J. Mater. Environ. Sci. 6 (9) (2015) 2583-2595
ISSN : 2028-2508
CODEN: JMESCN

Contribution of the Principal Component Analysis (PCA) to the evaluation of the physico-chemical pollution of raw wastewater from the city of Khenifra -Morocco-

Baroud S.[1*], Belghyti D.[1], Aziz F.[2,3], Sadi M.[1], ElKharrim Kh.[1]

[1]*Laboratory Environment and Renewable Energies, Faculty of Science, University Ibn Tofail PO Box 133 Av. 14000 Kenitra, Morocco*

[2]*National Center for Study and Research on Water and Energy, PO Box 511; Cadi Ayyad University, Marrakech, Av. Abdelkrim Elkhattabi, 40000, Morocco.*

[3]*Laboratory of Hydrobiology, Ecotoxicology and Sanitation (LHEA, URAC 33), Faculty of Science Semlalia, Marrakech-Morocco.*

Received 2015, Revised 2015, Accepted Aug 2015
[*]*Corresponding Author. E-mail:baroud044@yahoo.fr;Tel: (+212672386980)*

Abstract

The present study aimed to characterize raw wastewater of Khenifra city (Morocco), to evaluate pollution in relation to the demographic and socio-economic profiles of the population connected to the network sanitation, and interpreting the results with the contribution of ACP. The physico-chemical characterization of raw wastewater revealed that liquid effluents are loaded with organic matter in terms of COD (COD average = 556.02 mg/L) whether a load of 3373.94 kg/day, a BOD_5 (Avg. = 284.55 mg/L) with a load of about 1731.20 kg /day. TSS (Avg. = 239.20 mg/L) whether a load of about 1457.04 kg/day, and mineral expressed in terms of electrical conductivity (Avg. = 1801.61 µS/cm) with a pH of 8.13. The mean levels of total phosphorus and TKN are of the order of 94.07 mg/L and 12.17 mg/L, respectively. Although these wastewater has a high organic load (BOD_5 /COD = 0.51 and MES/BOD_5 = 0.85) they have satisfactory biodegradability. The exam of ratio COD/BOD_5 = 2.00 highlights the good biodegradability which biological treatment seems entirely appropriate. Statistical analysis of the results by principal component analysis (PCA) performed on 56 individuals and 9 variables (Flow rate, Temperature, EC, TSS, TKN, TP, COD, BOD_5) show the existence of a strong positive and significant correlation between the TSS, BOD_5, COD and electrical conductivity. The factorial plan F1, axis of pollution, represents 42.44% of the variance. The second plan F2 represents only 25.24%.

Key words: Pollution, Wastewater, PCA, COD, BOD_5, Biodegradation

1. Introduction

The wastewater management is a huge problem challenged the world. This is due to increasing population, extensive industrialization, and high urbanization [1]. The urban development and the form it takes, allow asking about their impact on the environment. Given that the domestic and industrial activities generate toxically effluents constitute the major sources of the natural water pollution load [2].

The quality of wastewater effluents is responsible for the degradation of the receiving water bodies, such as lakes, rivers, streams, etc. But, the potential deleterious effects are manifold and depend on volume of the discharge, the chemical and microbiological concentration/ composition of the effluents.

So it seems that the wastewater effluent contribute with different modalities of pollution. Some of these include eutrophication, increased water purification cost, interference with the recreational value of water, health risks to humans and livestock, excessive loss of oxygen and undesirable changes in aquatic populations [2]. Among indirect interventions to limiting urban spread is the wastewater management given the apparent lack of efficiency of direct instruments [3,4].

Wastewater releases of the Khenifra city (an urban city in Morocco) are estimated at 14.707 m^3 per day, this wastewater is discharged to the Oued Oum Errabia without treatment [5]. This situation presents real threats to the city's environment and its inhabitants were more directly or indirectly exposed to the waterborne diseases risk.

Before assessing the impact of wastewater discharges on the receiving environment, it seems logical to present the physico-chemical characteristics of raw wastewater from the city of Khenifra. The physico-chemical characterization parameters of urban effluents are a good way to estimate the quality of urban wastewater and its impact on the receiving environment [6].

The objective of this study consists firstly in physico-chemical analysis by determining some major and global parameters, indicators of the state of pollution, then to a detailed assessment of the degree of organic pollution of wastewater, and finally to a statistical analysis to interpret the results with a data analysis tool of the temporal variability of the physico-chemical quality of wastewater from the city of Khenifra.

2. Materials and methods

2.1 Site of study

Khenifra city is located in Meknes -Tafilalet region at an altitude of 830 m, latitude 32º 56,142 'and longitude 05º 40 465 "on the banks of the Oum Errabia Oued, in the crowded corridor basalt flows between the Middle Atlas of Mesata (Central Plateau Moroccan), Khenifra appears as a red city, reflecting the color of the clay soil that surround it, its geo- morphological position represents a basin surrounded by four major mountains west Bamoussa , Akllal east, north Bouhayyati (Table Zayan) and Jbel Lahdid south.

The city is crossed by the Oued of Oum Errabia. Its geographical position makes it a strategic location; it is on the main road 24 (road axis useful for Khenifra economy) 170 km from Fez and 320 km from Marrakech.

The climate of the Khenifra province is continental Mediterranean mountainous, cold and rainy in winter, hot and dry in summer. Rainfall varies from East to West and from North to South depending on the altitude, latitude and exposure. The superficial waters are exploited mainly from natural outlets and are commonly used in surface irrigation of the traditional type. Groundwater is generally shallow and does not allow continuous use and operation.Demographically, the population of the region amounted to 100,000 inhabitants in 2004, adapting the census data to the administrative division 2009.

