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Assessment of physicochemical and microbiological quality of leachates sampled from Polesgo site in Ouagadougou

Nafissatou Sawadogo [1*], Yacouba Sanou [2], Samuel Paré [2]

[1]*Laboratory of Sciences and Technology, New Dawn University/Ouagadougou, Burkina Faso.*
[2]*Laboratory of Analytical, Environmental and Bio-Organic Chemistry, University Joseph KI-ZERBO, Burkina Faso.*
Corresponding author: sawadogonafissatou@gmail.com

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sawadogonafissatou@gmail.com
Phone: +226 70888183

Abstract

The present study aimed to assess the physico-chemical and microbiological characteristics of leachates produced on the site of Polesgo. Leachate samples have been collected in Polesgo Site (Ouagadougou). Physical and chemical parameters of water samples such as pH, electrical conductivity, Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), nitrate, nitrite, fluoride, ammonium, sulfate and ortho-phosphate have been evaluated using standard methods. From experimental results, the basic pH values showed that the leachate is stabilizing and the electrical conductivity gives us information on the dissolved ion content of the effluent water. Concentrations of aluminum, iron and silicon are the most important and can be a source of pollution if infiltration. Low concentrations of lead and chromium were observed and suggest the presence of unauthorized waste in wastes treatment and recovery Center (CTVD). For the microbiological parameters, the high presence of fecal streptococci and E. coli shows the fecal contamination of water in this area.

1. Introduction

In Burkina Faso, mainly in Ouagadougou city, the treatment method of solid wastes is mainly landfill with a quantity of waste to be landfilled of 600,000 tons per year [1] for a population of 3,000,000 inhabitants [2]. Although the waste is buried, physical, chemical and biological activity continues within it. The percolating water called leachate can have an impact on the environment, mainly on surface and ground water [3]. In order to ensure the preservation of the environment, safety devices have been put in place on the site to avoid the infiltration of various pollutants, especially heavy metals which are the most durable and with the heaviest drawbacks. The major concern associated with waste storage facilities is the infiltration and circulation of leachate which contains pollutants that can contaminate groundwater [4, 5]. To prevent a possible groundwater contamination, safety devices have been put in place at the CTVD. The safety device consists of a layer of clay very well compacted, a layer of draining sand, the installation of geomembrane at the bottom of the cells and the basins of collection and treatment of the leachates. After more than 10 years of use, we wanted to contribute to the evaluation of the leachate characteristics. The objective of this study is to assess the chemical and microbiological compositions of the leachates from Polesgo site. More specifically, the study aims to determine the content of samples concerned physical, chemical, microbiological and metallic trace elements parameters.

2. Methodology

2.1 Presentation of the study site

The site of Waste Treatment and Recovery Center is located between latitudes 12°25'8.07 "N and 12°25'54.00 "N and longitudes 1°30'41.23 "W and 1°31'11.82 "W, in Ouagadougou City (Burkina Faso). It is bordered by four large rivers (deams): Zogona, Dassasgho, Kadiogo and Paspanga. The commune is located in the Sudano-Sahelian zone where temperatures vary between 19°C in January and 43°C in April [6]. The maps below show the situation of Ouagadougou and the facilities present on the site of the CTVD. The implementation of a master plan for waste management led to the construction of the CTVD with the mission of burying and recovering waste. The CTVD is located about ten kilometers north of Ouagadougou, in the district 4 sector 17 and covers an area of seventy (70) hectares divided into four (04) phases for a life span of twenty (20) years. In order to perpetuate the waste sector, particular emphasis has been placed on the recovery of waste upstream and downstream of this sector. The activity of recovery is ensured by the associative groups in partnership with the Commune. It allows to reduce the important quantities of waste which occupy unnecessarily the direction of the CTVD.

The criteria for the choice of the CTVD were motivated by the consideration of the respect of the environment, public and animal health. Among these criteria are the accessibility of the site (flood zones and high elevations are to be avoided), the impact of the site on the environment, public and animal health, site geology (avoid seismic or volcanic areas) and soil sealing, the hydrogeology of the site (take into account the water table and its piezometric level), the distance from infrastructures (health facilities, schools, etc.). Map 1 below shows the geographical location of the commune of Ouagadougou. Map 2 shows the solid waste treatment site and the location of the infrastructure it contains.

