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Physicochemical analysis of crude waste waters from industrial and domestic sources in the Kossodo market garden site (Ouagadougou)

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ABSTRACT: In Burkina Faso, Water resources are threatened today by pollution from domestic waste, industrial and agricultural discharges without adequate treatment. This pollution is the main cause of degradation of water quality. The objective of this study is to evaluate the physicochemical quality of the water in the market garden site of Kossodo watered with sewage sludge from the city of Ouagadougou industries. Indeed, seven (7) wastewater samples collected over a 90 days period at the site where a Water Treatment Plant (WTP) was installed were analysed in the laboratory. The parameters were pH, EC, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, NH_4^{+}, NO_3^{-}, HCO_3^{-}, CO_3^{2-} , BOD_5, SM and COD. The analytical data was compared to WHO standards. The Results show that the concentrations of the chemical elements are very high in the wastewater, but hardly exceed the levels recommended by the standards for agro-pastoral needs. Electrical conductivity indicates that 57% of the samples analysed are not saline. Phosphorus and potassium concentrations are low. There is a strong mineralization resulting from industrial or domestic pollution. The physicochemical characterization of the raw wastewater revealed that this liquid discharge is very heavy in organic matter in term of COD (Avg.= 341.52 mg/L), in BDO_5 (Avg.= 260 mg/L), in Suspend Matter (Avg.= 307.6 mg/L) and mineral matter expressed in terms of chlorides (Avg.= 75.968 mg/L), electric conductivity (Avg.= 580.24 µs/cm) and alkalinity expressed as $CaCO_3$ (Avg.= 220.70 mg/L) with a pH of 7.5 (±0.3). The average levels of nitrates and orthophosphates respectively of the order of 33.11 mg/L and 86.74 mg/L. Over the entire sampled site, most of the wastewater analysed is suitable for agriculture.

KEYWORDS: wastewater, market gardening, physical-chemical, pollution, quality, Ouagadougou.

1 INTRODUCTION

Water is one of the essential elements for most large pet food processing companies of chemical origin. In this context, wastewater is considered as an additional water resource and as an appreciable fertilizer input [1], [2], [3]. After use, the wastewater is returned to the environment. This wastewater is generally loaded with organic matter, and becomes an important source of pollution for the receiving environment and populations in permanent contact with this wastewater or consuming agricultural products irrigated with these waters. Source of life on earth, water is one of the most important natural resources for the socio-economic development of nations. In fact, as a food in its own right, water intended for human consumption must be available in quantity and quality without presenting any health risks. However, its rarity makes it one of the problems facing humanity. According to WHO and UNICEF [3], 1.1 billion people do not have access to drinkable water, especially in arid zones. More recent estimates [4], [5] indicate that this situation would lead to the death of 1.6 million children each year due to diarrheal diseases and nearly 4 million deaths from water and environmental diseases. In addition, population growth, the development of urban planning, the evolution of hygiene and the industrial expansion in Burkina Faso are causing an increasing demand for good quality of water and subsequently, there is an increased volumes of water released after use. This wastewater is a useful resource for market gardening, especially in urban areas. Similarly, in arid and semi-arid regions, the reuse of these waters for irrigation is gaining increasing momentum, as some authors [6], [7], [8] have shown that the importance of this practice is due to the availability and free of charge of these wastewater containing a high rate of chemical fertilizer elements. In addition, the sustainability of wastewater availability is linked to urban growth and urbanization. Indeed, some large cities release more than 70% of their water consumption after use [9]. The large volume of water discharged has led to a strong demand for its valorization as irrigation water in third world cities [9], [10], particularly in the city of Ouagadougou (Burkina Faso). However, the use of wastewater in urban agriculture can cause soil pollution, agricultural products including market gardeners and various diseases. In such a context, it is necessary to know the chemical characteristics of these wastewater and their evolution in the soil.

2 MATÉRAL AND MÉTHODS

2.1 DESCRIPTION OF STUDY AREA

This study was conducted in Burkina Faso (**Figure 1**), a Sahelian landlocked country located in West Africa in the Niger Loop between 9 ° 20 'and 15 ° 5' North Latitude, 2 ° 20 'East Longitude and 5 ° 30 'west longitude [11], [12].]. In fact, Burkina Faso is subdivided into three climatic zones: a Sahelian zone located beyond parallel 14 ° N and which occupies a quarter of the territory with an average annual rainfall of between 300 and 600 mm which lasts 2 to 3 months a year [7]. A Sudano-Sahelian zone located between the parallels 11 ° 30 'and 14 ° N occupies half of the territory and integrates the urban commune of Ouagadougou, city where the experimentation took place. And finally, the remaining quarter of the territory is occupied by a Sudanian zone located south of parallel 11 ° 30 'N. It records the most important precipitation, varying between 900 and 1200 mm and which lasts from 4 to 7 months a year.

