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Physicochemical characterization of leachates from two landfills in Brazzaville, Republic of Congo

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ABSTRACT: One of the biggest problems with landfilling waste is the landfill leachate that is produced when water passes through the waste. The composition of the leachate obviously depends on the nature of the buried waste, the presence of fermentable organic matter and the climatic conditions combined with the mode of operation of the site. The objective of this study is to make a physicochemical characterization of leachate from two public landfills in Brazzaville. To carry out this characterization, we made a series of leachate sampling from December 2021 to February 2022. The potentiometric and colorimetric methods were used for the determination or different parameters. During this period, the physicochemical analyzes carried out on these samples revealed high levels of biodegradable organic matter, with nitrates, chlorides and phosphates levels below the WHO standard. For the metals, we note the total absence of Pb in the two landfills. The Fe, Zn, and Cu contents do not exceed the WHO standard, while the Cd content for tsiémé landfill exceeds the WHO standard. The average value of the ratio (BOD5/COD) is 0.34 for the two sites, which shows that it is the intermediate leachate.

KEYWORDS: leachate, characterization, parameters, biodegradability, landfill, Brazzaville.

1 INTRODUCTION

Uncontrolled open landfill remains the most widely used means of waste disposal in developing countries. The waste recovery channels have not yet been mastered and incineration is not suitable given its fairly high cost and the high water content of this waste [1]. This way of managing is a real and permanent danger for the environment and human health. Thus, the determination of the physicochemical parameters can make it possible to assess its impact on the surrounding environments. Indeed, the leachate from the waste drains the heavy metals contained in the latter, and constitutes a potential source of pollution of the soil, groundwater and surface water. Leachate is a major vector of pollutant load and falls into the same category as municipal and industrial wastewater [2].

The landfills of the Tsiémé and Moukondo districts which were the subject of this study are open landfills and generate air, water and soil pollution. Indeed, these contain a large quantity of waste from various sources. The mixture between waste and water causes a fermentation of methane, which is a greenhouse gas.

In environmental management, the phenomenon of leaching is the process during which water infiltrates a storage site and is loaded with hazardous materials such as heavy metals and the water ends up in the water table by runoff. The liquid produced by this operation is leachate. The phenomenon is very present in all old household and industrial landfills where the waste has not been stored in an impermeable environment or with a runoff treatment process.

The chemical compositions of leachates is not only very diverse but also variable in time and space. The main parameters influencing the composition of the leachate are the composition of the buried waste, the degree of decomposition, the

humidity rate, the temperature, the rate of water infiltration into the waste, the climatic conditions and the age of the waste discharge. Faquhar thinks that leachate can come either from waste water, or from meteoric precipitation and also from groundwater [3].

2 MATERIAL AND METHODS

2.1 PRESENTATION OF THE STUDY AREA

Brazzaville is located on the right bank of the Congo River, it extends over approximately 30 km with an average altitude of 335m, a south latitude of 4°17 and an east longitude of 15°16 [4].

The city is limited:

- To the North by the Mbé tray which extends from East to West and overlooks the city and the Stanley Pool,
- To the east by the Congo River and to the south-west by the cataracts tray which connects to that of Mbé,
- To the west by a lot of hills [5].