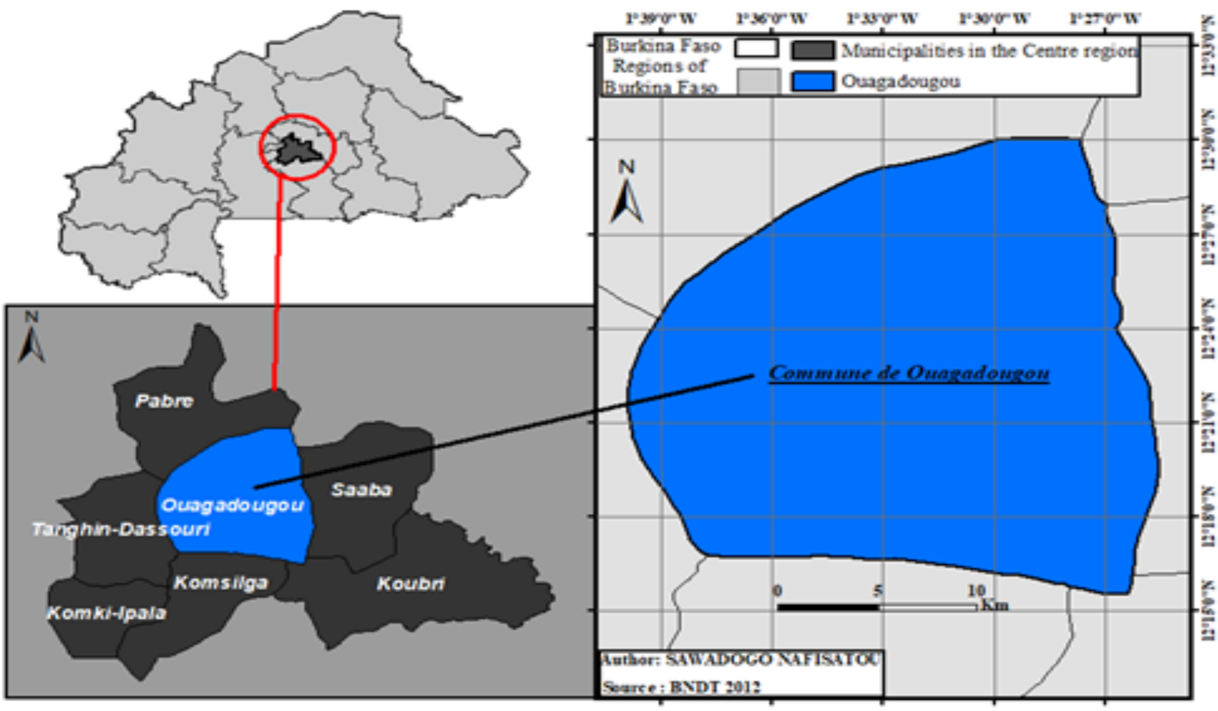

Figure 1: Location map of Ouagadougou

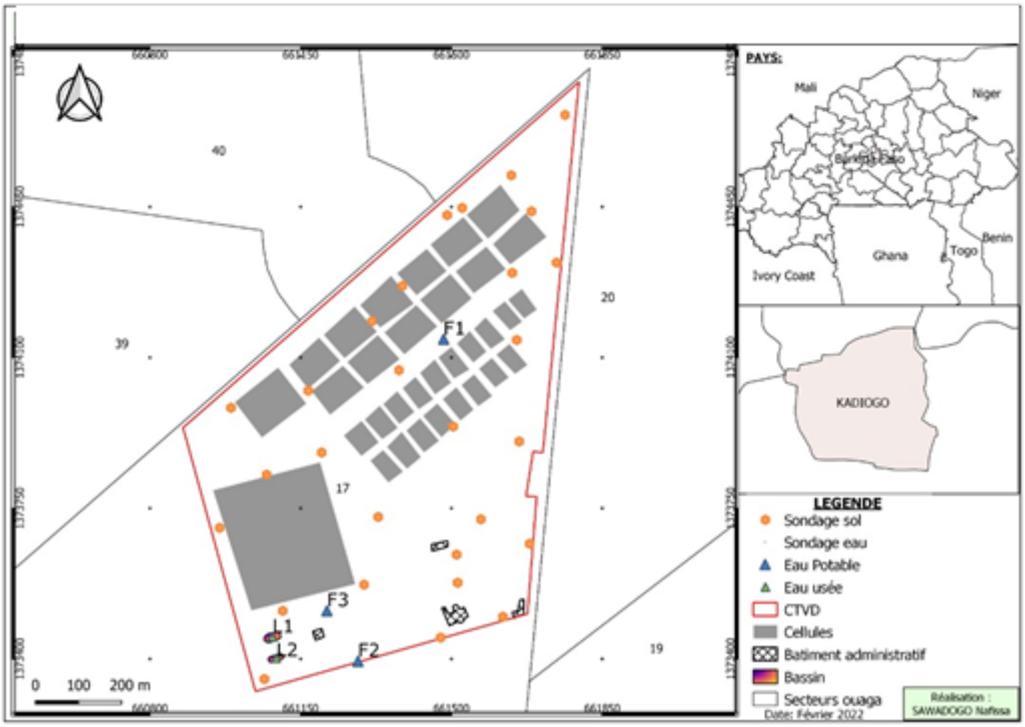

Figure 2: Map of the CTVD, infrastructure and water withdrawal points

The vegetation, is mainly made up of a classified forest, a few large trees lining some of the city's arteries and a few groves located on the outskirts of Ouagadougou. Two seasons characterize the commune: The dry season extends from October to May and is characterized by more or less hot and very dry weather, wind and dust, and strong sunlight. The rainy season extends from June to September and is marked by the monsoon. Rainfall averages 825mm per year. 15% of Ouagadougou's water supply comes from groundwater, with wells and boreholes ranging from 40 to 65 meters deep. In Ouagadougou, the upper aquifer is free and the lower aquifer is often captive, and it is this aquifer that is often tapped by boreholes [7].

2.2 Water sampling

Water sampling is a delicate operation to which the greatest care must be taken and which conditions the analytical results and interpretation. Indeed, the results of the analysis will be exploitable only if the sampling has a representative character. The samples taken are homogeneous, representative and obtained without modifying their characteristics. We carried out three campaigns of sampling: one between March and April 2021, another between July and August 2021 and finally one between November and December 2021.