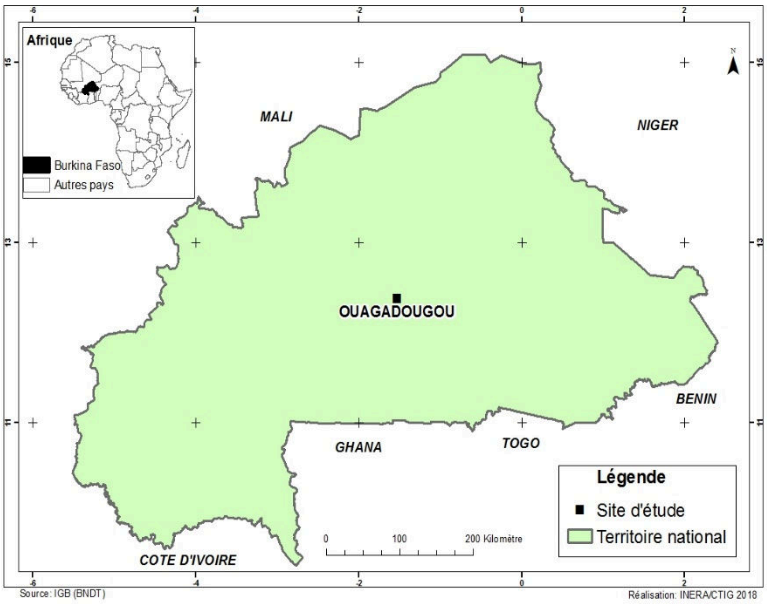

Fig. 1. Location of the study area (Maps INERA CTIG)

The water resources (**Figure 2**) come from the **sewage channels** along the edge of the classified forest that collect wastewater from the Tannerie, the Burkina Brewery Company (SOBBRA), Burkina Faso National Society of electricity (SONABEL), industrial paint and slaughterhouse. Indeed, these companies use mostly bicarbonates to clean water and discharge heavy metals. All this wastewater is discharged to a Water Treatment Plant (WWTP) set up as part of the

Ouagadougou city sewage network for the treatment of wastewater in order to provide irrigation water for quality. Despite these efforts to provide quality irrigation water, the problem of quality water still exists. [13], [14].

Fig. 2. Crude waste waters from the Kossodo canals (Ouagadougou)

2.2 SAMPLING PROCEDURE AND ANALYSIS OF WASTE WATERS

2.2.1 FIELD WORK

The methodology consisted in carrying out **raw sewage samples** for the study of the characterization. Samples were taken for a period of three (3) months at the Kossodo market garden site. Conservation of wastewater samples has been done in accordance with the general guide for the conservation and handling of samples according to ISO 5667 / 3b [15].

2.2.2 ANALYTICAL METHODS

The various physicochemical parameters determined are: the pH, the electrical conductivity (CE), the content of calcium, magnesium, chloride, nitrate, ammonium, carbonate, sulfate, COD, BOD_5, SM, nitrite, sodium, potassium, and phosphates, according to standard analysis techniques of WHO [16]. All physicochemical analyzes were carried out at the soil water plant laboratory of the National Center for Scientific and Technological Research (CNRST).

3 HYDROCHEMICAL FACIÈS

The hydrochemical facies of the wastewater were determined according to the Piper diagram [16] in order to have an indication of their qualitative aspect. The realization of these diagrams was made using the software Diagrams 5.6, designed by Simler [17]. This diagram is used in hydrochemistry for the description of water composition and for easy comparison or classification of the latter. It is composed of two triangles to represent the cationic facies and the anionic facies and a rhombus synthesizing the global facies. Concentrated point clouds represent for the different samples the combination of cationic and anionic elements. This type of diagram is particularly suitable for studying the evolution of the water facies as the mineralization increases or to indicate the types of dominant cation and anions. The Riverside Diagram [18] was also used to assess the risk of salinization and water sodization.

4 DATA ANALYSIS

The physico-chemical parameters data were subjected to one-way analysis of variance (ANOVA) and the differences between the mean values observed between days and periods were compared according to the Newman-Keuls test at the 5% threshold [19]. With Studio 1.1.423 software combined with R 3.4.3 software. Correlations at the 5% threshold between the different variables were analyzed in relation to sampling periods and days. The statistical analysis used is based on Principal Component Analysis (PCA). The PCA is a statistical method that aims to understand and visualize how the effects of isolated phenomena are combined [20], [21].

5 RÉSULTATS AND DISCUSSION

5.1 WASTE WATERS PHYSICOCHEMICAL QUALITY

The assessment of pollution of raw waste water is based on the determination of a number of physicochemical parameters characterizing this wastewater. The physico-chemical parameters of the wastewater are recorded in Table 1.

