Impact of reject of dairy wastewater into the aquatic environment: case of the Bayo dairy company (Brazzaville-Congo)

ABSTRACT

The development of industrial activities is the source of the production of large quantities of wastewater. The last-mentioned are rejected in the environment often without any prior treatment and have serious short-term and sometimes long-term environmental consequences. The objective of this work is to assess the environmental impacts and to propose a process for treating wastewater of reject from Bayo dairy in Brazzaville-Congo. The samples were taken at four (04) stations before, during and after production of dairy products. Multivariate statistical analysis of the physico-chemical data was carried out using Statistica 7.1 software. The results obtained show that the wastewater from the Bayo dairy has a basic pH which fluctuates between 8.32 and 9.17 with standard temperatures of reject. The salinity of the wastewater increases greatly during production, which shows a rising mineralization. The contents of MES (49.78-181.80 mg/L), MO (40.23-72.64 mg O_2/L), COD (51.08-98.91 mg O_2/L), BOD_5 (34.80-59.50 mg O_2/L) and the turbidity (26-179) NTU are moderately high and reflect an increase pollutant load before, during and after production of dairy products in stations S2 and S3. The COD/BOD_5 ratio reveals that the Bayo dairy wastewater is moderately biodegradable before, during and after production with a biodegradability coefficient which varies between 1.40 and 1.78. The ACP approves a possible industrial pollution from wastewater from the Bayo dairy and reports on the impact of the rejects in environment. Thus, this study is a contribution to raising awareness among the Congolese population and decision-makers on the quality of wastewater rejected by local industries.

Keywords: Wastewater, industrial discharge, environmental impacts, Bayo dairy, Brazzaville

1. INTRODUCTION

The development of industrial activities in the 21^{st} century is the source of a lot of wastewater production. The last-mentioned are thrown away in the environment and have consequences for aquatic biodiversity. However, protecting the environment is a major at stake and is preservation is the one of three pillars of sustainable development [1; 2].

As most food industries in the world, dairy processing units generate large volumes of industrial wastewater loaded with organic matters. Many by-products from the dairy industry are rejected in the environment and are a pollution factor due to their large quantity. These pollutants are quite considerable, but the largest part consists of liquid effluents which can constitute a pollution risk when they are poured out without prior treatment in the environment receivers [3; 4; 5].

Indeed, the degradation due to the rejection of waste water for cleaning and disinfection causes significant disorders such as the increase in microbial biomass, a decrease in the dissolved oxygen content, a proliferation of fungi and algae… etc., that means a possible eutrophication of the environment [6].

Concerning this study, the Bayo dairy company in Brazzaville-Congo has been manufacturing dairy products (yogurt and curds) since 2001 and rejects a considerable volume of waste water into Mpélélé river without prior treatment. These wastewaters rejected in the environment, the flow of which is not controlled, cause serious problems in the immediate receiving environment and the local population. However in 1991, the Congo made provisions relating to the environment and adopted the law n ° 003/91 of April 23, 1991 relating to environmental protection, of which article 28 stipulates that “spills, flows, rejects, direct deposits of all solid, gaseous and liquid substances liable to degrade the quality of water under Congolese jurisdiction are prohibited”. Despite the adoption of this law, environmental regulations are not rigorously applied in the Republic of Congo [7]. As a result, environmental legislation is becoming more and more restrictive for the protection of the environment [8]. Thus, the objective of this study is to assess the impact of wastewater from the Bayo dairy company about the Mpélélé river (receiving environment) before, during and after production of dairy products, in order to estimate the level of pollution. But also to predict the nature of the treatment to apply to this wastewater produced before its reject into the river.

2. MATERIALS AND METHODS

2.1. Study zone

The city of Brazzaville, capital of the Republic of Congo is administratively structured in nine districts. It is limited to the north by Djiri river, to the south by Tsagamani river with a latitude of 4°15', to the east (longitude 15°14') and to the west respectively by the Congo river and Djouari river (Ngoma Tsé-tsé district) [9]. The study was carried out in the southern zone of Brazzaville, in particular in the 8th Madibou district where the Bayo dairy factory is located in the Massissia quarter (fig. 1).