Spot sampling was conducted at the landfill site. Sampling points were the leachate from two ponds located on the site. The leachate samples were taken with a cane, at several sampling points and at different depths to have a horizontal and vertical heterogeneity. They were packaged in sterile borosilicate glass bottles of 500 mL for bacteriological parameters, and in plastic bottles of 1 L for physico-chemical parameters. At the time of sampling, for the chemical analysis, the bottles are rinsed again 3 times with water to be analyzed and then filled to the brim. The cap is placed in such a way that there are no air bubbles in the bottle, and that it is not ejected during transport. For the leachates we have the L1 and L2 samples. All vials are kept in a thermostatically controlled cooler at 4°C equipped with a cold accumulator until they are returned to the laboratory. Microbiological parameters sought are essentially total coliforms, fecal coliforms including E. coli and fecal streptococci which are indicator germs of fecal contamination. Heavy metals were analysed using the acid digestion method with a microwave assisted plasma optical emission spectrometer produced by the manufacturer Agilent. Temperature, pH and electrical conductivity (EC) were measured respectively in situ with a pH-meter (pH522) and a conductimeter HACH 44600. Analysis of chemical parameters such as nitrates, nitrites, fluorides, ammonium, sulfates, ortho phosphates and COD was carried out by calorimetry using a flame spectrophotometer. Leachate pond 1 named L1 and Leachate Pond 2 named L2 will be used in following paragraphs of this work.

3. Results and Discussion

3.1. Physico-chemical composition of water samples

3.1.1. Values of BOD_5 and COD

Change of BOD_5 and COD in samples gives us important information on the leachate of site. Results of COD and BOD_5 analysis are given in Figures 3 and 4.