Tableau 1. Physico-chemical parameters of wastewater from the city of Ouagadougou

Periods	P1	P2	P3	P4	P5	P6	P7
pH (H_2O)	7.5^{bc}	7.47^{bc}	7.73^{c}	7.45^{b}	7.24^{ab}	7.25^{ab}	7.12^{a}
Conductivity (µS/cm)	530.33^{a}	542.5^{a}	564^{ab}	592^{bc}	594.33^{bc}	612.5^{c}	626^{c}
NO_3^-(mg/L)	13.95^{a}	24.45^{ab}	28.78^{ab}	29.88^{abc}	37.64^{bd}	45.48^{cd}	51.58^{d}
NH_4^+ (mg/L)	27.84^{ac}	30.64^{bc}	33.48^{c}	25.20^{ab}	23.94^{a}	22.50^{a}	22.90^{a}
Na^+ (mg/L)	47.4^{a}	49.9^{ab}	51.1^{ab}	52.7^{ab}	53.28^{ab}	54.29^{b}	56.1^{b}
BDO_5 (mg/L)	118^{a}	121^{a}	202^{b}	301^{c}	341^{d}	356^{e}	381^{f}
COD (mg/L)	289.67^{a}	301^{b}	326^{c}	353^{d}	361^{e}	371^{f}	391^{g}
Cl^- (mg/L)	92.63^{f}	91.43^{f}	85.97^{e}	82.9^{d}	71.92^{c}	68.95^{b}	37.97^{a}
Ca^{2+} (mg/L)	24.5^{b}	27.25^{c}	29.2^{cd}	31.55^{de}	32.7^{e}	23.9^{b}	17.4^{a}
Mg^{2+} (mg/L)	3.1^{a}	5.54^{a}	3.8^{bc}	4.15^{c}	4.65^{d}	5.15^{e}	5.65^{f}
HCO_3^-(mg/L)	198.02^{a}	205^{b}	216.71^{c}	224.15^{d}	228.35^{de}	233.7^{ef}	239^{f}
SO_4^{2-}(mg/L)	29.15^{b}	16.4^{a}	36.9^{d}	37.6^{d}	32.4^{c}	40.9^{e}	42.15^{e}
K^+ (mg/L)	46.29^{b}	45.76^{b}	28.95^{a}	25.7^{a}	25.85^{a}	25.30^{a}	26.93^{a}
SAR ($mole^{1/2}.L^{1/2}$)	21.36^{bc}	17.95^{a}	16.50^{a}	18.17^{a}	17.47^{a}	18.97^{ab}	22.01^{a}
MES (mg/L)	210.8^{a}	228.5^{a}	253.5^{a}	345.5^{b}	357.5^{b}	367.5^{b}	392^{b}
P_2O_5 (mg/L)	91.8^{e}	91.13^{e}	87.47^{d}	86.37^{c}	85.73^{c}	83.47^{b}	81.23^{a}
DDL	6						
Probability	< 0.0001						
Manning	S						

** Results are means of 3 replications; S = significant, Test Student Newman-Keuls At the threshold of 5 %, the difference is not significant between values added by the same letter in the same line. P1:1 day, P2:15 days, P3:30 days, P4: 45 days, P5: 60 days, P6: 75 days, P7:90 days.*

5.1.1 PH (H_2O)

During the study period (Table 1), the decreasing evolution of the pH value of the pH value of the pH value of the pH value of the pH value of 7.39 and extreme values of 7.12 to 7.33. El Halouani in Oujda [22] and by Oulkheir in Kenitra [23]. Indeed, according to the FAO [24] and some authors [25], [26], [27], the pH of the irrigation water market is between 6.5 and 8.5, because of these values the solubility of most microelements is optimal. As the pH values of the samples are between 6.5 and 8.5, they are considered as meeting the limits for the direct discharge of water into the receiving medium. Therefore, the pH values being acceptable, they could be valued as irrigation water.

5.1.2 ELECTRIC CONDUCTIVITY OF WATER (EC)

Electrical conductivity is probably one of the simplest and most important for quality control of wastewater. It reflects the degree of global mineralization and provides information on the salinity rate. The results obtained show a more or less significant variation of the mineralization expressed in mean conductivity. The EC values obtained show the very high mineralization of wastewater, with the highest value of 626 µS/cm. The results obtained (Table 1) show an increasing evolution of conductivity higher than the WHO guideline value of 300 µs/cm [27], [28], [29]. Similarly, these average values are less than 2700 µs / cm, considered as the limit value of direct rejection in the receiving medium [30]. In fact, just like pH, conductivity is strongly influenced by temperature, biological processes, but also by calcocarbonic equilibrium [30], [31], [32] : this explains the low values of the conductivity at the beginning of the samples. The conductivity not to be few directly proportional to the mineralization, it is also a function of the chemical composition of the water and the mobility of the ions.