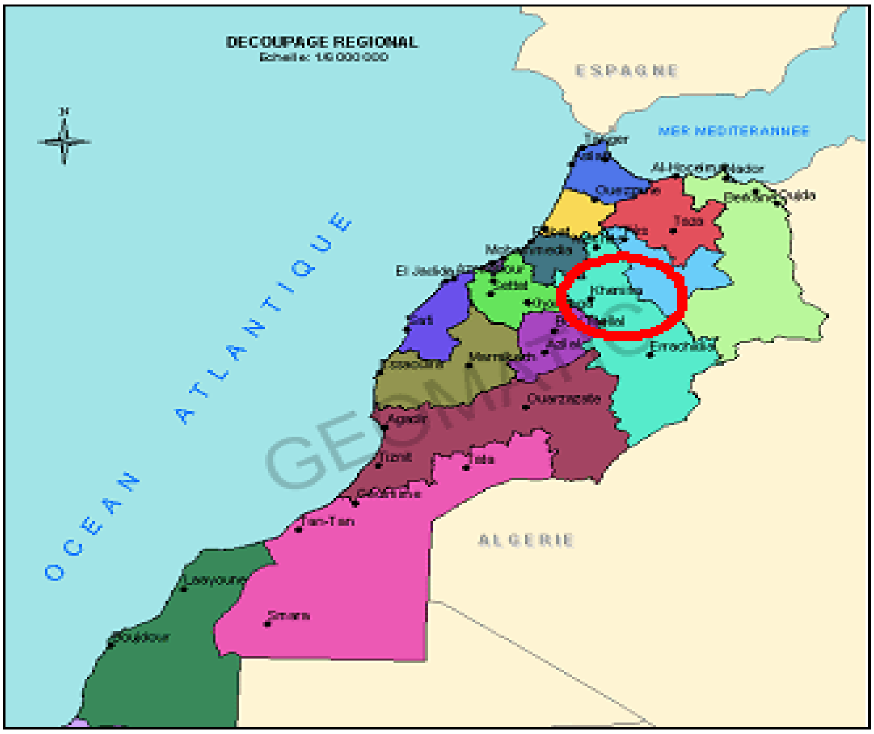

Figure 1: Localization map of Khenifra city.

2.2 Sampling and analytical methods

Daily samples were taken at the inlet of the wastewater treatment plant of Khenifra between January 2014 and March 2014. Samples of raw wastewater are collected in polyethylene bottles of 1 liter and transported to the laboratory for analysis in 4°C.

The hydraulic monitoring of the daily flow rate is determined using a Venturi channel type HQT-48ON. The studied physico-chemical parameters are Temperature, pH, Electrical Conductivity (EC), Chemical Oxygen Demand (COD), Biological Oxygen Demand for 5 days (BOD_5), Total Suspended Solids (TSS), Total Kjeldahl Nitrogen (TKN) and Total Phosphorus (TP).
The temperature was determined by a numerical thermometer and pH by a numerical pH meter type HQ11d. The electrical conductivity was measured with a conductivity meter HQ14d. The TSS (total suspended solids) is determined by filtering a volume of waste water on cellulosic filter (0.45 µm) [7].
BOD_5 (Biological Oxygen Demand 5 days) is determined by the respiratory method using a BOD numerical meter type BOD Direct HACH LANGE.
The Total Kjeldahl Nitrogen (TKN), total phosphorus and COD (Chemical Oxygen Demand) are analyzed by colorimetric methods using a mass spectrophotometer type DRB 200, according to the analysis standard of Rodier [7].

2.3. Statistical analysis
The statistical study was based on Principal Component Analysis. The PCA is a data analysis tool that helps to explain the structure of correlations or covariances using linear combinations of the original data. Its use reduces and interprets the data in a small space [8].
The matrix of intermediate correlations, correlations between variables and the axes and the projection of variables in the space of axes F1 and F2 were obtained with SPSS 20 software (Statistical Package for the Social Sciences).

3. Results and discussion
3.1 Hydraulic parameters
The evaluation of flow rate versus time allows the building of a curve as shown in Figure 2, which have an average flow rate of variation between 4170.00 m^3/d and 115135.00 m^3/d as minimum and maximum extremes average values. Indeed the amplitudes of the variations are of the order of 7343.00 m^3/d and the average standard deviation of 1426.08 m^3/d (Table 1).

Table 1: Temporal evolution of raw wastewater daily flow rate

Parameters	average	Interval	Standard deviation (SD)
Daily flow rate (m^3/d)	6485.23	4170.00 - 11513.00	1426.08

Figure 2 shows the temporal evolution of the daily flow of raw wastewater from the city of Khenifra. The average of the input daily volume of wastewater is 6485.24 m^3/d. This presents 44.09% of the flow of the project of the realization of the Khenifra WWTP in 2025 horizon.

3.2 physicochemical parameters
The evaluation of the pollution of the raw wastewater is done by determining a number of physico-chemical parameters characterizing these waters. The physico-chemical characteristics of raw wastewater from the city of Khenifra are summarized in Table 2.
The average temperature of the raw wastewater of Khenifra recorded is of the order of 15.72°C, and as minimum and maximum extremes average values between 14.20°C and 19.50 °C (Figure 3). The values of the temperature of raw wastewater are less than 30°C, considered as a direct discharge limit value in receiving environment. Similarly, these values are lower than 35 ° C, considered to be indicative limit values for water destined for irrigation [9].
The evolution of the pH of wastewater discharges from the city of Khenifra during the study period (January 2014 to March 2014) showed that the inlet of raw wastewater to the WWTP are fairly basic with a mean value of 8.13 and extreme values of 7.77 to 8.54 (Figure 4). It should be noted that the pH values of less than 5 or greater than 8.5 affect the growth and survival of microorganisms [10]. In addition, the pH is an important element for the interpretation of the corrosion in the pipes and installations in WWTP.