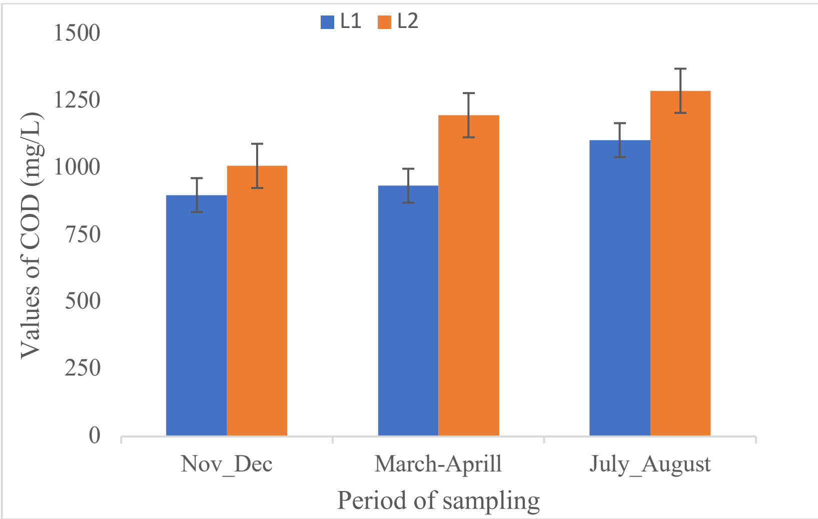

Figure 3 Evolution of COD per measurement campaign

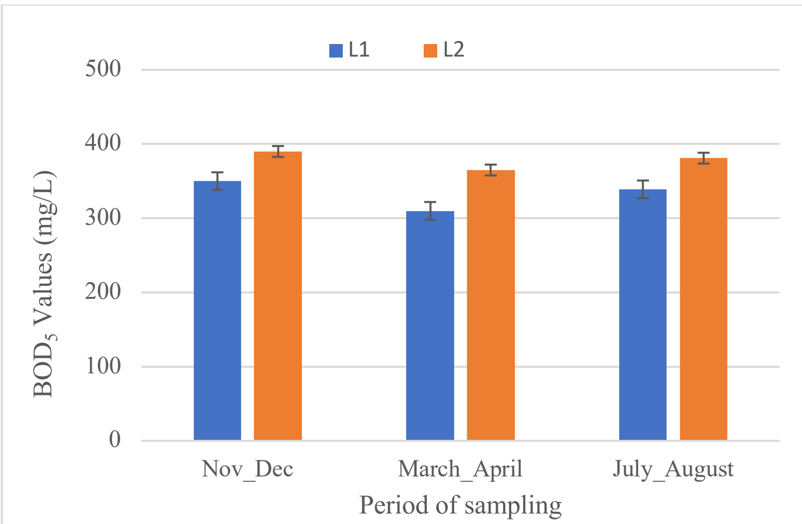

Figure 4 : Evolution of BOD_5 per measurement campaign

Variations of BOD_5 and COD are relatively low but still high. Indeed, for landfills like those of El Jadida, the average is around 1005 mg/L [8]. The BOD_5 is an indicator of organic pollution of water. It expresses the level of biodegradability of the effluent [9]. Values of BOD_5 are lower during the dry and hot season than during the winter. This is due to the high temperatures which are between 39 and 42°C 10]. The bacterial activity is intense and higher. It is the same for the biological activities [11]. This activity will allow to degrade a part of the biodegradable elements more quickly which will lead to a decrease of BOD_5 between March and April. Moreover, during this period the leachate input is low and allows the water velocity within the basin to decrease: this phenomenon also allows the intensification of the microbiological activity [9]. Highest BOD_5 is noticed between November and December because in this period, the temperatures are close to a max of 34 and a min of 18°C [12] and do not favor a good bacterial activity. As for the rainy season, it is quite normal that the value of BOD_5 is higher than in the dry season because the temperature is lower.
In contrast, COD values do not evolve in the same way as BOD_5 values. The values during the dry season are higher than those in December. Those of July-August are higher than the previous ones. High values of COD over time are explained by the presence of non-biodegradable waste, such as tires, batteries, plastics, glass and metals [13]. The report COD/BOD_5 (Table 1) gives an indication of leachate maturity[14], the following limits are given as well:

- BOD_5 /COD > 0.6 : young and unstable leachate
- 0.1< DBO_5 / DCO < 0.6: moderately stable leachate.
- BOD_5 / COD < 0.1: old and stable leachate.