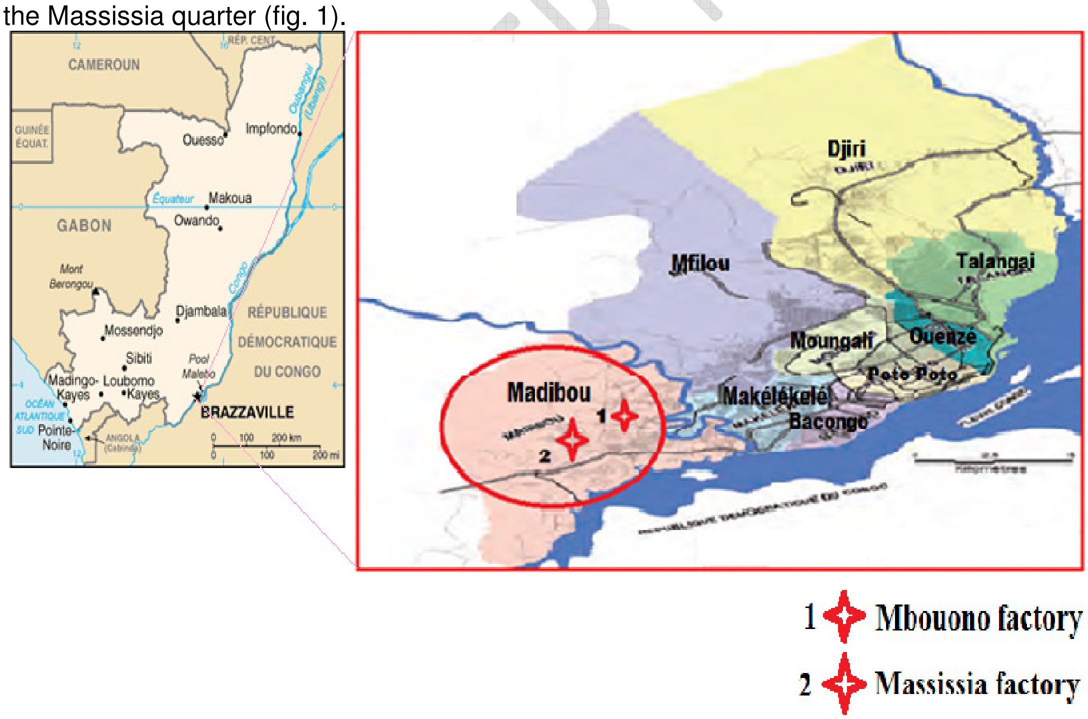


Fig.1 : Map of the study area and location of Bayo company sites

2.2. Choice and coding of sampling stations

Four (04) water sampling stations (S) in the second Massissia site were chosen (Fig. 2) :

- S1: raw river water upstream from the outlet of the plant waters;
- S2: river water downstream from the outlet of the plant waters;
- S3: drop point of wastewater factory in Mpélélé river;
- S4: Collection point for all raw wastewater in the factory before it is discharged into the Mpélélé river.

Stations S1 and S2 are chosen to assess the impact of this wastewater of reject before, during and after production of dairy products in Mpélélé River and are equidistant from 70 meters from station S3.