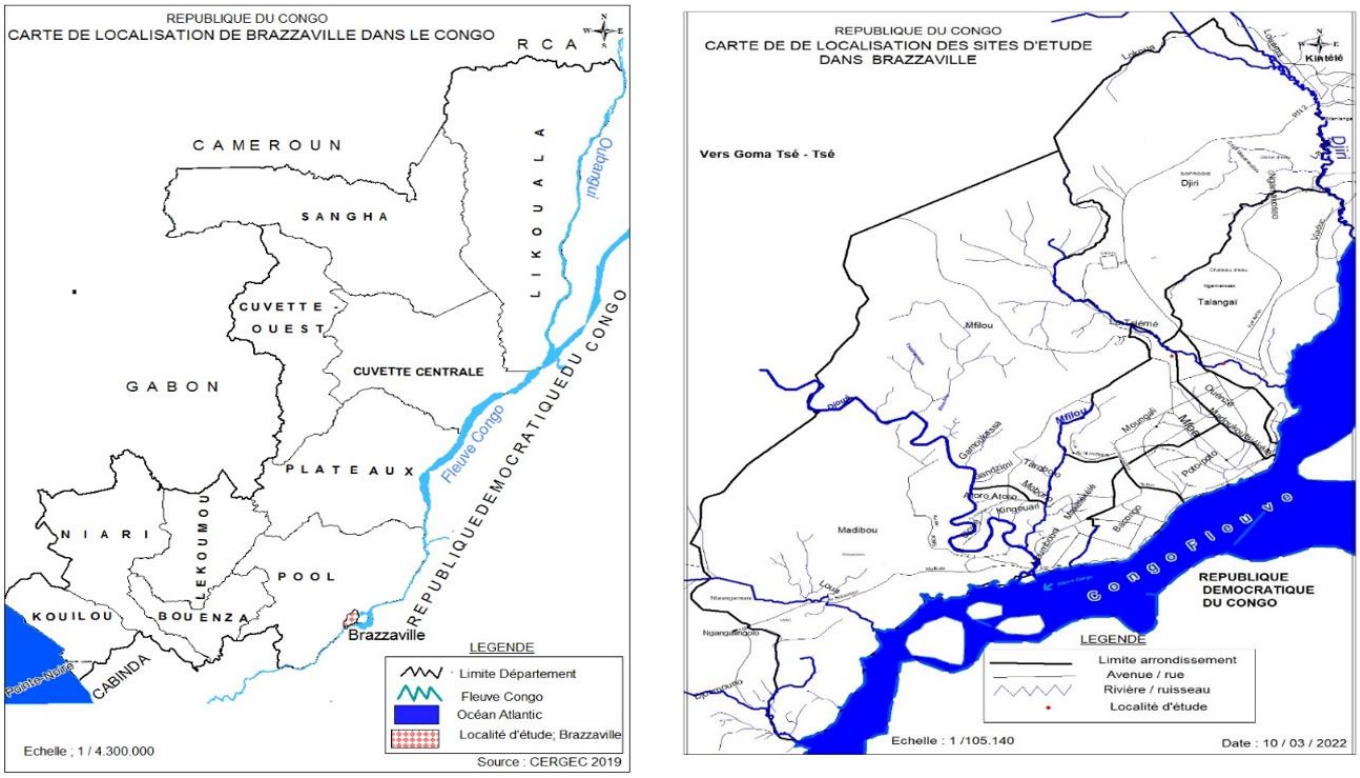

Fig. 1. Localisation of the study area

The figure 2 and table 1 show respectively the images of Tsiémé and Moukondo landfills, and their GPS coordinates.

Fig. 2. Images of Tsiémé and Moukondo landfills

Table 1. GPS coordinates of the landfills

Landfills	Latitude	Longitude
Tsiémé	4,22994	15,28378
Moukondo	4,22756	15,26872

2.2 SAMPLING OF LEACHATE

Three leachate sampling campaigns were carried out at the two public landfills during a period from December 2021 to February 2022. The samples were taken at one location at each landfill site. A drop was created at each landfill and a bottle was placed to receive the flowing leachate in 1.5 L capacity plastic bottles previously washed with distilled water then rinsed with the effluent [6]. The figue 3 shows the technique used to collect leachate samples. The samples thus taken were transported to the laboratory in a cooler for analysis. During sampling, same physical parameters such as pH, conductivity and temperature were measured in situ.

Fig. 3. Leachate sampling

2.3 PHYSICOCHEMICAL ANALYZES

Different analytical methods were used for the determination of several parameters: The potentiometric method for determining temperature (T°C), pH, electrical conductivity (EC) using a multiparameter Water Quality Meter EZ9908, and turbidity using an ORIAN AQ3010 Turbidity Meter.

The colorimetric method for determining nitrates (NO_3^-), ortho-phosphates (PO_4^{3-}), chlorides (Cl^-), trace metal elements (Fe, Cu, Zn, Cd) using a Lamotte SMART spectrophotometer and COD using an Aqualytic AL800 spectrophotometer. It consists of adding a reagent to the tanks or tubes, then dosing the mixture with a spectrophotometer at well-defined wavelengths. At these wavelengths, the absorbance of the solution is proportional to the concentration of the parameter to be determined if the conditions of the Beer-Lamber law is respected. The BOD5 using an Aqualytic BOD meter.

The BOD5/COD ratio makes it possible to estimate the biodegradability of organic matter [7] and to characterize the age and the state of the flow. It must be remembered that BOD5/COD is a ratio which evolves over time, it provides information on the nature of the biochemical transformations that prevail within the discharge [8].

3 RESULT AND DISCUSSION

The composition of the leachates, at different sampling campaigns, sometimes presents significant differences.

3.1 PHYSICAL PARAMETERS

The color and smell of leachate from the two landfills studied are the first indicators of pollution. The landfills analyzed have a blackish color and a foul odor indicating the influence of the waste on the water quality.

The Figure 4 represents the variation of the temperature of the leachates. The temperature values are between 26 and 30°C during the three sampling campaigns.