Table 1: Ratio of BOD_5 and COD

Name	Sampling Period	L1	L2
BOD_5/COD	*Nov_Dec*	0.0581	0.0591
	March_April	0.052	0.0474
	July_August	0.054	0.0446

The reports of BOD_5/COD (Table 1) are ranged between 0.5 and 0.4 for L1 and L2 indicating that both leachates in Polesgo site are moderately stable because the biodegradability is less but the organic load is complex [15]. With time, this ratio will decrease and the effluent will tend to become non-biodegradable.

3.1.2. Values of pH and electrical conductivity

The **figures 5 and 6** show the evolution of pH and electrical conductivity (EC), respectively during the measurement campaigns. Results (fig.5) show average pH values of 8.15 for L1 and 8.32 for L2 respectively. Knowing that the reference limit values are between 6.5 and 9.0 for leachate samples. The hydrogen potential (pH) is slightly alkaline for both discharges. The pH values obtained in the leachates could be related to the low concentration of volatile organic compounds and the biological evolution **[8]**. These basic pH values confirm that the leachate is stabilized or in the process of stabilization as predicted by the COD/BOD_5 values **[16]**. For an acidic pH, the leachate is young and for a basic pH it is old or stabilized **[17]**.This also shows an intense evaporation of the leachate. Indeed, as the landfill ages, the leachate is depleted in volatile organic compounds. This will then lead to a rise of the pH to 7 or more. These values confirm that we are dealing with an old stabilized leachate.
From analysis of EC (Fig.6), the electric conductivity varied around 2600 µS/cm for L1 and 2800 µS/cm for L2 corresponding to the values of effluents coming from landfills [18]. The leachates were

therefore rich in dissolved salt ions [19]. High conductivities were also related to the age of the landfill. This advanced age was manifested by high conductivities and alkaline pH [16]. This conductivity reflects the amount of soluble salts which increases slightly with the age of the CET [20].