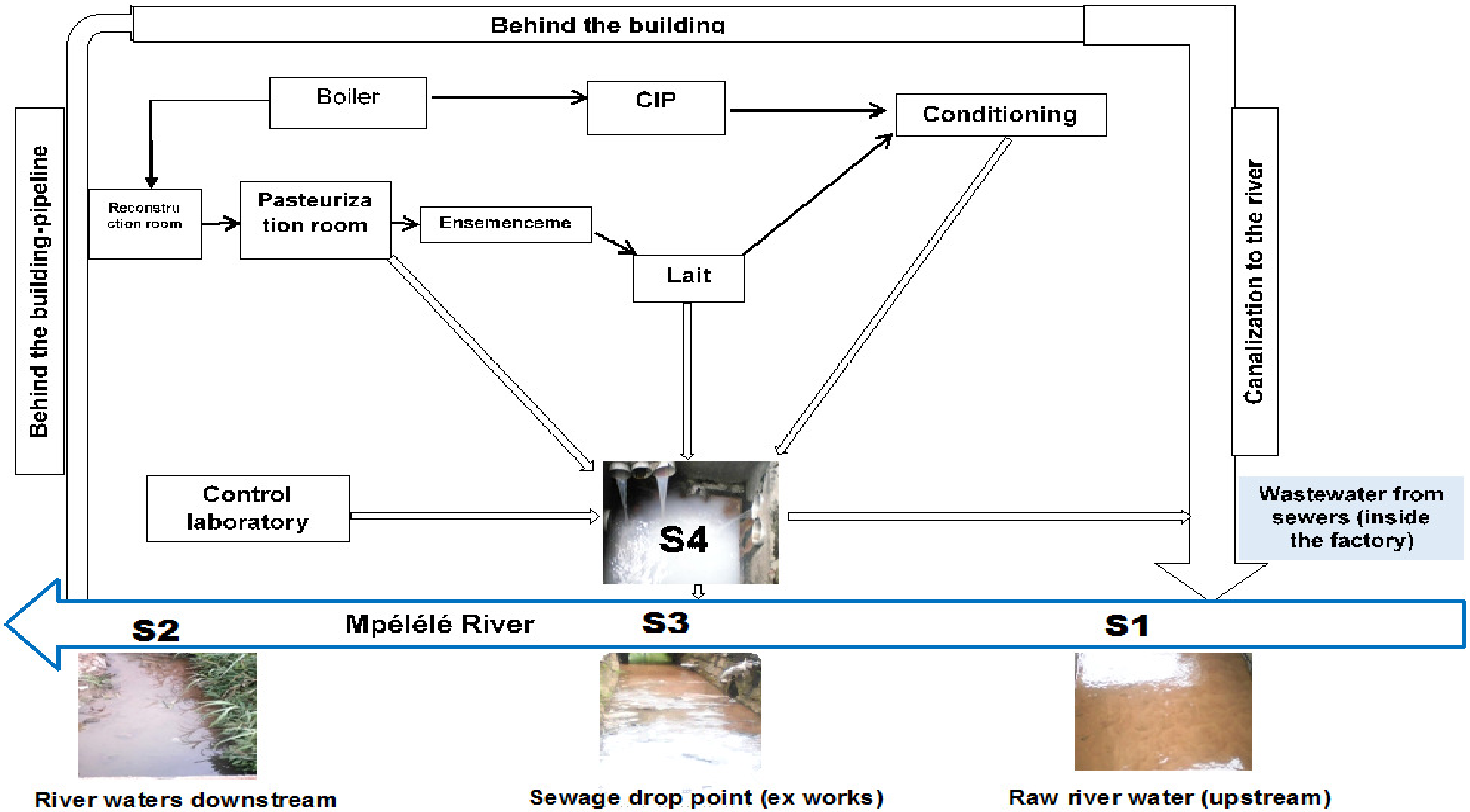


Fig. 2. Diagram of a part of the Bayo dairy installations and location of sampling stations

2.3. Waters sampling

In all twelve (12) samples were taken in duplicate between September and December 2018 (rainy period); or four (04) samples per sampling phase (before, during and after production of dairy products). These samples were taken from a pre-conditioned small glass bottles by means of a stick. A sampling cane was manufactured for the sampling of river water upstream and downstream. The samples were transported and stored in the laboratory of Bayo dairy company and in the laboratory of the National Research Institute for Exact and Natural Sciences (IRSEN), according to the conditions mentioned by Rodier et al. [10].

2.4. Physico-chemical analysis methods

The physico-chemical analyzes were carried out in the laboratory of Bayo dairy company and in the laboratory of the National Research Institute for Exact and Natural Sciences (IRSEN) in Brazzaville (Congo). Several methods have been used to determine the different physico-chemical parameters:

- the potentiometric method for determining the temperature (T °), the hydrogen potential (pH), the electrical conductivity (CE) and the total dissolved salts (TDS) made using a multi-parameter HI9813-6 HANNA ;
- suspended solids (MES) by membrane filtration (0.45 µm) and the turbidity made using a turbidimeter (MERCK turbicant model: 1100 IR);
- the Full Alkalimetric Title (TAC) and the Total Hydrotimetric Title (THT) were determined by volumetry with 0.035 N sulfuric acid and 0.01 N EDTA respectively.
- chloride ions (Cl^-), fluorides (F^-), nitrates (NO_3^-), ortho phosphates (PO_4^{3-}), sulfates (SO_4^{2-}) and chemical demand in oxygen (COD) were determined by colorimetry using a lovibond spectrophotometer. This method consists in adding for each parameter a specific reagent in tanks or tubes, then dosing the mixture with a spectrophotometer at well-defined wavelengths. At these wavelengths, the absorbance of the solution will be proportional to the concentration of the parameter to be measured if the conditions of Beer-Lambert law are respected [11];
- the biochemical oxygen demand after 5 days (BOD5) was evaluated by dilution and seeding according to standard NF EN 1899-1;
- The content of organic matter (MO) was determined by the empirical relationship below mentioned by Rodier et al. [10]:

$$\text{MO (mg } O_2\text{/L)} = \frac{(2 \times DBO5 + DCO)}{3}$$

2.5. Nature of the treatment of waste water from Bayo dairy

To predict the nature of the treatment to apply to the wastewater from Bayo dairy company, the COD/BOD_5 ratio was calculated. When this ratio is less than 3, the effluent is considered as easily biodegradable and a biological treatment process is envisaged. Otherwise, the effluent is moderately biodegradable or hardly biodegradable and a physico-chemical treatment process is necessary [10].