5.1.3 NITRATE AND AMMONIUM

The analysis of nitrates and ammonium ions in wastewater samples provides information on the presence of organic matter in the soil. An examination of Table 1 reveals that the nitrate contents of the wastewater analyzed are 99% below the Maximum Allowable Value (50 mg / L) set by WHO [2], [27], [33] and 1 % only is polluted. As a result, the waters studied are not subject to nitrate pollution (Figure 3).

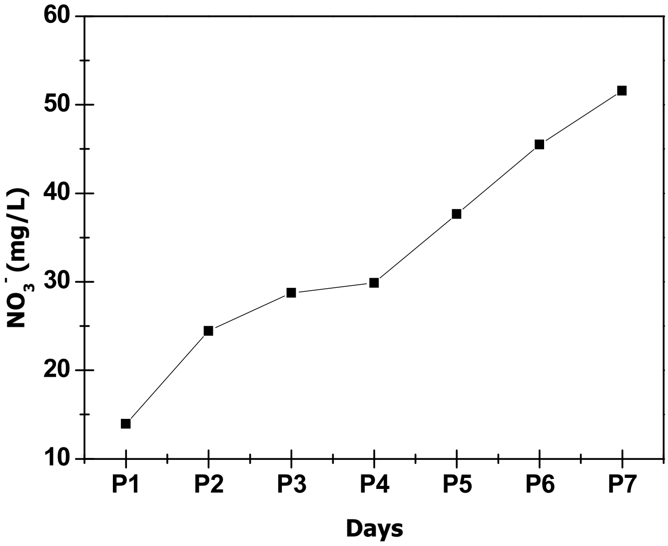

Fig. 3. Temporal evolution of nitrate in wastewater

Ammonium, meanwhile, has significant concentrations, with a maximum of 33.48 mg / L which was observed from P3 (30th day) (Figure 4). This can be explained by the oxidation of the organic material, which consequently leads to an increase in the ammoniacal nitrogen. But these values remain below the value allowed by the WHO standards (45 to 50 mg/L) [27], [34]. Indeed, the oxygen demand by ammonium is very high; they are odorous molecules (nitrogen compounds) that cause bad smells. This makes it possible to classify the wastewater of Ouagadougou industrial zone among the effluents with the least amount of ammonia nitrogen.

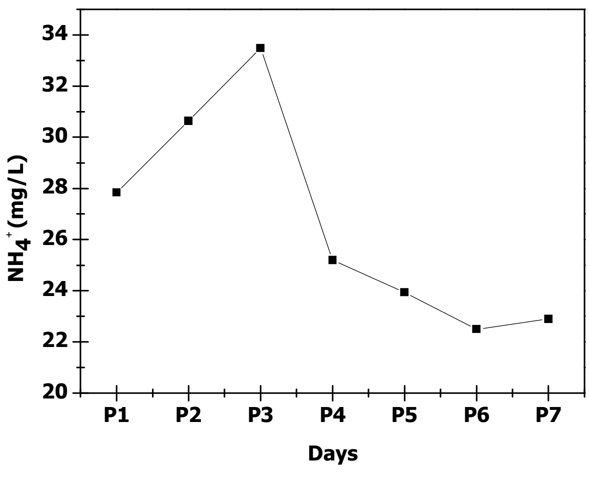

Fig. 4. Temporal evolution of ammonium in wastewater

5.1.4 SODIUM AND POTASSIUM

The sodium content (Figure 5), evolve to reach a maximum rate of 56.1 mg/L raised in P7, a light spatial variation is recorded for the other samples. According to the results of the analyzes carried out during the study period, the sodium contents are globally low. Concerning this parameter, the majority of wastewater analyzed during this study are eligible for agriculture, because no value exceeding the maximal allowed value (150 mg/L) by the WHO has been recorded [33], [35]. The results of the potassium analyzes show that their contents vary from 25.3 mg/L for P6 to 46.29 mg/L for P1 thus having a small variation, therefore below the WHO standard (200 mg / L) [27] (Table 1).