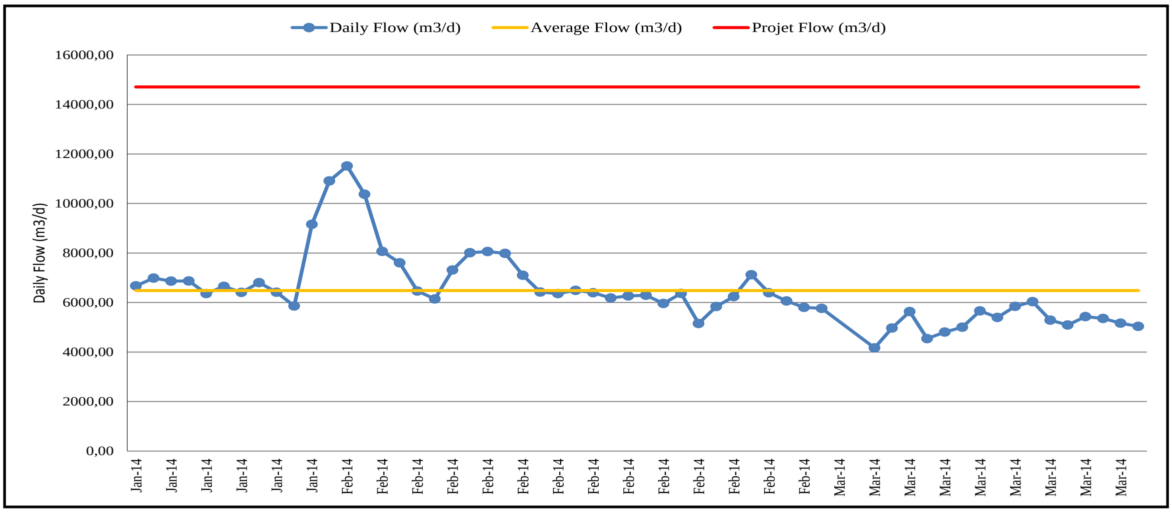

Figure 2: Raw wastewater daily flow rate temporal evolution of Khenifra city

Table 2: Physico-chemical parameters of raw wastewater of Khenifra city

Parameters	Unite	Average	Interval	SD
Major parameters				
Temperature	°C	15.72	19.50-14.20	0.85
pH		8.13	8.54-7.77	0.15
Electrical conductivity (EC)	µs/cm	1801.61	2162-800	262.86
Global parameters				
Total suspended solids (TSS)	mg/L	240.49	83.30 - 476.00	97.52
Biological oxygen demand (BOD_5)	mg/L	284.55	78.00 - 538.37	108.77
Chemical oxygen demand (COD)	mg/L	556.02	108.00 1092.00	214.86
Total Kjeldahl Nitrogen (TKN)	mg/L	94.07	76.00 - 204.00	26.46
Total phosphorus (TP)	mg/L	12.17	8.14 - 18.50	3.04
Ratios				
COD/BOD_5		2.00	1.54 – 3.24	0.36
BOD_5/COD		0.51	0.31 - 0.65	0.08
TSS/ BOD_5		0.85	0.22 – 1.31	0.15

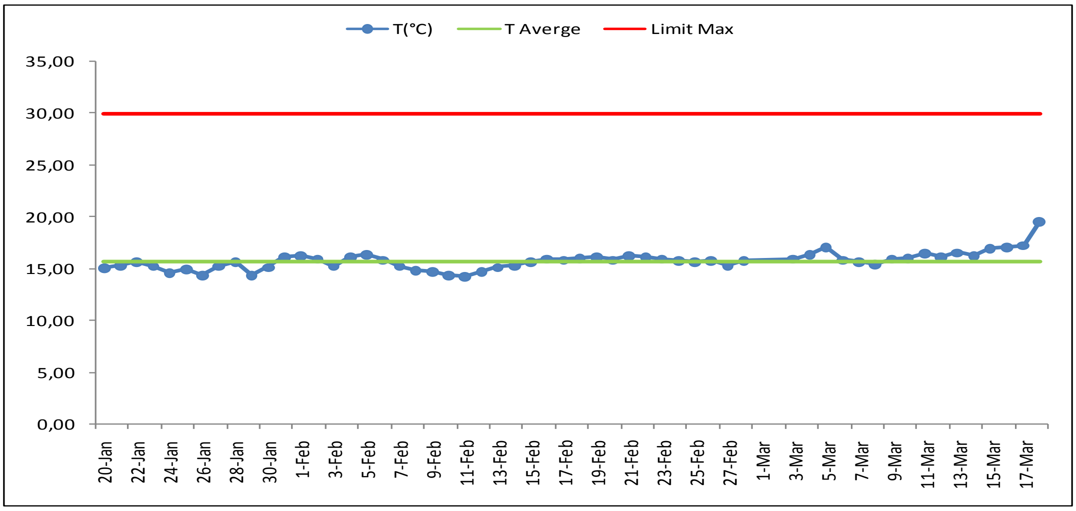

Figure 3: Temperature temporal evolution of raw wastewater of Khenifra city.

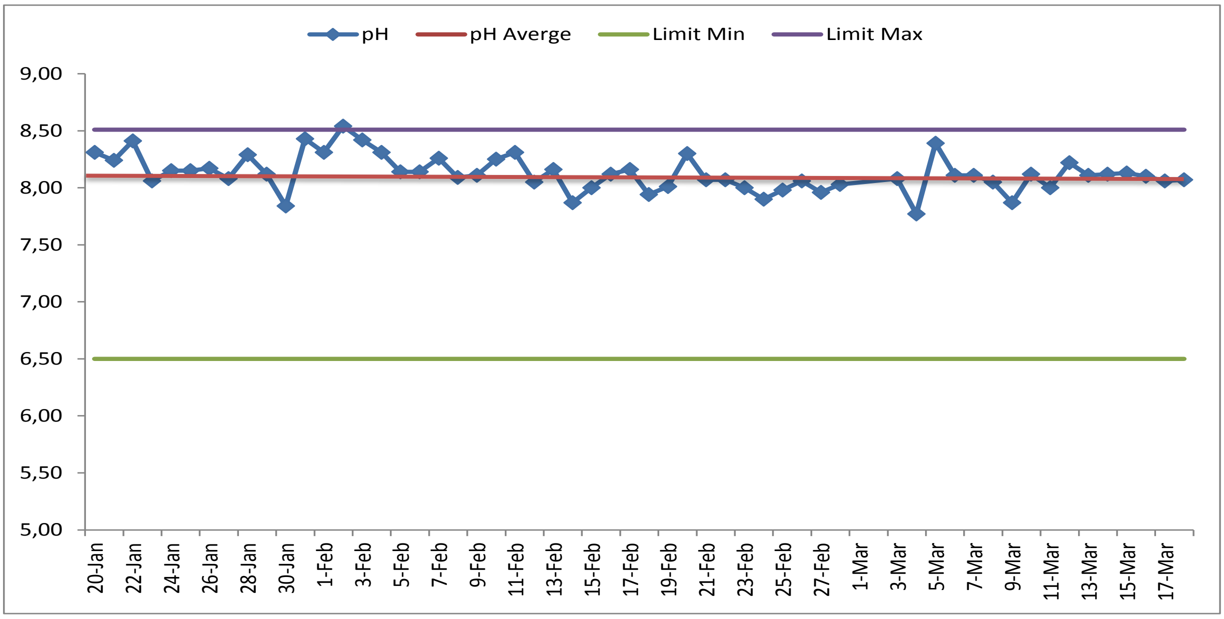

Figure 4: pH temporal evolution of raw wastewater of Khenifra city.

Electrical conductivity indicates the degree of salinity or the concentration of dissolved salts in water. It is one of the simplest and most important parameters for the quality control of wastewater. The average values are between 800.00µs/cm and 2162.00 µs/cm with 180.61µs/cm as total average value (Figure 5).
The results show that the average values are less than 2700µs/cm, considered as direct discharge limit value in receiving environment [9].
These results are different from those encountered in wastewater of Ouagadougou and Noukchoutt [11, 12]. Those of Oujeda [10] and for wastewater of BelKsiri [13]. The values of electrical conductivities from wastewater of Khenifra are also lower than those found in Marrakech [14].