2.6. Treatment method and data analysis

Two software programs were used: Microsoft Excel 2016 and Statistica 7.1 software. The approach of Multivariate Statistical Analysis consists in performing a Principal Component Analysis (PCA) and an ascending hierarchical classification (CAH) using Statistica 7.1 software on reduced centered variables. This analysis makes it possible to synthesize a large number of data, in order to extract the main factors which are at the origin of the simultaneous evolution of the variables and their proper relationships [12; 13]. Multivariate statistical analysis includes four (04) descriptors and 17 variables which are: T °, pH, CE, TDS, MES, Turb., TAC, THT, Cl^-, F^-, NO_3^-, SO_4^{2-}, DBO_5, PO_4^{3-}, DCO, MO et DCO/DBO_5.

3. RESULTS AND DISCUSSION

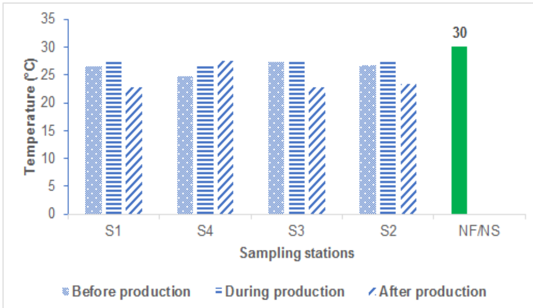
3.1. Wastewater impacts related to physical parameters

Temperature : Average values fluctuate between 22.6 and 27 ° C before, during and after production and comply with French and Senegalese standards [14; 15] (fig. 3). These values do not constitute a risk of thermal pollution for the receiving environment [26].

Hydrogen potential : Average pH values vary between 6.2 and 9.17. We observe that before production, the wastewater from stations S1, S2 and S3 has slightly acidic pH values (6.2 - 6.6); which is opposite for the waters of station S4. While during and after production in stations S2, S3 and S4, the pH values are basic and fluctuate between 8.32 and 9.17. These average values nevertheless remain within the limits of French standards [14], except for station S4 (9,17) during and after production (fig. 4). The increase in pH values during and after production of dairy products could be due to the discharge of dairy wastewater which increases alkalinity, since the average pH values upstream (S1) remain acidic. Thus, these values do not present a major risk for the receiving environment.

Electrical conductivity and total dissolved salts : the average conductivity values are between 320.80 and 750.80 µs / cm, before, during and after production of dairy products and are within the range of French and / or Senegalese standards (2000 µs / cm) [14; 15]. Total dissolved salts like electrical conductivity characterize inorganic salts dissolved in water and vary in the same direction. These contents vary between 126 and 180 mg / L before, during and after production. The highest values are observed at stations S3 and S4. We note that the values of electrical conductivity and total dissolved salts downstream (S2) are generally higher than those upstream (S1) before, during and after production of dairy products (fig. 5; fig. 6). This shows that the discharge of wastewater significantly increases the salinity of the river water (receiving environment) and is the main cause of mineral pollution. This salinity would come from dairy wastewater which is rich in mineral elements (calcium, magnesium, etc.) during production and from the chemicals (sodium hydroxide, detergents and disinfectants) used for cleaning before and after production. This increase in mineralization has already been observed by Hamdani et al. [16] after cleaning the milk production facilities.

Turbidity and suspended matter : Figure 7 shows the variation in turbidity depending on the four sampling stations. It appears that the minimum value is 26 NTU at station S1 (before and after production) and the maximum value is 179 NTU at station S4 (during production). The highest values are those of station S4, followed by station S3 and at the end of station S2 which are greater than the guide value (50 NTU) of wastewater reject according to French standard. Regarding the average MES content, it fluctuates between 49.78 and 181.8 mg / L before, during and after production and does not comply with the standards taken as reference (French and/or Senegalese) in all stations (fig. 8) [14; 15]. This suggests that the contribution of suspended organic and mineral particles to the river is linked to the wastewater discharged during the production of dairy foods. But also, the washing of tanks and valves of installations before and after production.
It should be noted that the increase in turbidity and the MES content give a cloudy appearance, a bad odor and causes the death of fish by asphyxiation and prevents the penetration of light into the water [10; 17].



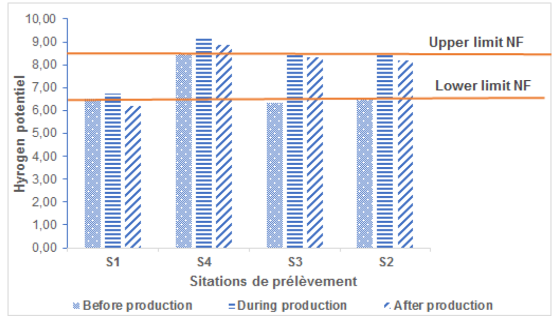
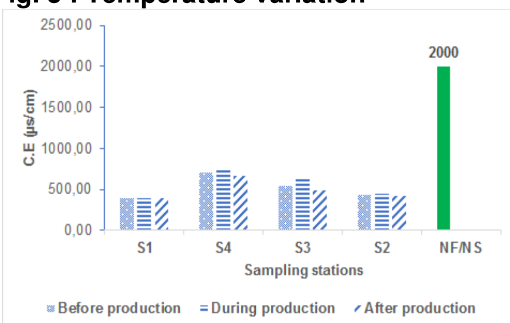