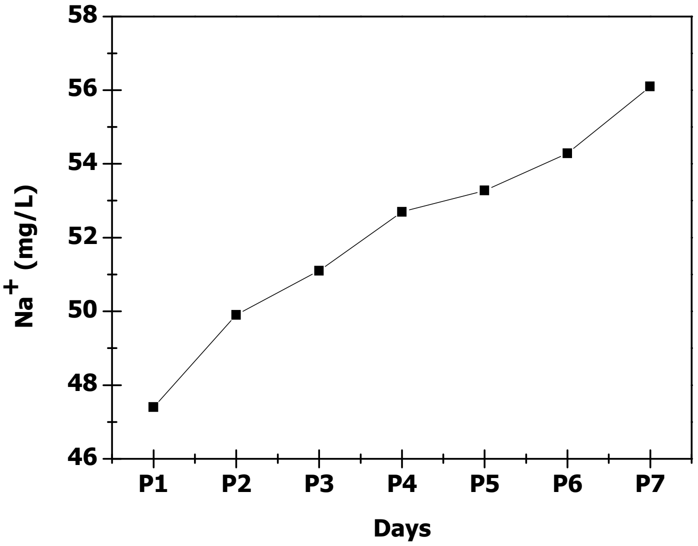

Fig. 5. Temporal evolution of the sodium in the wastewater

5.1.5 CALCIUM AND MAGNÉSIUM

The calcium content of wastewater reaches a maximum of 32.7 mg / L Ca2 + for P5 and 5.67 mg / L Mg2 + for P7 (Table 1). An increase of this concentration is observed in both chemical elements. Completion of these ions with others explain this evolution. This increase seems sufficient to question the infiltration of wastewater. Indeed, the solubility of CaCO3 is increased in the presence of proteins and weak acids, resulting from oxidations of organic matter [36]. Besides, the use of water containing Ca^{2+} and Mg^{2+} ions for watering plants can cause clogging of the system drop by drop [28]. These considerable values cover amply needs of all kinds of crops, even the most demanding.

The calcium and magnesium ion contents are too high for wastewater used in vegetable crops, the sodium concentration in the irrigation water is estimated by the sodium absorption ratio (SAR). The SAR describes the amount of sodium in excess of the calcium and magnesium cations, which can be tolerated relatively in the irrigation water. The SAR was determined from the sodium, calcium and magnesium levels according to equation 1

$$S.A.R = \frac{[Na^+]}{\frac{([Ca^{2+}] + [Mg^{2+}])^{1/2}}{2}} \qquad \text{équation 1}$$

For the samples, the average value of the SAR is 18.92, a very high value that can lead to salinization of soils irrigated by water of this type. A continuous use of water with high SAR will result in soil deconstruction. In general, the parameters responsible for the salinization of water are significant in the wastewater, this is the case of bicarbonates.

5.1.6 CHLORIDE AND SULPHATE

Table 1 above shows the measurement results for chloride content in wastewater. Chloride levels in the study area range from 37.97 mg/L to 92.63 mg/L. This content responds to a decreasing gradient, related either to chlorides complexation and their decantation along the path of the flow of wastewater in pipes with possible infiltration, or to a chemical transformation that prevents their detection. Indeed, it is recommended to have a water whose chloride content is between 0 and 100 mg/L for the irrigation of the plants [31], [32]. Therefore, studied waters are very good compared to the maximal value of 100 mg/L defined by the tolerance of irrigation water [27]. This leads to conclude that the studied wastewater presents no danger for agricultural activities, but also for the development of the species that depend on them.

Sulfates (Table 1) present very high levels respectively a maximum of 42.15 mg/L recorded in P7 (90th days), the presence of sulfates is probably due to an accumulation of these elements since industrialists often reject detergents to base of sulphiites (metastable state) which are transformed (oxidation) into sulfate. The sulfate contents obtained are below the WHO standards (250 mg/L [27], and can therefore be toxic for plants in market garden crops.

5.1.7 COD, BDO5, SM

La The Chemical Oxygen Demand (COD) represents the amount of oxygen consumed, in mg/L, by the oxidizable materials contained in an effluent [37]. It is representative of most of the organic compounds, but also oxidizable mineral salts. The wastewater studied presents a maximum of 391 mg/L (Table 1) in COD. This shows that the waste used in market gardening are highly oxygenated. As for BOD_5, the values recorded are from 118 to 381 mg/L with an average value of 260 mg/L. Besides, the average value in SM is 307.9 mg/L (Table 1). This result is often related to the heavy load of organic and mineral matters. The high rate of suspension solids in wastewater can cause a significant decrease in the infiltration of irrigated soil with this type of water; because several studies have showed that the hydric components of the soil are almost exclusively dependent on these surface hydraulic properties. The average SM values are much lower than those given by El Katri à Sidi Bennour [38] and Mohammed et al [39] in Morocco.

For a better appreciation of the origin of wastewater from these studied effluents from the Kossodo market garden site, the calculation of the ratios COD / BOD_5, BOD_5 / COD, MES / BOD_5 and the estimation of the oxidizable matter has very important (Table 2).

