment. This content is higher in May than in November and varies from point to point (Figure 11). In fact, the levels recorded in the month of November vary from 0 to 1.5 mg/L respectively at the levels of the Mahoulé pier and the middle of the channel at the height of the lagune maternity with an average of 0.85±0, 42 mg/L. On the other hand, the values obtained in May vary from 0 to 4.33 mg/L respectively at the Mahoulé pier and at Lake Hotel 2" with an average of 1.06±1.04 mg/L. These dissolved oxygen values observed in the channel are similar to those observed in [8]. According to [11], the maximum dissolved oxygen content for unpolluted surface water varies from 8 to 8.5 mg/L of water analyzed. The lowest rate (0mg/L) observed at the Mahoulé pier shows a high level of organic pollution at this site due to organic discharges from domestic sources. In the channel, the oxygen levels are very low and testify the existence of anaerobic conditions which are detrimental to aquatic life. The average values recorded for these two campaigns are not in this range of dissolved oxygen content. The dissolved oxygen content is partly in accordance with the standard, at the 5% threshold because the mean dissolved oxygen levels of the two campaigns are less than 8.5 mg/L (P=1.00) and do not have them they are less than 8 mg/L (P=0.00). In addition, these mean values are statistically equal for the two campaigns at the 5% threshold (P=0.442). Similarly, the links between the depth of the channel and the oxygen dissolved in the medium (P=0.034), and between the phosphate ions and the dissolved oxygen in the medium (P=0.027) are significant at the 5% threshold with respective correlation coefficients -0.532 and -0.551. This means that the dissolved oxygen content decreases as the depth and the phosphate ion content increase. Various are the cause of the depletion of surface water in oxygen, among which we can mention the high organic loads of water due to exogenous anthropogenic or natural inputs.

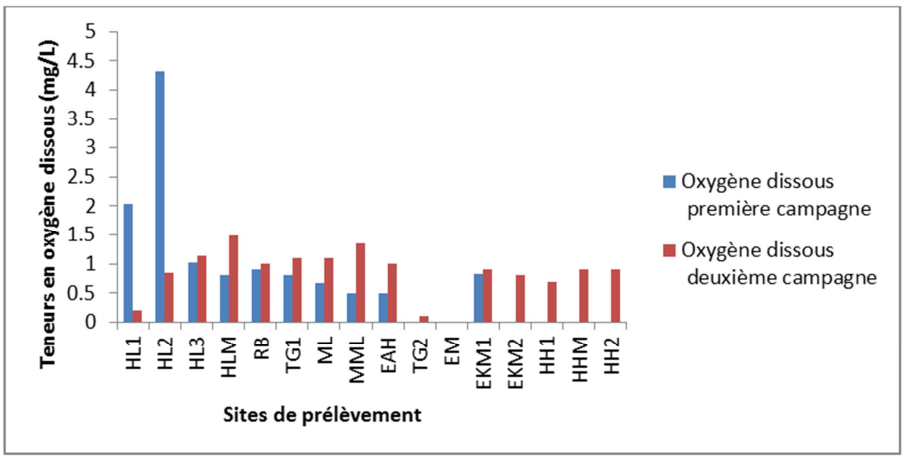

Figure 11. *Spatio-temporal variation of the dissolved oxygen content of the channel water.*

3.9. Spatiotemporal Variation of COD

Figure 12 shows the variation of the COD as a function of the sampling points. The chemical oxygen demand values of the recorded Cotonou Chenal water range from 45.44 mg O_2/L to 1863.04 mg O_2/L respectively at the Kpankpan pier sites (in the middle of the chenal) and the lake hotel. With an average of 669±615 mg O_2/L, almost all of these COD values are well above the discharge standards (100 mg O_2/L) allowed for surface water in the Republic of Benin, evidence of chemical pollution of the waters of the Cotonou Chenal. The comparison of the average log COD value with the norm set in the Republic of Benin (log100) reveals at the 5% threshold that the Cotonou Chenal has a high level of chemical oxygen demand (P = 0.00). According to [8] the COD of chenal water changes from 384.93 mg O_2/L to 787.70 mg O_2/L for an overall average of 585.27 mg O_2/L. Similarly, [20] and [12] found COD values between 963.33 mg O_2/L and 1672.22 mg O_2/L on Lake Nokoué and Cotonou Chenal. This state of affairs would be linked to the massive influx of organic pollutants into the area at the latitude of the Berlin restaurant and the ‘’Hotel du Lac”.