Fig. 3 : Temperature variation

Fig. 4 : PH variation



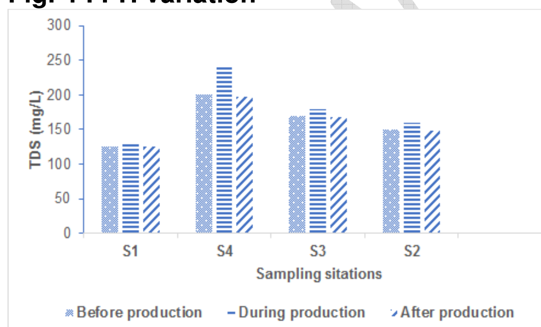
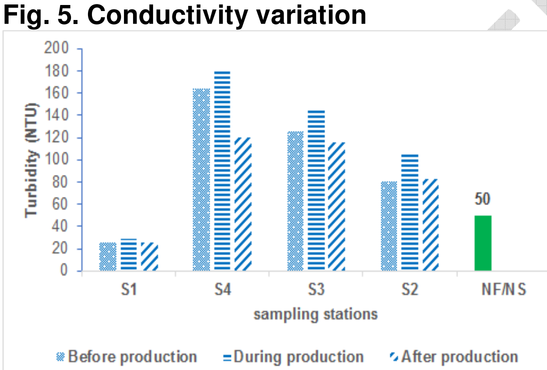


Fig. 5. Conductivity variation

Fig. 6. Variation in TDS contents



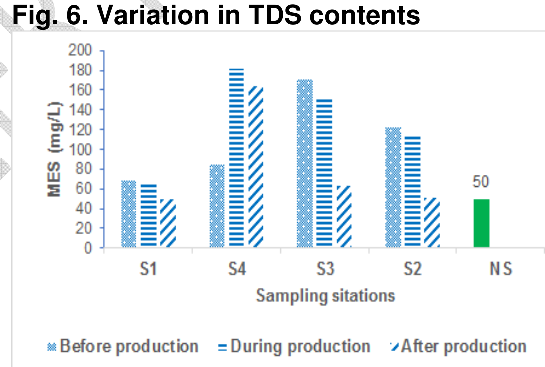


Fig. 7 : Variation of turbidity

Fig. 8. Variation of suspended matter

Legend : NF: French standards; NS: Senegalese standards; S1: raw river water (upstream); S2: raw river water (downstream); S3: wastewater drop point in the river; S4: wastewater from sewers.

3.2. Wastewater impacts related to chemical parameters

3.2.1. Mineral pollution

The results of analyzes of the waters studied before, during and after production of dairy products in four sampling stations are shown in Table 1.

Full alkalimetry (TAC) and total hydrotimetric titer (THT) : The average TAC values oscillate between 155.12 and 675.36 mg/L $CaCO_3$ before, during and after production and exceed the French guide value (100 mg/L of $CaCO_3$) in all stations. Those of THT are in the range of 110 to 270 mg / LCaCO3 and respect the French standard (300 mg/L $CaCO_3$)

during the three sampling phases [14]. Analysis of the values obtained shows a significant increase of TAC and THT content during production. This shows that the use of raw materials (milk powder) in the manufacturing chain could be at the origin of this increase in alkalinity [18].

Nitrates and orthophosphates : The nitrate concentrations before, during and after production fluctuate between 55.80 and 73.75 mg/L. Those with orthophosphates are in the range from 0.39 to 1.96 mg/L. We notice in general, the lowers nitrate contents before and after production of dairy products compared to the production phase. This slight increase in nitrates content and orthophosphates levels could be linked to the use of nitric acid and detergents for cleaning of installations and washing of compartment. According to bibliographic data, the presence of these elements in high contents causes the proliferation of algae and aquatic plants. This proliferation leads to a drop in dissolved oxygen in the aquatic environment [19; 20]. According to WHO, the main impact on the local population results from contamination by pathogens (bacteria, viruses, protozoa, etc.) of the river, which could have consequences for the health of consumers downstream. This, through drinking water, contact with water for recreational use or consumption of contaminated food (crustaceans or contaminated crops when the river is used for downstream irrigation) [21].