Tableau 2. Ratios wastewater of Kossodo market garden site

	Avg.	Max.	Min.	Standard deviation	Number of sample
COD/BDO_5	1.55	2.49	1.03	0.66	7
BDO_5/COD	0.74	0.97	0.4	0.24	7
SM/BDO_5	1.31	1.89	1.03	0.37	7
Oxidizable substances (mg/L)	191.7	253.4	125.4	90.51	7

5.1.8 BIODEGRADABILITY COEFFICIENT (COD/BDO5)

Wastewater can be classified into two categories: biodegradable and non-biodegradable. The calculation of the biodegradability coefficient of raw wastewater effluents makes it possible to define the biodegradability of the effluent. It is calculated by the ratio COD/BOD_5 and depends on the nature and origin of the wastewater that can be domestic or industrial, which requires different treatments according to Metcalf [40]. Indeed, the ratio COD/BOD_5 for raw wastewater is generally between 1.25 and 2.5. When the COD/BOD_5 ratio is between 3 and 7, the wastewater can be difficult to biodegrade. The raw wastewater from the Kossodo market garden site presents a COD/BOD_5 ratio ranging from 1.03 to 2.49 (Table 2) conformity with that of domestically dominated urban wastewater with a COD/BOD_5 ratio of less than 3 [41]. We can clearly observe that the wastewater is generally biodegradable for all the samples studied. The ratio obtained are similar to those reported by Aboueloufa [42] for wastewater from Oujda, where the ratio is less than 2.5.

5.1.9 RATIO BDO_5/COD

To characterize an industrial pollution, one often considers the ratio BOD_5/COD, which gives very interesting indications on the origin of a pollution of the wastewaters and its possibilities of treatment. For this study, the ratio is relatively high of the order of 0.74 as an average value (Table 2). It is the general case for discharges loaded with organic matter. This organic load makes these wastewater fairly unstable that is they will evolve quickly to forms "digested" with the risk of release of odors. Indeed, the wastewater from this collector is in organic predominantly. There is a highly significant correlation between COD and BDO_5 of wastewater at the Kossodo market garden site in the city of Ouagadougou. Figure 6 shows R^2= 0.9739 (y = 2.947x – 747.8373) for BDO_5 and COD followed by R^2 = 0.9825 (y = 136.4x + 0.6596) for SM and BDO5.

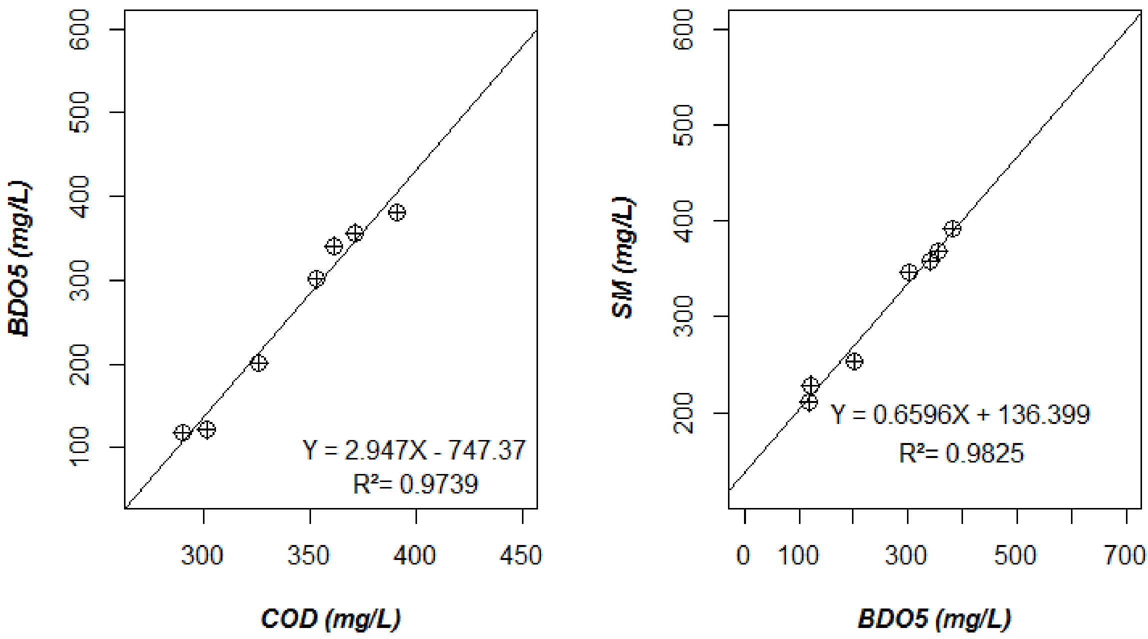

Fig. 6. Correlation established between DBO5, DCO and MES of wastewater

5.1.10 Ratio SM/DBO_5 and oxydables substances (MO)

For wastewater from the Kossodo zone market site, the BOD5 / COD ratio is high (0.74), which confirms that the wastewater drained by the collector (STEP station) is heavily loaded with organic matter (Table 2).). This result obtained is confirmed by the estimate of the oxidizable material, which is of the order of 191.7 mg / L with an average ratio of MES / DBO5 equal to 1.31.