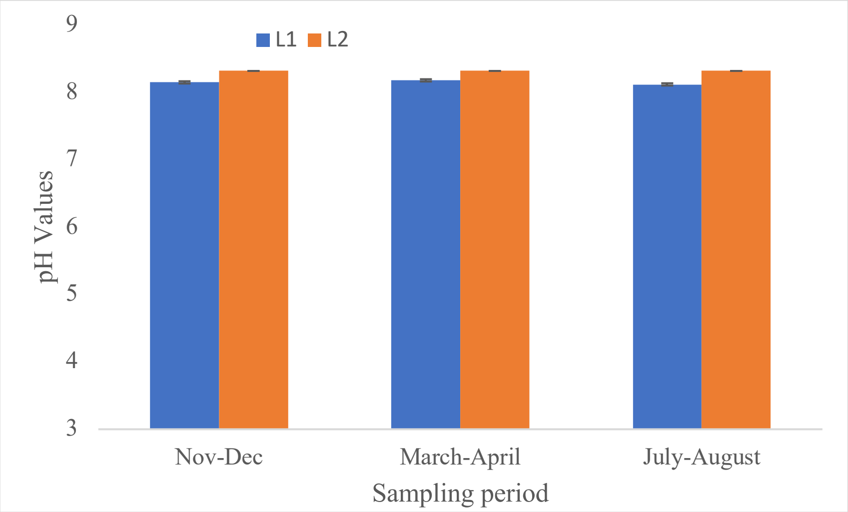

Figure 5: pH variations by campaign

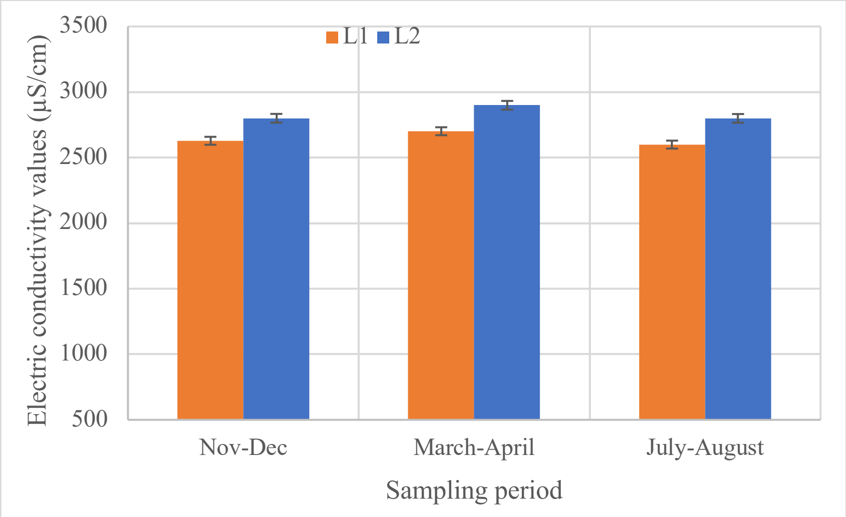

Figure 6 : Variations in conductivity by campaign

3.1.3. Ammonium amount

Below we can observe the variation of the ammonium content in the leachate. In Table 2, are listed the results of changes in ammonium amounts.

Table 2: Variation of ammonium by sampling campaigns

Sampling period	Unit	L1	L2
Nov-Dec	mg/L	151.5	883.5
March-April	mg/L	159.1	905.9
July-August	mg/L	151.5	823.1

It is an indicator of pollution and its presence reflects a partial degradation of organic matter. The ammonium ion was found in natural waters at concentrations that can vary between 0.1 and 10 mg/L; it is an important indicator of pollution. We have average values of 154 mg/L for L1 and 871 mg/L for L2. L2 basin is more loaded than L1: a large amount of ammoniacal nitrogen in a wastewater means that the pollution is recent, which explains the high values at L2. In both samples, we observed that during the rainy season, the concentration decreases which can be explained by the dilution of the leachate. This chemical element is the main reducing agent in landfill leachate and is an important long-term pollutant [5].

3.1.4. Concentrations of Nitrates and nitrites

From lab analyses, Concentrations of nitrate are ranged from 3.9 to 6.89 mg/L. Table 3 shows the nitrate levels in the samples.

Table 3: Evolution of nitrate for the sampling campaigns

Sampling Period	Unit	L1	L2
Nov-Dec	mg/L	3.9	6.1
March-April	mg/L	4.3	6.89
July-August	mg/L	3.9	5.9

Nitrates are the final stage of nitrogen oxidation, and represent the highest oxidation state form of nitrogen present in water[21]. Nitrites come from either a reduction of nitrates or incomplete oxidation of ammonium ions [22]. In the leachate basin 1 there are no nitrites, but in the leachate basin 2 there is a slight concentration: they have an average value of 0.06 mg/L. The nitrate concentrations in the leachate remain relatively low or nil because of the reduction reactions that occur [8].

3.1.5. Amounts of ortho-phosphates and fluorides

Table 4 represents the contents of orthophosphates in the leachate samples. In Table 5, are listed the amounts of fluorides in the both L1 and L2 samples.

Table 4: Variations in the concentration of ortho-phosphates

Sampling Period	Unit	L1	L2
Nov-Dec	mg/L	0.11	0.55
March-April	mg/L	0.15	0.75
July-August	mg/L	0.11	0.41

Table 5: Variations of Fluoride ions in Leachate samples

Sampling Period	Unit	L1	L2
Nov-Dec	mg/L	0.88	0.79
March-April	mg/L	1.01	0.89
July-August	mg/L	0.88	0.65

It was noticed that orthophosphate concentrations in L2 were higher than that in L1. High orthophosphate amounts were due to the ashes of industrial special and biomedical wastes. The concentration of sulfates was very low in L1 leachate basin. It has an average of 0.99 mg/L in Leachate L2, Sulfate concentrations are not significant in leachate samples.

3.1.6. Amount of mineral content

The concentrations of mineral elements such as calcium, potassium, sodium and magnesium could be determined by the figure 7 below.