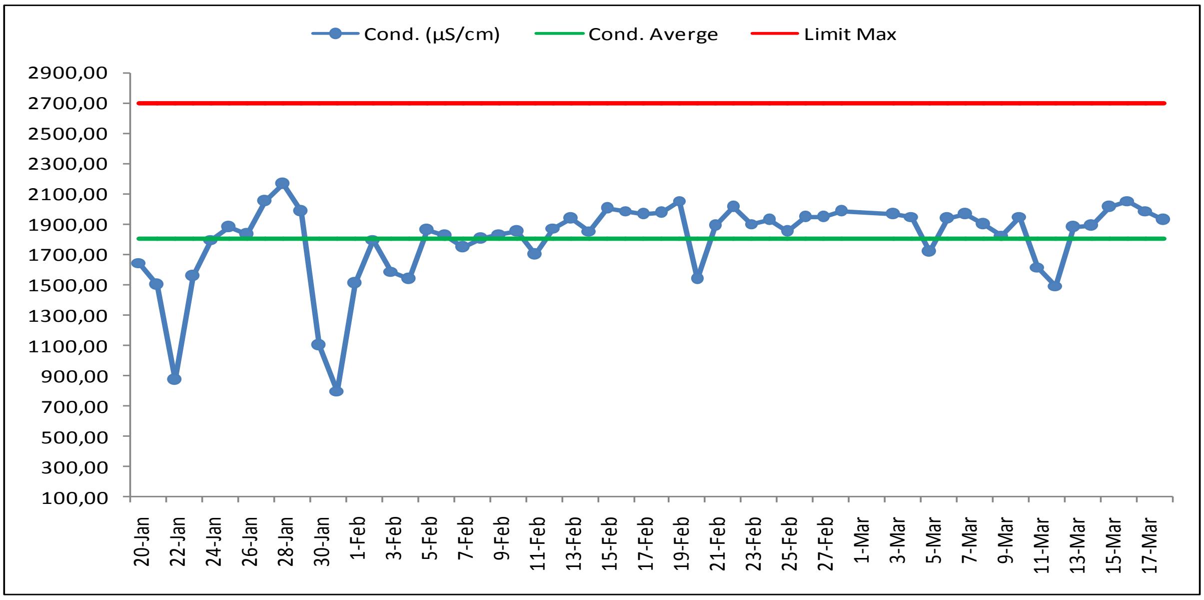

Figure 5: Electrical conductivity temporal evolution of raw wastewater of Khenifra city

Biological oxygen demand is the quantity of oxygen on (mg/L) which consumed by the purifying biomass to decompose organic matter in the effluent [15]. The values of the concentration of BOD_5 varied from between 78.00 mg/L as the minimum value and 538.37 mg/L as the maximum value (Figure 6), with an average value of 293.2 mg/L.

These concentrations are comparable to those found in wastewater from the city of Marrakech [16], and lower than those found in Kenitra (335 mg/L) [17] and higher than those encountered in Souk ElarbaGharb (162 mg/L) [14]. These concentrations are above the water reuse standards for irrigation and direct discharge standards (100 mg/L) [9].

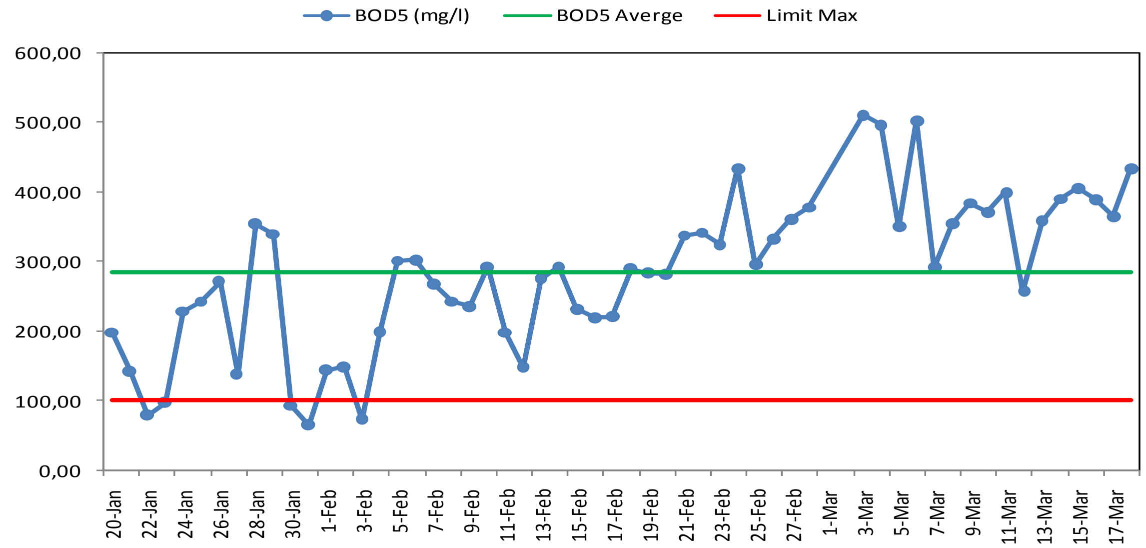

Figure 6: BOD_5 temporal evolution of raw wastewater of Khenifra city.

The chemical oxygen demand (COD) is the amount of organic matter oxidizable by chemical means [15]. The contents of the COD of raw wastewater from the city of Khenifra range between 108.00 mg/L and 1092.00 mg/L with an average of 551.02 mg/L (Figure 7).
These concentrations are comparable to those found in wastewater from the city of Ouarzazate (571 mg / l) [10], higher than those found in Kenitra (501.00 mg / L) [17], and Souk ElarbaGharb (235.00 mg / L) [18] and lower than that found in Nouakchott (603.40 mg/L) [12]. These levels are much higher than the direct Moroccan discharge standards and reuse for irrigation [9].