In addition, the COD / BOD5 ratio is low (1.55), which allows us to deduce that the organic matter load in the wastewater from this collector is easily biodegradable according to Zerhouni [41].

5.1.11 Bicarbonate

The found values of the alkalinity show that the wastewater of this collector is characterized by an average content of calcium bicarbonates ($CaCO_3$) of the order of 221 mg/L (Table 1).

5.1.12 Phosphate

Phosphorus levels recorded in orthophosphates do not vary significantly during the sampling cycle. The recorded values vary between 81, 23 mg / L and 91.8 mg / L with an average value of 86.74 mg / L (Table 1). In fact, phosphorus compounds exist in natural waters and wastewater in various forms, namely soluble orthophosphates, water-soluble phosphates and organophosphorus derivatives [43]. Generally, this high value of the phosphate content does not pose any problems in the biological activity of the soils. Its presence has no particularly harmful effects, but it is an indicator of anthropogenic pollution [44].

5.2 HYDROCHEMICAL FACIÈS

The Piper diagrams corresponding to the raw waste water samples from the seven sampling sessions are shown in Figure 7. They explain the hydrochemistry of the wastewater studied on the Piper diagram. Examination of the contents of major elements shows that the mineralization of these waste waters is governed by the sodium and potassium ions for the cations and by the bicarbonate ions and the nitrate ions for the anions. Thus, according to the ionic dominance of these waters, we can distinguish: (1) at the level of the anions (triangle on the right) the waters are moderately bicarbonated and have a low nitrate nitrate tendency which is linked to the high nitrate and / or chloride contents of certain waters; (2) for cations (left triangle), these waters are sodic and / or potassium. Overall, the projection obtained by the combination of the cation-anion (diamond) complex gives a bicarbonate and sodium chloride facies. These results show that these wastewaters have undergone a certain deterioration in their quality, which can be explained by the infiltration or leaching of polluting ions such as nitrates, chlorides, sulfates [45], [46], [47].

Thus, the slight evolution towards the pole of chloride and nitrate ions, two major indicators of anthropogenic pollution explains a certain contamination of wastewater by these elements. This could be due to a lithological input and infiltration of industrial effluents from the area that would have modified or contributed, by direct or induced transfers of industrial contaminants, the chemistry of these waters.