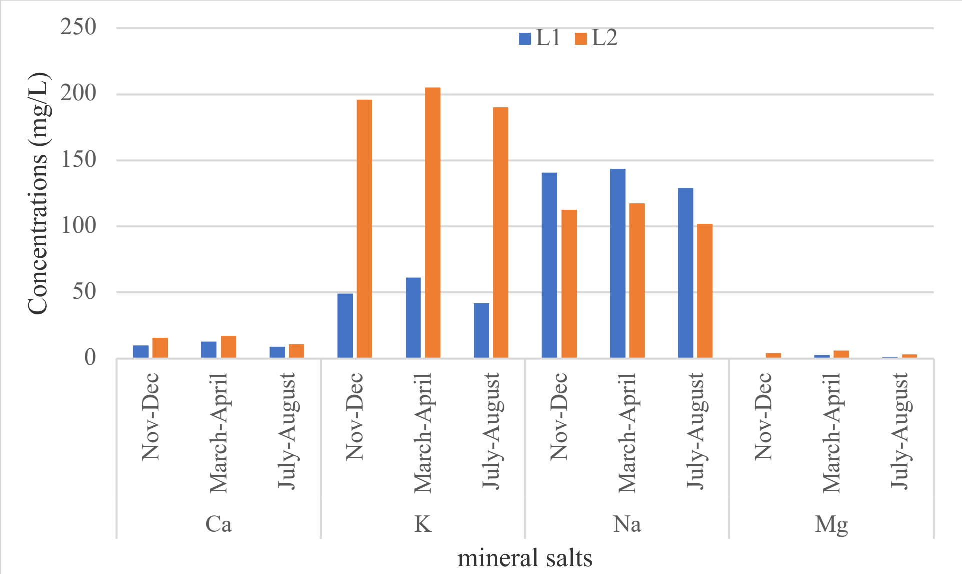

Figure 7: Concentration of mineral salts

Concentrations of mineral salts such as potassium and sodium were the highest in both samples L1 and L2 comparatively to calcium and magnesium. High concentrations were found between March and April and this result was due to evaporation of leachates. The content of dissolved organic substance depends on the amount of Na, Mg and Ca [5], the increase of these contents is due to the low organic matter between March and April. Indeed, this organic matter participates in the complexation of these ions. High potassium content shows the important presence of ash from waste incineration [5]. High content of cations in the leachate indicates a strong presence of mineral matter.

3.1.7. Values of heavy metals

We were able to determine the content of heavy metals. From analysis of all metals present in the table of periodic classification, only those detected by analysis method are listed in figure 8. Despite the low amount of heavy metals, they can be affect the quality of groundwater resources if there is potential infiltration in the soils. The concentrations of aluminum, iron and silicon were the most significant although it is leachate from household waste for ash from biomedical waste incineration. This is due to the fact that there is no selective sorting of the waste before landfilling and the lack of treatment of the leachate. These values are still low compared to industrial waste sites but constitute a danger if any infiltration occurs.

3.2. Microbiological parameters of water samples

The contents of microorganisms such as fecal streptococci, escherischa coli, fecal coliforms and total coliforms were measured and are represented in Figure 9. The number of microorganisms is very important in the study of microbiological quality. The peaks of microorganisms are observed during the warm period. Indeed, at this time the biological activity is very intense leading to an important microbial activity because the environment favors the bacterial multiplication. The presence of faecal coliforms and Escherichia coli shows that there is a pollution of faecal origin [23].Their presence in the leachate confirms that faecal matter has been illegally dumped in the cells [24].