Sulfates, fluorides and chlorides : The contents of these different salts vary according to the three sampling phases considered in this study. For sulphate ions, the concentration fluctuates between 247.50 and 376.00 mg/L. These contents are in the range from 1.95 to 3.70 and 355.00 to 887.00 mg/L respectively for the fluoride and chloride ions. Analysis of the results in the Table 2 shows that these levels generally increase from upstream (S1) to downstream (S2). This proves that the reject of raw wastewater from station S4 before, during and after production of dairy products significantly increases the salinity of the waters of this river. However, the majority of the riverside population in this district uses the water from this river for market gardening. These high content in sulphates and in chlorides could compromise the growth of vegetable crops [21].

Table 1. Parameters of mineral pollution before, during and after production of dairy products

Parameters	**$S1_{AV}$**	**$S1_{PD}$**	**$S1_{AP}$**	**MG**	**$S2_{AV}$**	**$S2_{PD}$**	**$S2_{AP}$**	**MG**	**$S3_{AV}$**	**$S3_{PD}$**	**$S3_{AP}$**	**MG**	**$S4_{AV}$**	**$S4_{PD}$**	**$S4_{AP}$**	**MG**
THT	110.00	250.00	150.00	170,00	150.00	260.00	190.00	200.00	140.00	250.00	110.00	166.67	160.00	270.00	180.00	203.33
TAC	315.25	600.48	160.16	358.63	195.16	580.75	170.13	315.35	280.22	675.36	155.12	370.23	263.71	610.48	215.17	363.12
NO_3^-	56.37	55.80	57.65	56.61	64.90	62.45	64.90	64.08	72.20	70.55	73.75	72.17	70.80	71.58	72.63	71.67
PO_4^{3-}	0.42	0.40	0.39	0.40	0.68	0.59	0.68	0.65	1.11	0.85	0.95	0.97	1.90	0.85	1.96	1.57
SO_4^{2-}	248.00	247.50	248.00	247.83	274.00	273.59	272.45	273.35	328.00	325.52	328.00	327.17	376.00	375.50	376.00	375.83
F^-	2.05	2.50	2.60	2.38	2.00	1.95	2.50	2.15	2.50	2.05	2.75	2.43	3.70	3.60	3.50	3.60
Cl^-	355.00	358.00	361.20	358.07	635.40	629.00	639.00	634.47	782.00	753.00	710.00	748.33	730.00	887.00	781.00	799.33

Take notice : All chemical parameters are expressed in mg/L, except TAC and THT which are expressed in mg / L CaCO3
S1: raw river water (upstream); S2: raw river water (downstream); S3: wastewater drop point in the river;
S4: raw sewage from sewers; MG: general average for the three sampling phases; AV: before; PD: While; AP: after

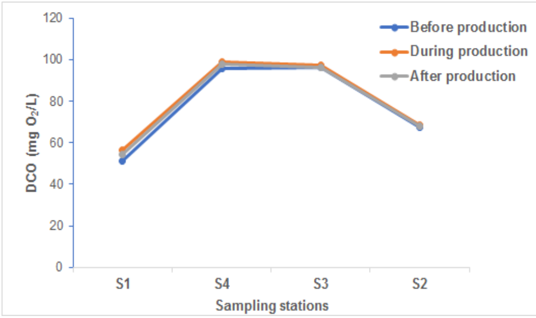
3.2.2. Organic pollution

Chemical oxygen demand : The COD content is in the range of 51.08 to 98.91 mg O_2/L and complies with the Senegalese standard (100 mg O_2/L) for rejecting wastewater into the receiving environment [15]. However, higher values are observed in stations S3 and S4 compared to stations S1 and S2 during the three sampling phases (fig. 9). This increase in COD levels confirms the increase with the pollutant load in stations S3 and S4 which would be linked to the production of dairy products and the cleaning of the facilities before and after production. We also note that these COD values found in this study are much lower than the values found by Hamdani et al. [16] and Ahmed EL et al. [22] in Morocco.

Biochemical oxygen demand : The average values obtained before, during and after production of dairy products are in the range from 34.80 to 59.50 mg O_2/L and do not respect the Senegalese limit value (40 mg O_2/L) of reject of effluents, except those from station S1. As with COD, we observe an increase in the BOD_5 polluting load in stations S3 and S4, followed by station S2 before, during and after production of dairy products (fig. 10). The reject of these wastewater into the river significantly increases this polluting load which varies very little upstream (S1). The BOD5 values obtained remain very low compared to those found by Hamdani et al. [16; 23], Ahmed EL et al. [22] in Morocco. These data show that the organic pollutant load discharged by the company Bayo into the Mpélélé river is low compared to other dairy industries in Africa reported in the literature. However, this organic pollution could already have negative effects due to their accumulation in the receiving environment, given its duration which exceeds a decade.

Organic matter : Figure 11 shows the variation in organic matter content according to sampling stations during the three phases of wastewater discharge. Analysis of the curves in this figure shows a minimum value of 40.23 mg/L during production and a maximum value of 72.64 mg/L recorded during the same phase. In addition, the highest contents are obtained in station S4 followed by station S3. These data confirm the results obtained for COD and BOD_5 which are closely linked.