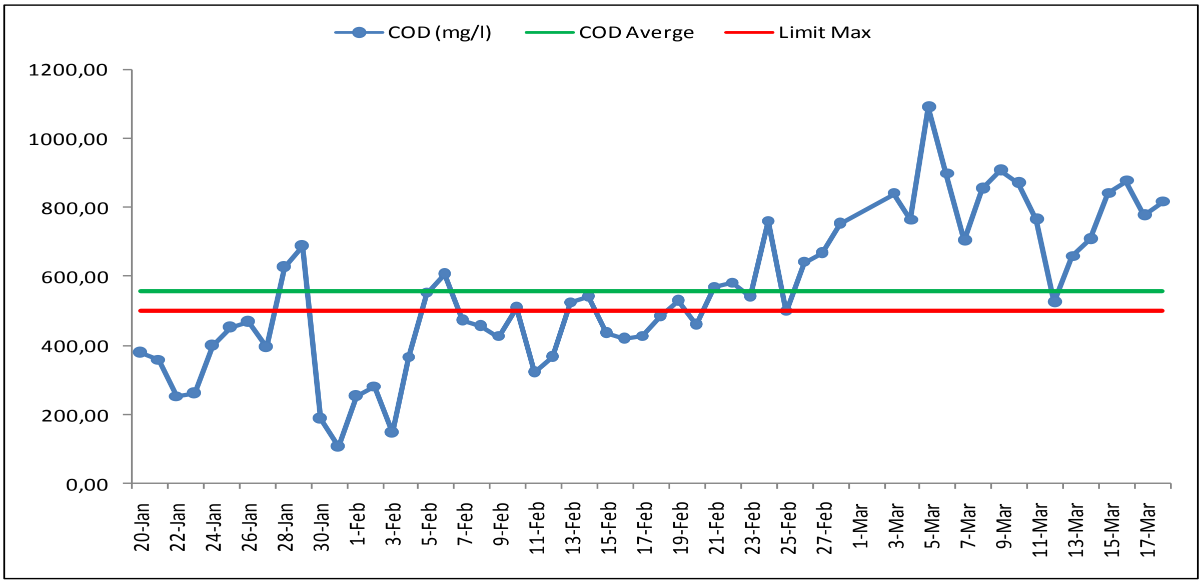

Figure 7: COD temporal evolution of raw wastewater of Khenifra city.

The total suspended solids, can lead to physical or biological clogging and thus a reduction in soil aeration anaerobic conditions [19]. TSS also contributes to unbalance the aquatic environment by increasing turbidity and can have a direct adverse effect on the respiratory apparatus of fish [15].

The analysis of the results (Figure 8) shows that wastewater from the city of Khenifra have TSS concentrations oscillating between 83.30 mg/L and 536.34 mg/L with an average value of about 239.75 mg/L. These concentrations are lower than those found in the city of Oujda (Morocco) [10] and largely exceeding the standard for the direct discharge of wastewater recommended by WHO [9].

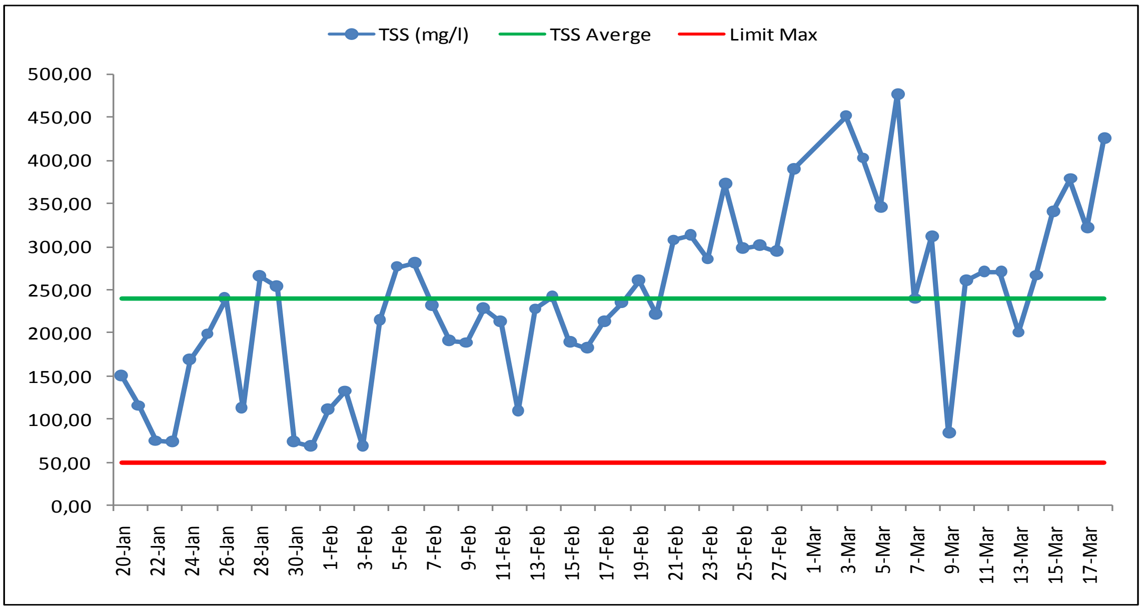

Figure 8:TSS temporal evolution of raw wastewater of Khenifra city.

The content of total kjeldhal nitrogen of raw wastewater of Khenifra is about 94.07 mg/L with a minimum value of about 67.00 mg/L and a maximum value of 204.00 mg/L (Figure 9). The amount of excess nitrogen can have adverse impacts on the environment. When an increase in nutrients occurs, as nitrogen, from either point sources or diffuse entry and increases primary productivity, and causes a shift in trophic status, an aquatic system is said to be experiencing eutrophication. This is concurrent with increases in harmful algal blooms and associated detrimental effects on aquatic food webs, commercial fisheries and public health [22].
Indeed, nitrogen in excessive quantities may, firstly, cause in high soil permeability the contamination of groundwater and, on the other hand, delay ripening of crops and increase the tendency to pay for grain.

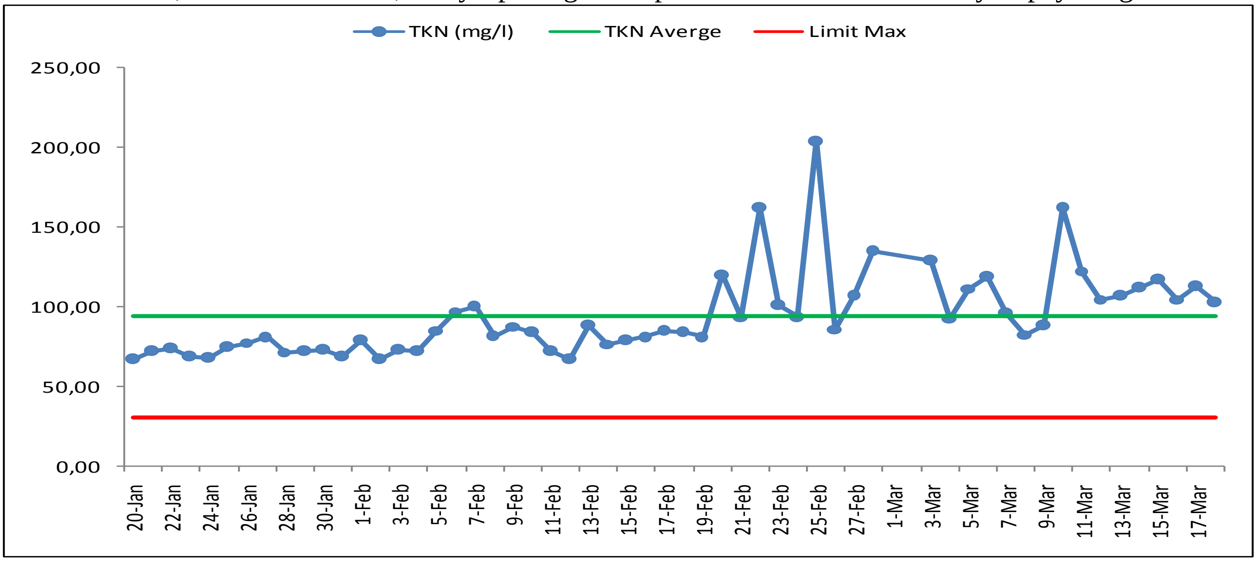

Figure 9: TKN temporal evolution of raw wastewater of Khenifra city.