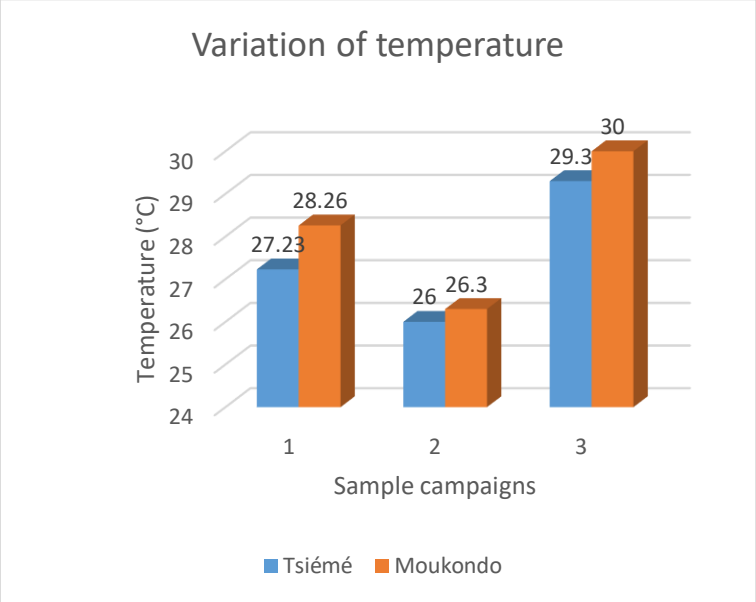

Fig. 4. Variation of temperature of leachate

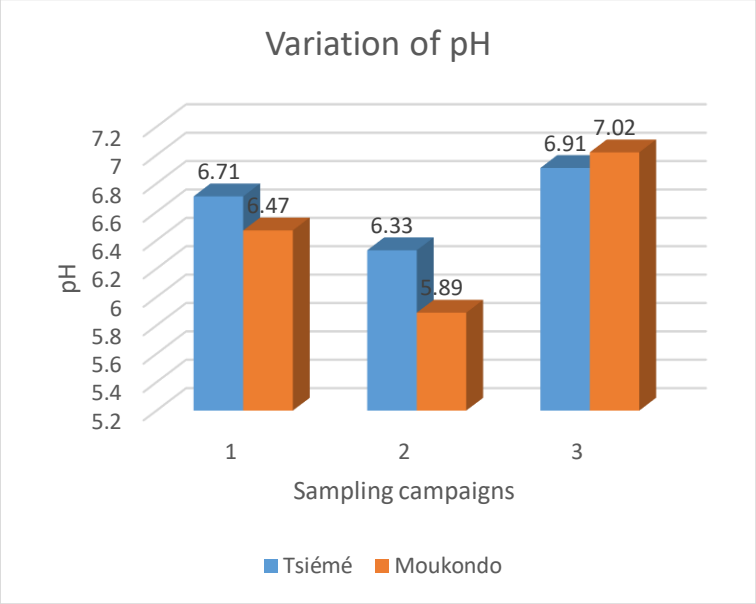

Fig. 5. Variation of pH of leachate

The temperature vary from 26 to 29.3°C for tsiémé landfill with an average of 27.23°C and from 26.3 to 30°C for Moukondo landfill with an average of 28.26°C. At high temperature, the intensification of bacterial activity activeness the degradation of the organic matter present.

The figure 5 represents the variation of the pH during the three sampling campaigns of the two landfills. The pH values are between 5.89 and 7.02.

The pH vary between 6.33 and 6.91 with an average of 6.71 for tsiémé landfill, it varies between 5.89 and 7.02 for Moukondo landfill with an average of 6.47. Indeed, During the transition phase to anaerobiosis, acid fermentations and acetogenesis begin, CO_2 and volatile fatty acids which leads to a decrease in pH. As the landfill ages, anaerobic conditions are established; methane production begins at the same time as carbon dioxide and hydrogen begin to be consumed. The volatile fatty acids are consumed, the pH increases, until neutrality [9].

The figure 6 represents the variation of the electric conductivity (EC) of the leachate. The EC values are between 271 and 1811 µS/cm during the three sampling campaigns.