Treatment to be applied to waste water : The calculation of the biodegradability coefficients of the effluents from the Bayo dairy shows values which vary between 1.40 and 1.78 before, during and after production (fig. 12). The range of values obtained during the three sampling phases indicates that the effluent produced by the Bayo dairy is easily biodegradable and a biological treatment can be applied before their discharge into the river [10; 24]. The biodegradability coefficients obtained are close to that of 1.81 found by Hazourli et al. [25]. These ratios are comparable to those of the majority of the dairy industries where the ratios are between 1.5 and 2 [26; 6].



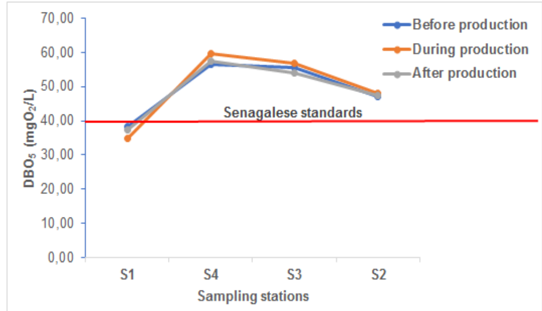
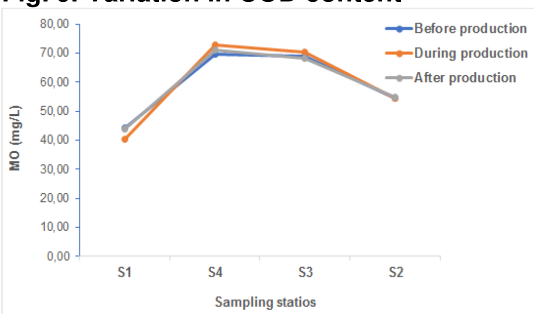


Fig. 9. Variation in COD content

Fig. 10. BOD_5 content variation



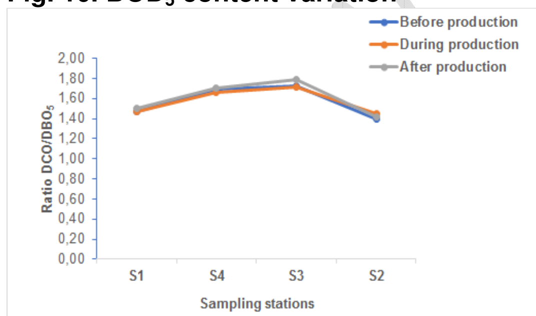


Fig. 11. Variation in MO contents

Fig. 12. Variation in biodegradability coefficients

Legend : S1: raw river water (upstream); S2: raw river water (downstream); S3: wastewater drop point in the river; S4: wastewater from sewers

4. Multivariate statistical analyzes of physico-chemical parameters

The average values of the seventeen (17) physico-chemical parameters during the three sampling phases for each station are used to achieve the following results :

- **Principal Component Analysis (PCA)**

he determination of the total number of significant factors was carried out according to the criterion of Kaiser [27]. The projection of the variables in the factorial plane (F1 x F2) shows a total variance of 90.59% or 76.22% for the factor F1 against 14.37% for the factor F2 (Table 2). This is quite sufficient and can be used to provide the information sought.

Table 2. Eigenvalues and variance of factors

Factors	Own values		% total variance	
	individual	accrued	individual	accrued
F1	12.96	76.22	12.96	76.22
F2	2.44	14.37	15.40	90.59

The different correlations between these variables are translated in the space of the two main axes of the factorial plane (F1 x F2) (fig. 13). The factor F1 is negatively controlled by: pH, T°, TDS, TAC, SO_4^{2-}, MO, NO_3^-, F^-, Turb., Cl^-, MES, PO_4^{3-} , DCO, DBO_5, DCO/DBO_5 This factor characterizes a pole of global mineralization and/or organic pollution of dairy

wastewater.
On the other hand, the factor F2 is controlled in negative by the electrical conductivity (CE) and only highlights the mineral pollution of the wastewater from the dairy.