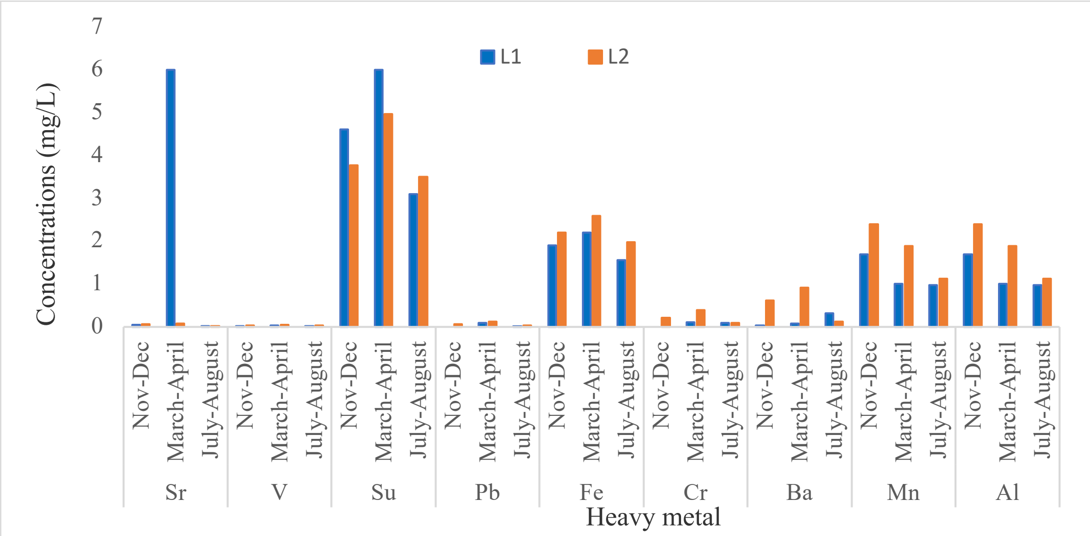

Figure 7 : Variations of heavy metals

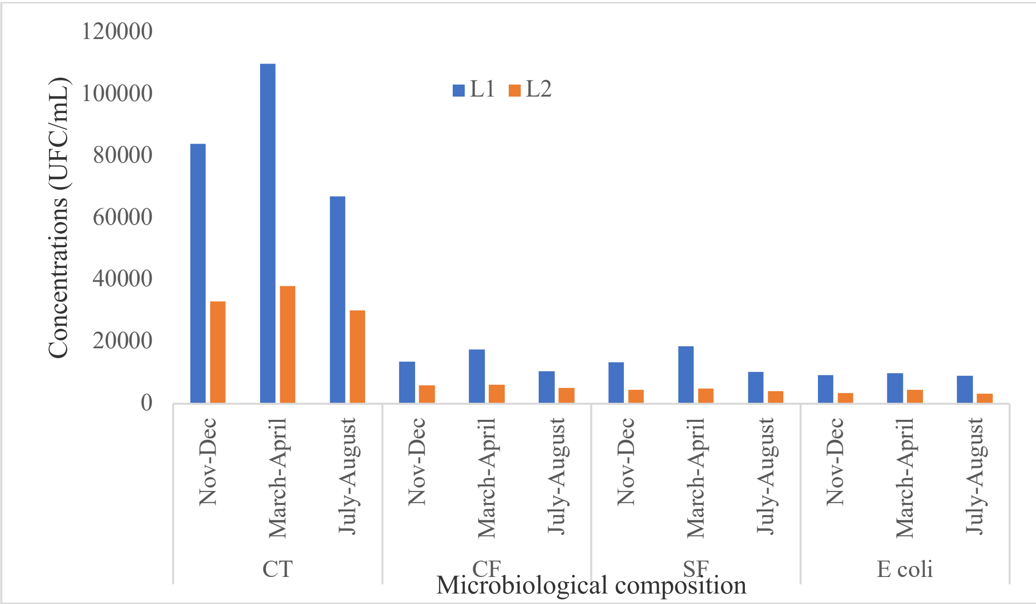

Figure 9 : Bacteriological concentrations of leachates

Conclusions

The waste treatment and recovery center after more than 10 years of operation, contain the leachates which have intermediate age because the BOD_5/COD ratio is between 0.054 for L1 and 0.049 for L2. From conductivity values, the leachates are rich in dissolved salt ions. Heavy metal analysis showed high concentration of iron, aluminum and silicon. There are low concentrations of lead and chromium; this is not normal and suggests that there are wastes not destined that are illegally dumped there. The mineral content is high for K, Ca and Na ions. This reflects a high content of dissolved organic matter which is responsible for the complexation of these ions. Microbiological parameters showed a very important load such as Escherichia coli and fecal streptococci of very high concentrations for leachates of household and biomedical waste

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