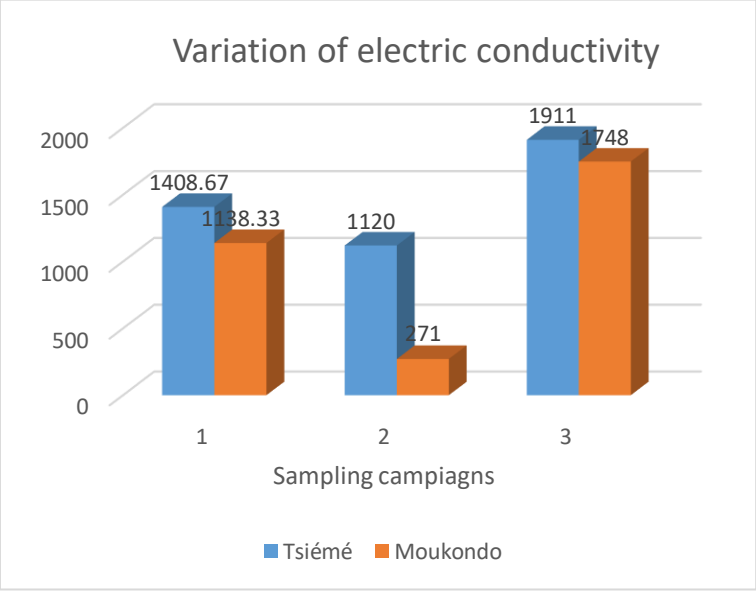

Fig. 6. Variation of electric conductivity of leachate

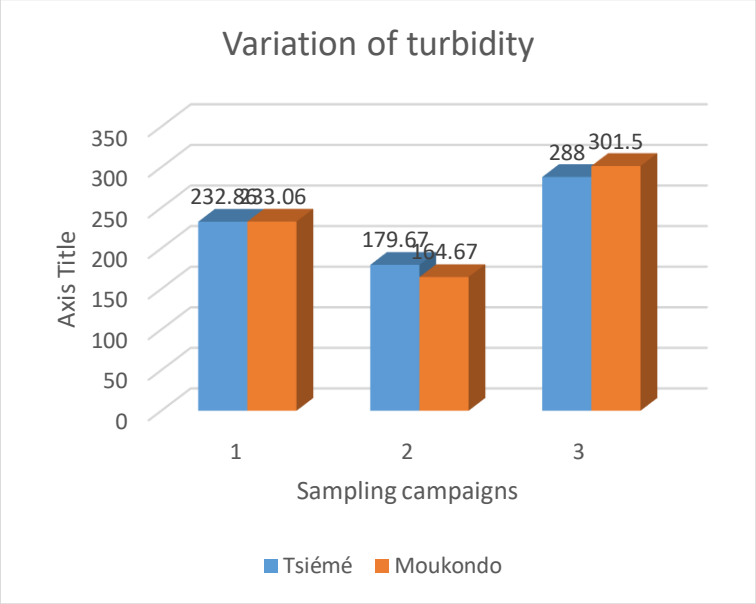

Fig. 7. Variation of turbidity

The average values of electric conductivity of Tsiémé and moukondo landfills are respectively 1408.67 and 1138.33 µS/cm. The high values were recorded during the period when it was not raining heavily and the low values during the rain. These low values could be explained by the phenomenon of dilution. Indeed, during the rainy period, the leachate receives a large quantity of water, thus causing a considerable dilution of the chemical elements present [10].

The figure 7 represents the variation of turbidity of the leachate. The turbidity values are between 164.67 and 301.5 NTU during the three sampling campaigns.

The turbidity vary between 179,67 and 288 NTU wth an average of 232.86 NTU for the Tsiémé landfill and between 164.67 and 301.5 NTU with an average of 233.06 NTU for the Moukondo lanfill. The high turbidity values which greatly exceed the standard can be explained by the advanced state of waste decomposition.

The figure 8 represents the variation of suspended solids during the three sampling campaigns from the two landfills.

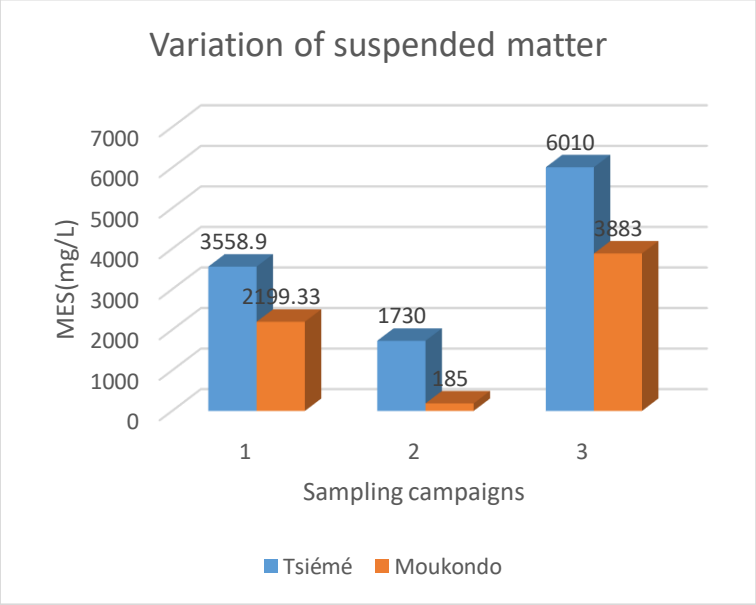

Fig. 8. Variation of suspended matter of leachate

The values fluctuate between 185 and 6010 mg/L. The highest value (6010mg/l) is observed at tsiémé landfill during the second campaign and the lowest value (185mg/l) at moukondo landfill during the first campaign. These leachates have very high suspended solids values with averages of 3558.9 mg/L for Tsiémé landfill and 2199.33 mg/L for moukondo landfill. This is a common characteristic of all landfills household waste [11]. The high contents of suspended solids are explained by the fact that during the period of short dry season in Congo, Brazzaville (January, February), there is no significant rainfall which can induce phenomena of considerable dilution of the juice discharge, from where the leachates become increasingly rich in suspended solids. These values are higher than those recorded in Essaouira, Morocco by El Mohammedia [12], but which remain much lower than those recorded at the Agadir, Morocco landfill by Lekehal [13]. These high concentrations represent an indicator of the high organic and mineral load due to the nature of the waste.