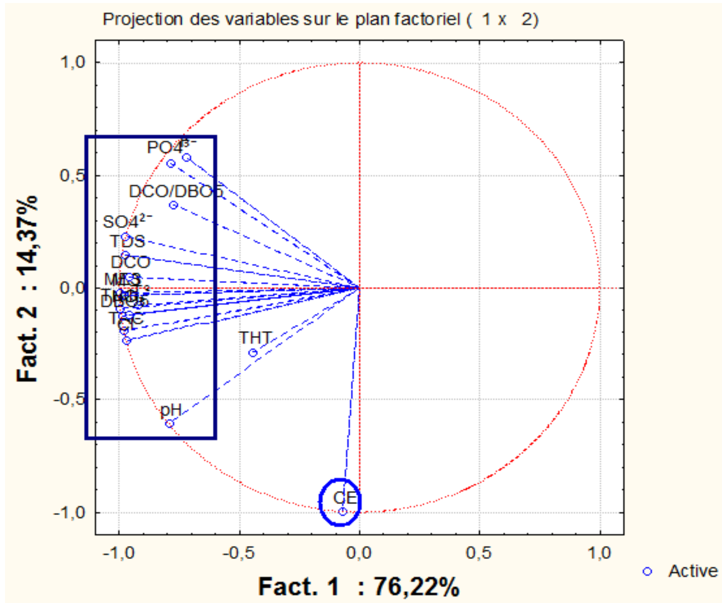


Fig. 13. Correlation of physico-chemical parameters in the factorial plane (F1 x F2)

- **Ascending hierarchical classification (CAH)**

To properly understand the physicochemical quality of the waste water from Bayo dairy, a CAH is realized to know the grouping of parameters. The observation in Figure 14 shows the different groupings by class of physicochemical parameters in the classification dendrogram. The latter shows four (04) classes:

- Class C1 combines the TAC, SO_4^{2-} , TDS and THT. These parameters show the strong mineralization and the alkaline character of the waters;
- Class C2 groups the Cl- ions and the CE which characterizes mineral pollution with high contents of chloride ions (887.00 mg / L);
- Class C3 includes Turb, MES, MO, COD, BOD_5 and NO_3^-. It confirms the correlation between the different parameters and indicates the organic pollution caused by the Bayo dairy;
- The C4 class consists of: T °, pH, PO_4^{3-}, $F^-$and the COD/BOD_5 ratio. It represents the organic inputs influenced by temperature and minor ions which contribute to the development of microorganisms and also shows the biodegradability of the effluent [24].

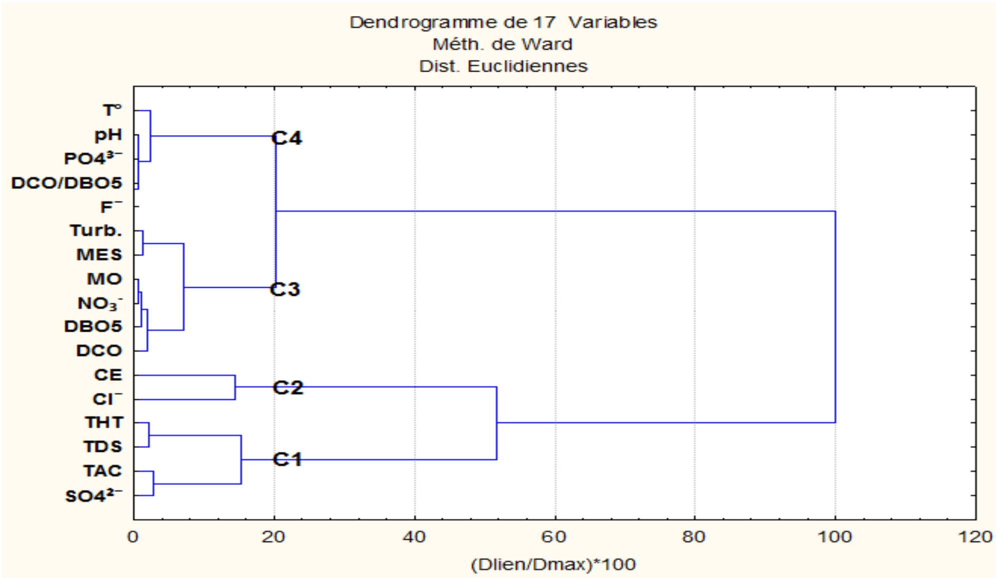


Fig. 14. Dendrogram for the classification of physico-chemical parameters

5. Conclusion

This study permits to approve the quality of wastewater from a dairy industry in the city of Brazzaville (Laiterie Bayo). The results obtained show mineral and organic pollution of the waters analyzed. The activity generated by Bayo dairy has an impact on the aquatic and terrestrial receiving environments. Thus, Bayo dairy company contributes to the pollution of surface waters by the high inputs of insoluble particles, major ions, nutrients, hydroxides and organic matters. The results of Principal Component Analysis (PCA) and the Ascending Hierarchical Classification (CAH) highlight industrial pollution from wastewater from Bayo dairy and account for the impact of rejects into Mpélélé river. Biological treatment of the water produced before it is discharged into this river is possible to limit this pollution and contribute to the sustainable development of our country. The evaluation of the bacteriological and metallic pollution of these waters would be necessary to complete this work.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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