In practice, the total Kjeldahl nitrogen is an indicator of environment pollution and its control allows monitoring contaminations evolution [21].

Total phosphorus concentrations evolution in the raw wastewater of Khenifra has shown that they are more concentrated with an average content of 12.97 mg /L, and the extreme values of 7.02 mg/L to 19.15 mg /L (Figure 10).These values exceed the Moroccan standard direct discharges to the receiving environment [9]. This increase in the phosphorus content is due to a high degree of mineralization of the organic matter.

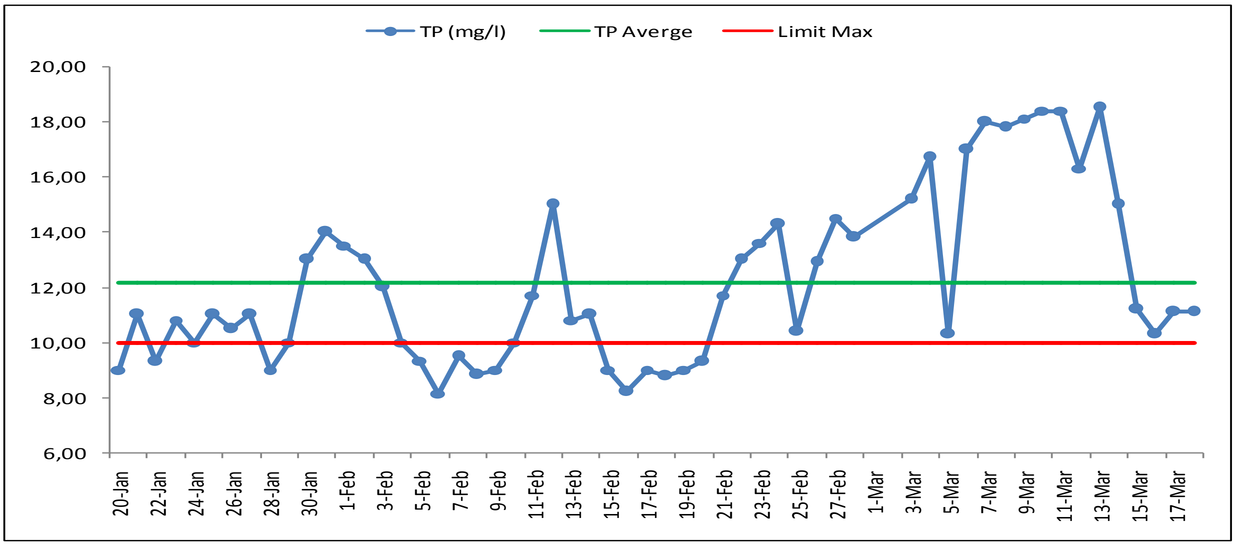

Figure 10: Total phosphorus temporal evolution of raw wastewater of Khenifra city.

3.3. Assessment of organic pollution of wastewater

For a better understanding of the origin of the waste water, the calculation of ratios COD/BOD_5, BOD_5/COD, TSS/BOD_5 and estimate the oxidizable matter (OM) have significant interests (Table 3).

Using these characterization parameters is a good way to give an image of the pollution level of effluent from the city of Khenifra and also to optimize the physico-chemical parameters of wastewater in order to propose a suitable processing mode.

The ratio COD/BOD_5 is important in the definition of a raw wastewater treatment chain. Indeed, a low value of COD/BOD_5 involving the presence of a large proportion of biodegradable materials allows envisaging biological treatment. Conversely, a large value of this ratio indicates that a large portion of the organic material is not biodegradable and, in this case, it is preferable to consider a physico-chemical treatment [22].

The average value of the ratio COD/BOD_5 is 2.00, which is consistent with the wastewater with a COD/BOD_5 lower than 3 [23]. This result supports the conclusion that these effluents have a domestic dominant character.

Table 3: Ratios of BOD_5, COD and TSS of raw wastewater and estimating OM

	Average	Max	Min	SD
COD/BOD_5	2.00	3.24	1.54	0.36
BOD_5/COD	0.51	0.65	0.31	0.08
TSS/BOD_5	0.85	1.08	0.22	0.14
OM	375.04	634.00	78.67	140.69

Ratio COD/BOD_5

The ration COD/BOD_5 used to indicate whether the wastewater discharged directly into the receiving environment has characteristics of domestic wastewater (COD/BOD_5 less than 3) [24]. The results are an indication of the importance of pollutants little to non-biodegradable [6]. Wastewater has a COD/BOD_5 ratio of about 2.00, between 2 and 3 (Figure 11). So we can conclude that even if the wastewater discharge has a high organic load, they are readily biodegradable [25].