3.2 ORGANIC PARAMETERS

The figure 9 represents the variation of COD of the leachate. The result showed that the COD contents fluctuate between 219 and 7375 mg of O_2 /L during the three sampling campaigns

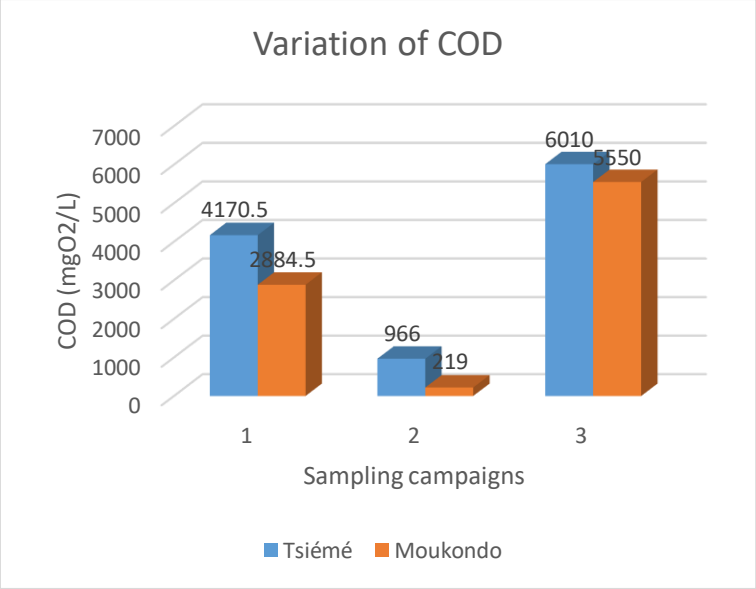

Fig. 9. Variation of COD of leachate

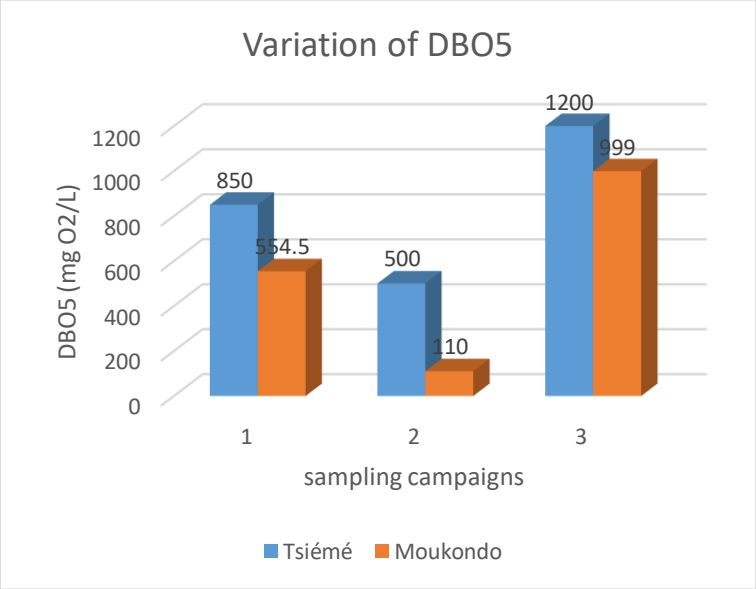

Fig. 10. Variation of DBO5 of leachate

High COD values are observed during the first and second sampling campaigns in the tsiémé landfill, and during the second sampling campaign in moukondo landfill.

The COD is representative of most organic compounds and oxidizable mineral salts. The average contents of tsiémé and Moukondo landfill are respectively 4170.5 and 2884.5 mg of O_2/L. High COD values indicate a very high organic load and show that these influent liquids are in the reducing conditions. This indicates that the phenomenon of anaerobiosis is predominant in both discharges. Indeed, oxygen is strongly solicited for the degradation of organic matter and the oxidation of minerals present in the effluent [14].

The figure 10 represents the variation of BOD5 of leachate. The values vary from 110 to 1200 mg of O_2/L during the three sampling campaigns. The highest value (1200 mg of O_2/L) is observed at Tsiémé landfill during the second sampling campaign and the lowest value at Moukondo landfill during the first sampling campaign.

The BOD5 varies from 500 to 1200 mg O_2/L with an average of about 850 mg O_2/L for Tsiémé landfill and from 110 to 999 mg O_2/L with an average of about 554.5 mg of O_2 /L of Moukondo landfill. The ratio (BOD5/COD) provide information on the biodegradability of organic molecules and the relative age of the landfills studied. The values of the BOD5/COD ratios are between 0.50 and 0.18 for Moukondo landfill with an average of 0.34, and between 0.52 and 0.16 with an average of 0.34 for Tsiémé. These values show that the leachates from the two landfills are rich in biodegradable organic matter. Thus, according to Amokrane [2] the BOD5 / COD ratio is greater than 0.5 for young leachates and less than 0.1 or even to zero for stabilized leachates. It is deduced that the leachates studied are between these two states. The value of 0.34 from the average of the various BOD5/COD ratios indicates that the leachates studied are of average biodegradability. This means that the organic molecules contained in the leachates have not yet reached the final stage of their degradation. At this stage, they are characterized by an unstable phase of methane fermentation which favors the phenomenon of anaerobiosis and the maintenance of discharges in an active degradation phase [15].