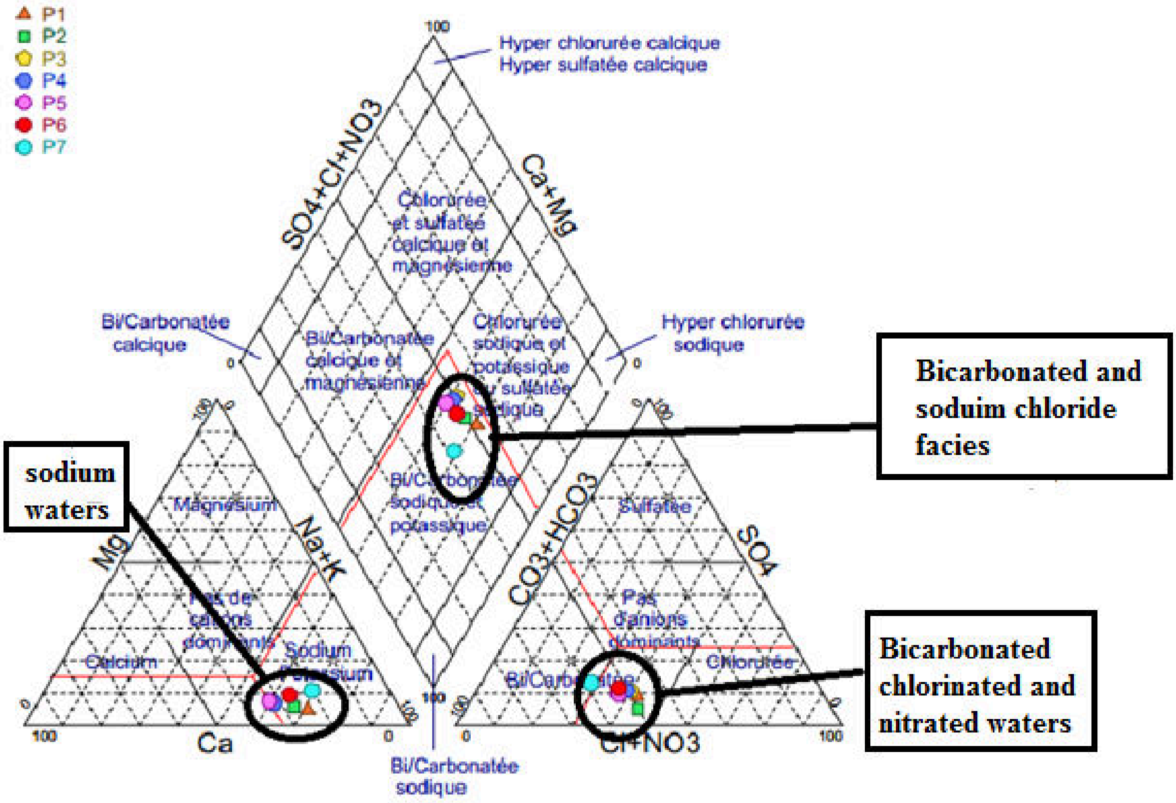

Fig. 7. Classification of crude waste waters on Piper diagram

Figure 8 (card) which presents the spatial distribution of the SAR average according to the Bradai method [18], shows that the strong values of the SAR are observed in all the samples. In this zone of study, the SAR is upper to 5 and waters can cause a danger of alkalinization of the ground, that is a danger of sodicité and salinity [48].

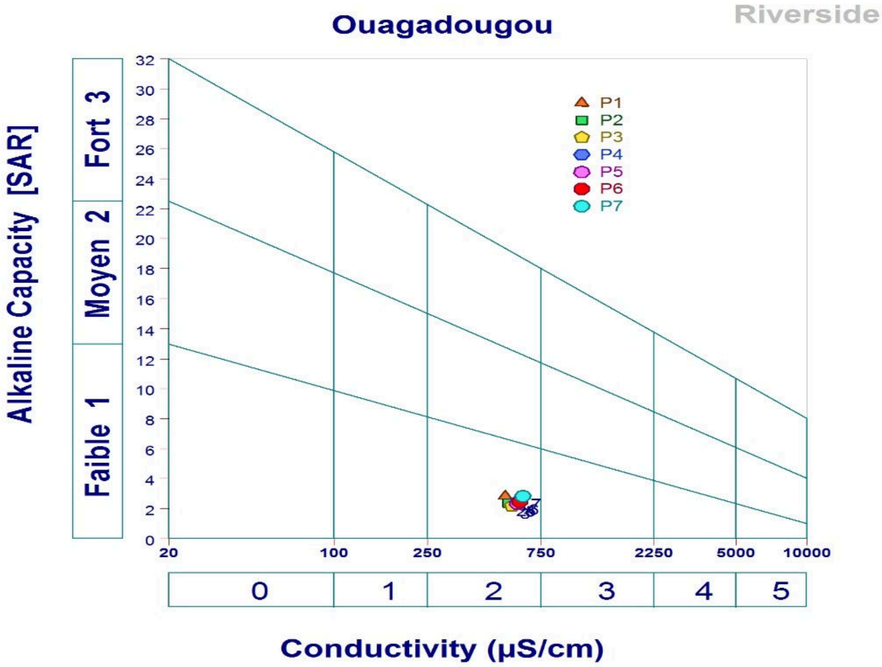

Fig. 8. Diagram for classification Riverside crude waste waters based SAR [20].

SAR : sodium adsorption ratio (méq/L).
CE: Electric conductivity at 25 ° C (µS/cm).

6 CONCLUSION

The results of the analyses carried out made it possible to assess the physicochemical quality of the wastewater used on the Kossodo market garden site in the Ouagadougou. The contents of chemical elements make it possible to conclude that the wastewater can be valorized in urban agriculture without major risk of soil and plant pollution. However, the high content of certain salts such as sodium in these waters leads to the conclusion that the wastewater must be analyzed continuously in order to assess the evolution of the soil salinization level and to make corrections if necessary. These waters are of great benefit because of their high content of nutrients for the soil. Indeed, all these analyzes have been showed that wastewater contains enough substances to make a rich soil, but what must be remembered is that these waters must be well treated to reduce their content in certain elements in order to avoid any fast degradation of soils. The use of wastewater for irrigation purposes is of great interest in that they can replace the chemical fertilizers that used in the long run lead to premature soil degradation. This use of wastewater nevertheless makes it possible to cope with the ever-increasing needs of the populations' water, so it is important for us to work in the direction of making better use of this resource in Burkina Faso. The reuse of these waters for agricultural purposes is also a source of pollution. Indeed, when it is rejected in nature, it becomes a source of pollution for the environment because its high rate of nitrates contributes to the pollution of the atmosphere, due to nitrogen emission. As a recommendation, regular monitoring and rationalization of wastewater use for irrigation is needed for sustainable use of agricultural land.

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