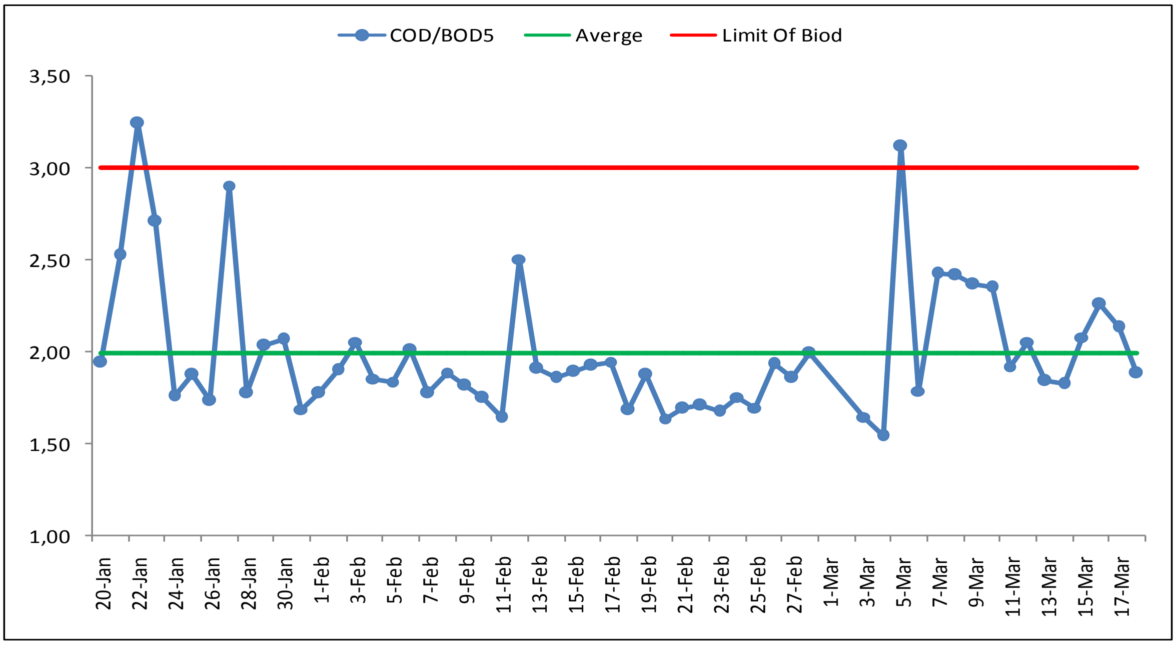

Figure 11: The ratio COD/BOD_5 temporal evolution of raw wastewater of Khenifra city.

Ratio DBO_5/COD

It is often considered the ratio of BOD_5/COD, which provides powerful insights into the origin of sewage pollution and its treatment options [25]. In discharges of wastewater from the city of Kenifra, the ratio of BOD_5/COD is of the order of 0.51 confirming that these waters are heavily loaded with organic matter in contrast weakly loaded with inorganic matter (Table 3) and readily biodegradable[6].

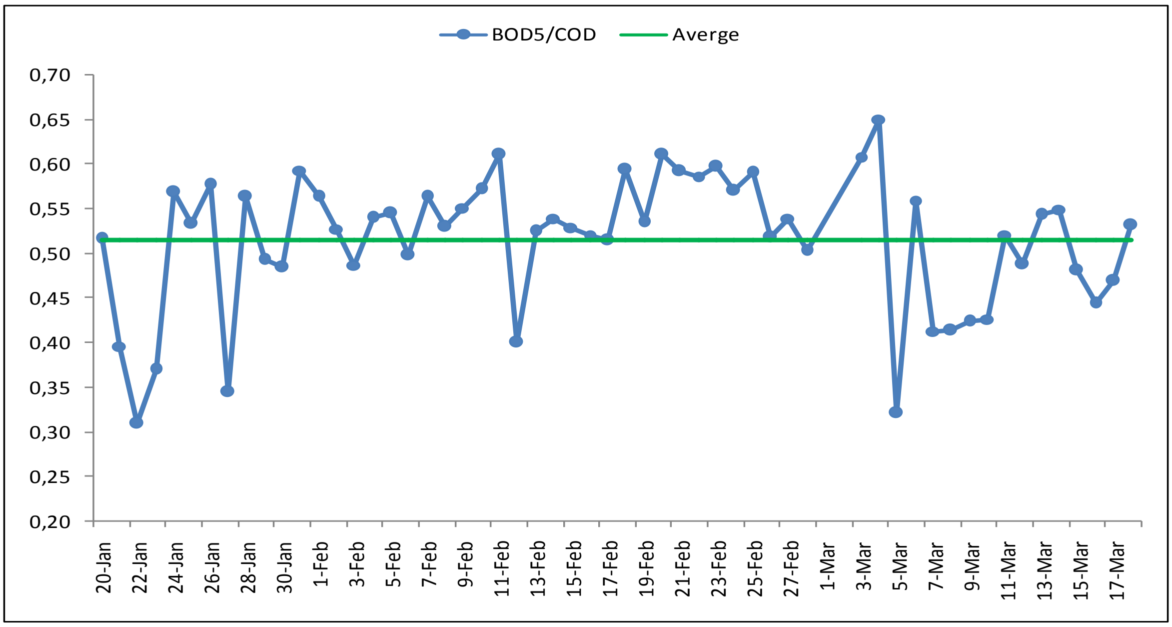

Figure 12: The ratio BOD_5/COD temporal evolution of raw wastewater of Khenifra city.

Ration TSS/BOD_5 and Oxidizable matter (OM)

In the level of discharged wastewater, the BOD_5/COD ratio is high (0.51), which confirms that they are highly loaded with organic matter. This result is confirmed by the estimation of the oxidizable material, which is in the order of 378.25 mg/l with an average ratio of TSS/BOD_5 of 0.83, Furthermore, the ratio COD/BOD_5 is low (2.00), which allows to infer that the wastewater effluent from the city of Khenifra is loaded with organic matter and readily biodegradable [6].

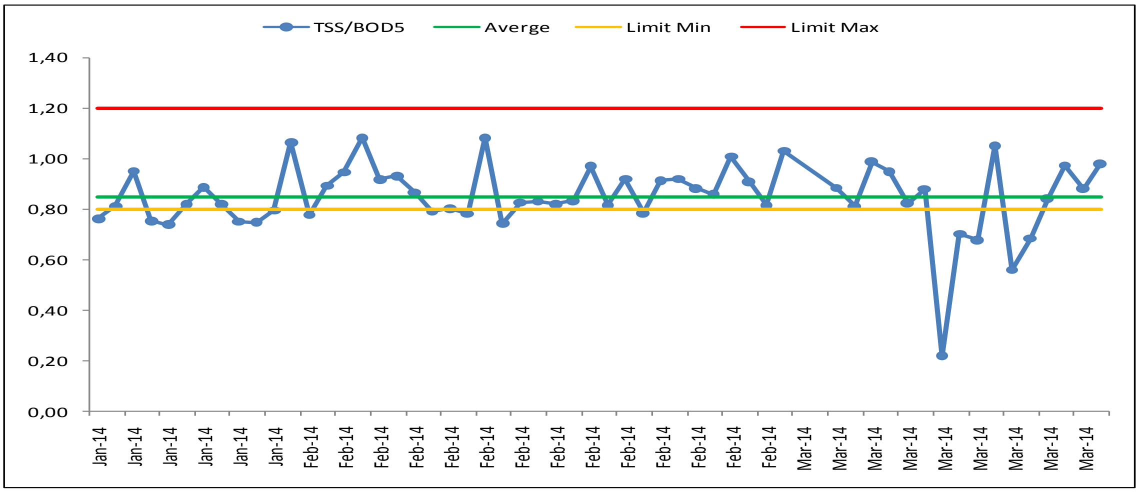

Figure 13: the ratio TSS/BOD_5 temporal evolution of raw wastewater of Khenifra city.