3.3 CHEMICAL PARAMETERS

Figure 11 represents the variation of nitrate of leachate. The nitrate concentrations fluctuate between 7 and 17 mg/L during the three sampling campaigns.

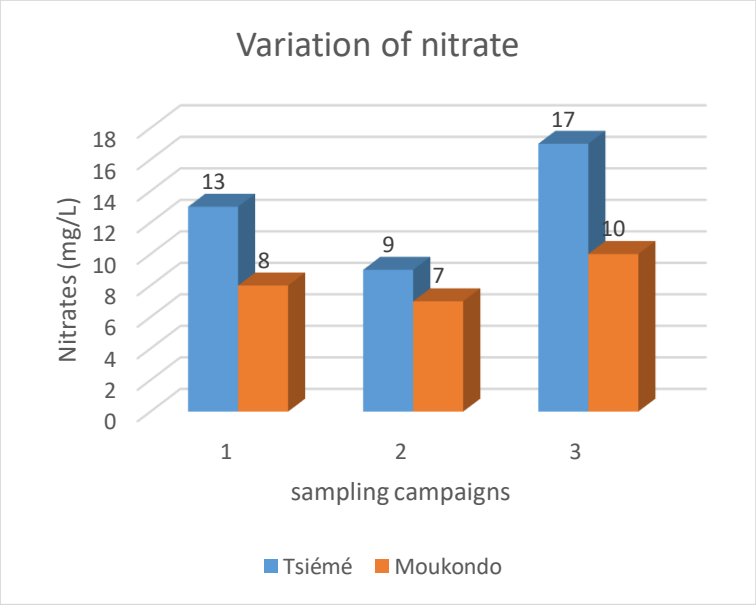

Fig. 11. Variation of nitrate of leachate

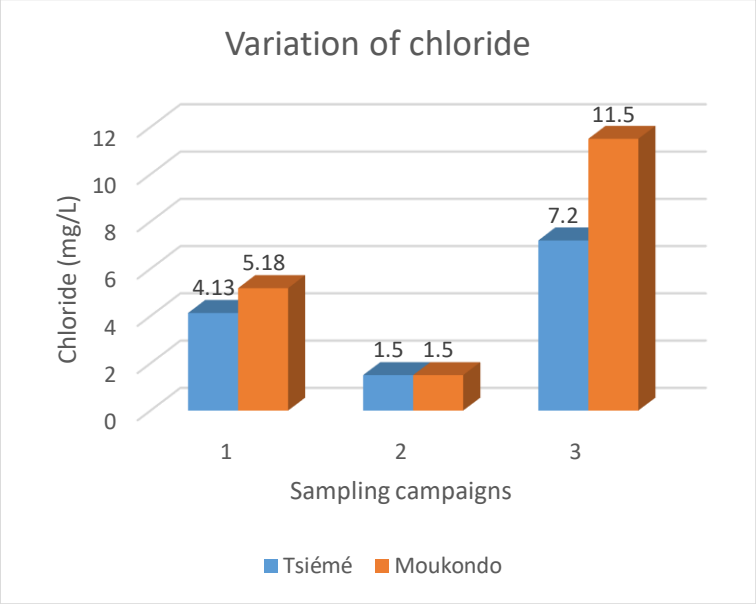

Fig. 12. Variation of chloride of leachate

The average contents of Tsiémé and moukondo landfills are respectively 13 and 8 mg/L. These values are well below the concentration accepted by the WHO, which is 50 mg/L. the average for Tsiémé landfill is comparable to that obtained at the Meknes landfill (Morocco) 14.17 mg/L by Zakaria [16]. The low concentrations of nitrates can be the result of the decrease in oxygen in the leachates, which leads to deduce that the phenomenon of anaerobiosis is predominant in the landfill [17].

Figure 12 represents the variation of chloride of leachate. The chloride concentration fluctuates between 7 and 17 mg/L during the three sampling campaigns. The average contents of Tsiémé and moukondo landfills are respectively 4.13 and 5.13 mg/L. These values do not exceed the standard accepted by the WHO, which is 250 mg/L.

Figure 13 represents the variation of phosphate of leachates. The concentrations fluctuates between 0 and 1.14 mg/L during the three sampling campaigns.