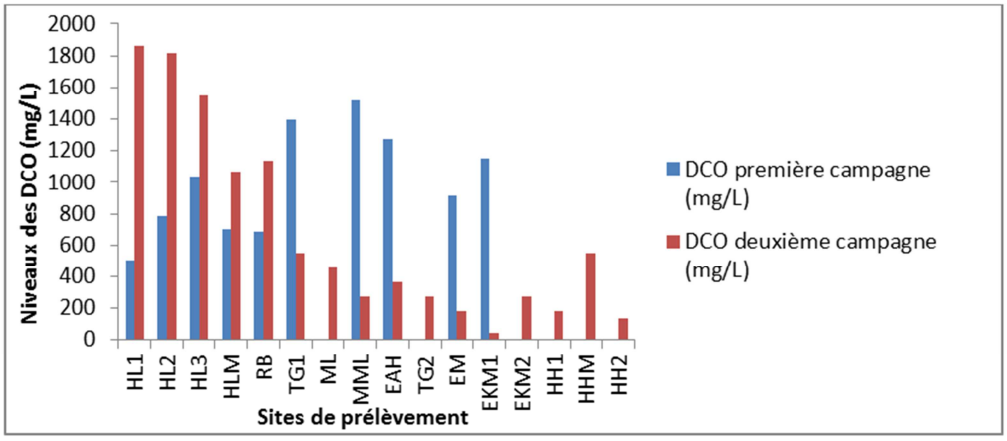

Figure 12. *Spatio-temporal variation of COD in chenal water.*

3.10. Spatio-temporal Variation in Lead Content

Figure 13 presents the spatial variation of the lead content of the Cotonou Channel water column during the second season. The analysis in the figure shows that lead levels in water range from 0.001mg/L to 0.86 mg/L. The average lead levels obtained in the channel during this season is significantly higher than the limit value (0.22 mg/L) prescribed by WHO. This justifies the affirmation of the contamination of the channel water pollution by lead. Our recorded values are lower than that obtained by [8] (1.45mg/L). This suggests a decrease in the sources of pollution of channel water by lead. The high content observed in Abokicodji could be explained by two phenomena to know: the presence of solid waste on the banks at this level and the traffic of petroleum products which would have led to spills during the landings and shipments of gasoline containers.

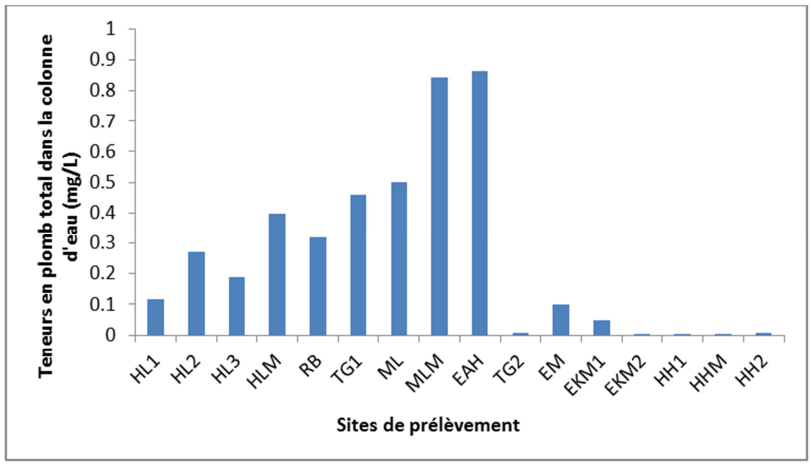

Figure 13. *Spatial variation of total lead content in chenal water.*

4. Conclusion

This study made it possible to inventory the sources of pollutant input into the Cotonou chenal and to monitor the level of chemical pollution of the water. It showed that several direct and indirect sources of pollution of the Cotonou Chenal still remain despite all the efforts at various levels for the development of the banks of the Chenal. These are public defecation sites, garbage dump sites, collectors and evacuation chenals of the city of Cotonou that open into Nokoué Lake and Cotonou Chenal, maintenance and repair garages. motorcycles and automobiles, road, maritime and fluvio-lagoon transport on the chenal and Nokoué lake, the Gbogbanou dyers who discharge wastewater containing dyes likely to contain sodium hydrosulphite, lead chromate and various other pollutants and liquid and/or solid discharges from agro-food industries and health facilities are all activities and behavior identified as a source of pollutant inputs into the chenal. From the analysis of parameters followed by the chenal waters, it appears that the chenal water is polluted by the contaminants of the discharges coming from the different sources of pollution. Nevertheless, a decrease in lead water pollution of the chenal is observed. Awareness is therefore necessary to safeguard the aquatic life of this ecosystem.

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