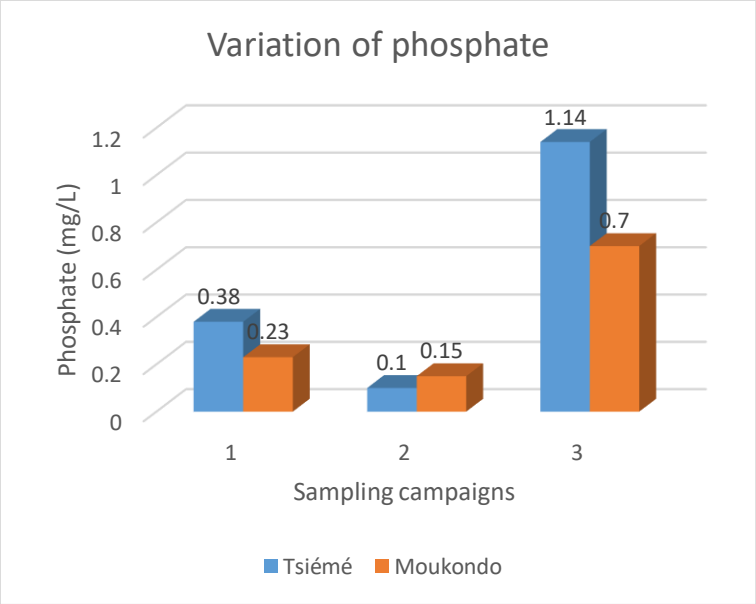

Fig. 13. Variation of phosphate of leachate

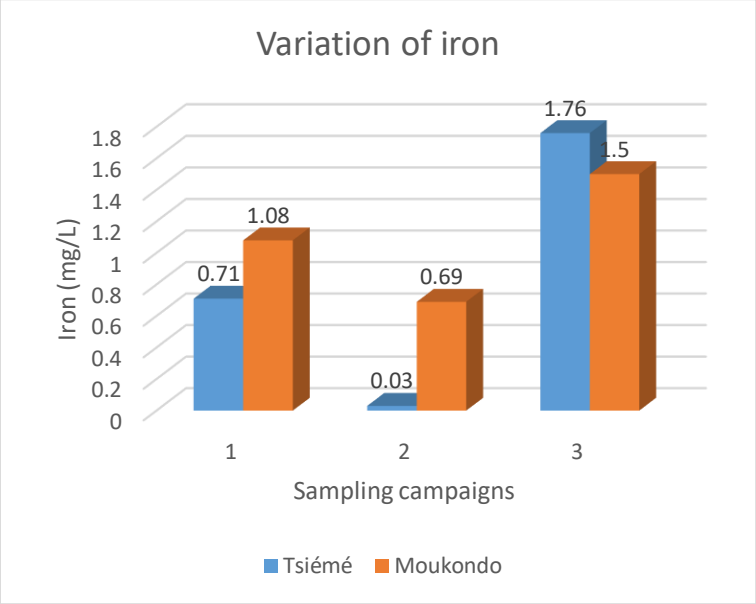

Fig. 14. Variation of iron of leachate

For this parameter, the results shows that it's concentration is lower than the WHO standard which is 5 mg/L. The average of Moukondo landfill which is 0.38 mg/L corroborates with that of the Meknes landfill in Morocco [13].

Figure 14 represents the variation of total iron of leachate. The values vary between 0.03 and 1.76 mg/L during the three sampling campaigns. The highest value is observed at tsiémé landfill during the second sampling campaign.

Figure 15 represents the variation of copper of leachates. The values vary between 0.01 and 1.36 mg/L during the three sampling campaigns.

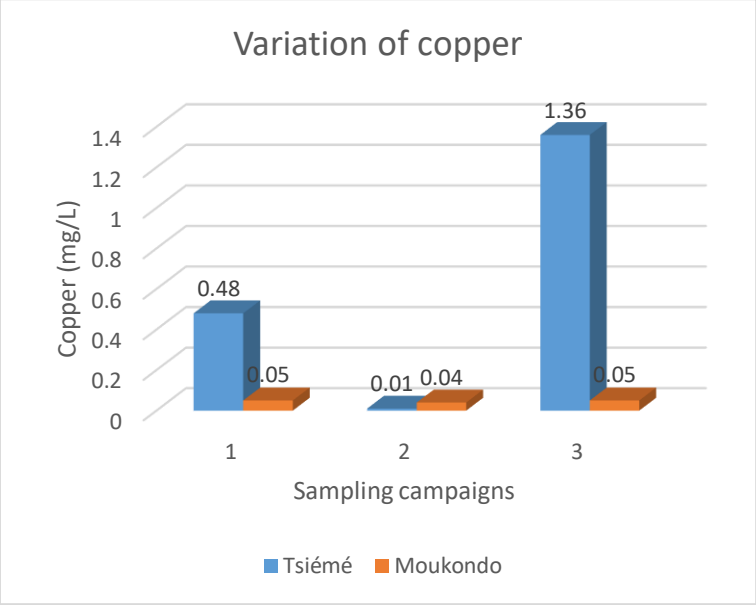

Fig. 15. Variation of copper of leachate

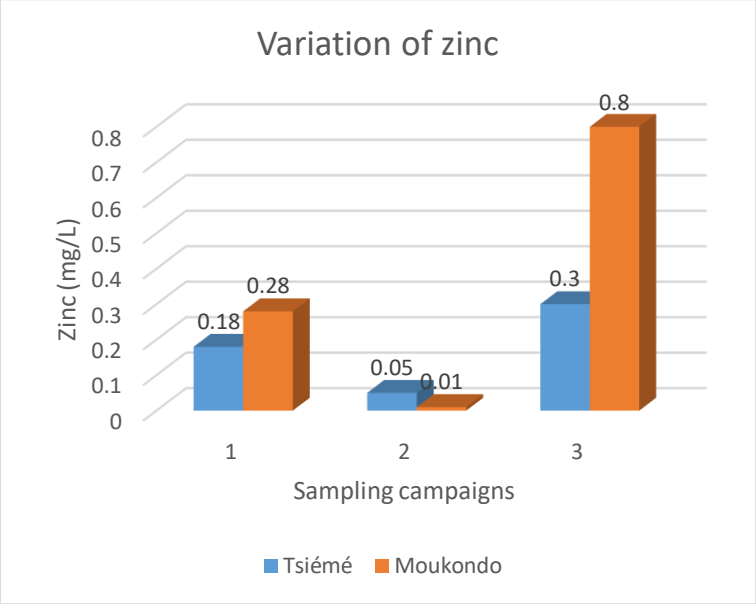

Fig. 16. Variation of zinc of leachate

Figure 16 represents the variation of zinc of leachate. The zinc concentration vary between 0.01 and 0.8 mg/L during the three sampling campaigns.

Figure 17 represents the variation of cadmium of leachate. The concentrations vary between 0 and 0.9 mg/L during the three sampling campaigns

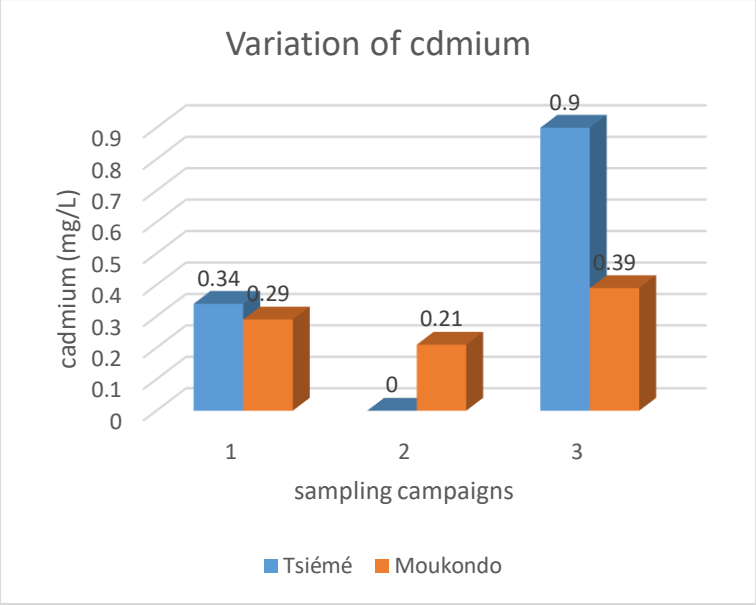

Fig. 17. Variation of cadmium of leachate

The leachates from the two landfills revealed the absence of lead, which could be linked to the fact that the landfills are low in scrap metal [18]. There are also low concentrations of metals below the WHO standard, these are: total iron (Fe^{2+}/Fe^{3+}), copper (Cu^{2+}), Zinc (Zn^{2+}). The Copper is a metal present in its natural state in the earth's crust in its pure state and in many ores [19].

On the other hand, the two landfills revealed the presence of cadmium at higher concentration which exceeds the WHO standard (0.2 mg/L). This could be explained by the presence of plastics [20].

4 CONCLUSION

This study consisted in physico-chemical characterization of leachate from two public landfills in Brazzaville. The analyzes were carried out using potentiometric and colorimetric methods to determine differents paramters.

At the end of this study, it appears that :

- After more than 5 years of operation, the Tsiémé and Moukondo landfills enter the unstable phase of methane fermentation with the ratio BOD5/COD = 0.34 which promotes the phenomenon of anaerobiosis. These leachates are thus considered as intermediate leachates, a state which is confirmed by its average pH close to neutrality 6.71 and 6.47.
- These leachates are thus characterized by a high organic load with a COD which exceeds the reference value, the leachates are under reducing conditions, which confirms that the phenomenon of anaerobiosis is predominant;
- Mineral pollution is reflected by high electrical conductivity which reaches 1408.67 for tsiémé landfill and 1138.33 µS/cm for Moukondo landfill, followed by NO_3^- (13 and 8 mg/L) and PO^{3-}_4 (0.38 mg/L) which clearly indicates the importance of the mineral and organic loads and the phenomenon of anaerobiosis described above;
- The Fe, Zn, Cu, contents are at trace levels not exceeding the WHO standard, with a total absence of Pb in the two sites,
- The Cd content for tsiémé and Moukondo landfills exceeding the norm.

As they do not meet discharge standards, leachate with a high polluting load constitutes a risk of contamination of surface and groundwater. The results of this study clearly indicate that these landfills constitue a danger to humain health, especially for residents living around.

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