In addition, values of the ratios TSS/BOD_5 obtained are low compared with those found in the city of Kenitra [25]. The values obtained could be explained by the fact that the suspended solids settle rapidly upstream release points causing a decrease in their content in the raw wastewater, this decrease is even larger than the discharge flow rate is low (Figure 14).

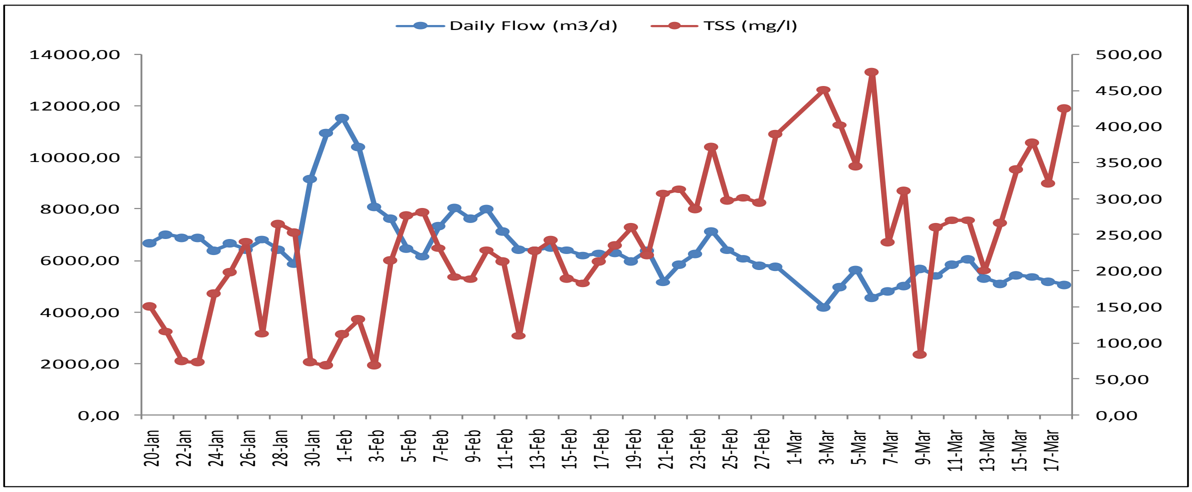

Figure 14: TSS and flow rate evolution of raw wastewater of Khenifra city.

3.4 Statistical analysis

The data processing by the Principal Component Analysis, using as variables, flow rate, temperature, pH, conductivity, total suspended solids, BOD_5, COD, Total Kjeldahl Nitrogen (TKN), total phosphorus (PT) (mg/L) and as individuated the 56 samples taken at the inlet of the Khenifra WWTP.

To facilitate the visualization of cloud points are projected in a two-dimensional space. Matrices of inter-element correlations are given in Table 4.

The correlation study between the variables (Table 5) showed a highly significant positive correlation between the TSS with COD (0.782) and BOD_5 (0.903) and a negative and moderately significant correlation with the rate (-0.653).

Also a negative and weakly significant correlation was observed between TSS and total phosphorus and pH.

A positive correlation was observed weakly significant between the TSS and the temperature and the electrical conductivity.

We give in Table 6 the correlation coefficients between the variables and the two axes F1 and F2. Figure 15 reveals the projection of the spatially variable axes F1 and F2.

Table 4: Matrix of inter-element correlations

Variable	Flow	T	pH	Cond.	BOD_5	COD	TSS	TKN	TP
Flow	1.000								
T	-0.273	1.000							
pH	0.459	-0.074	1.000						
Cond.	-0.581	0.097	-0.415	1.000					
BOD_5	-0.704	0.414	-0.456	0.606	1.000				
COD	-0.748	0.459	-0.378	0.568	0.889	1.000			
TSS	-0.653	0.449	-0.335	0.563	0.903	0.782	1.000		
TKN	-0.553	0.538	-0.257	0.492	0.721	0.682	0.749	1.000	
TP	0.359	-0.116	0.173	-0.096	-0.077	-0.090	-0.207	-0.176	1.000

Table 5: Correlations between variables and factors

	F1 (42.44 %)	F2 (25.24%)
TKN (mg/L)	0.840	-0.207
TSS (mg/L)	0.828	-0.382
BOD_5 (mg/L)	0.822	-0.451
COD (mg/L)	0.818	-0.401
T(°C)	0.773	0.255
pH	-0.127	0.754
Flow (m^3/d)	-0.549	0.671
Cond. (µS/cm)	0.413	-0.651
TP (mg/L)	-0.004	0.459

Figure 15 reveals the projection of the spatially variable factorial axes F1 and F2, the first F1 axis, which explained 42.44% of the variance is expressed by its positive pole by TSS, BOD_5, COD and TKN, while the second axis F2, which represents 25.24% of the variance, is constituted by the TSS, BOD_5 and COD in the negative direction and pH, temperature and flow rate in the positive direction.

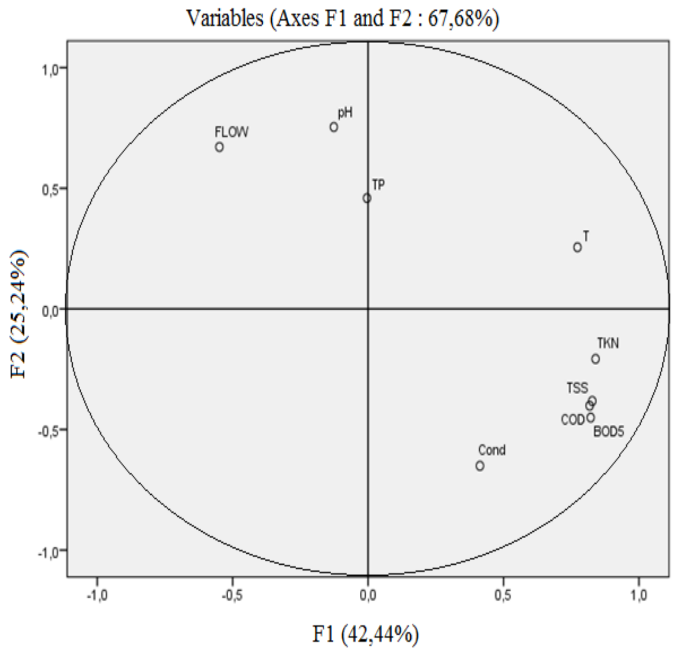

Figure 15: Variables projection in the axes of space F1 and F2

Generally, this correlation of the circle formed by the axes F1 and F2 give 67.68% of the total information shown, according to the axis F1, a contrast between the flow and the pH of the one part and the degree of pollution by organic matter, suspended solids and on the other hand conductivity. According to the axis F2, there is the same opposition as the first axis, and also between the waters with phosphorus highly polluted waters by nitrogen. The high levels of these parameters characterize highly mineralized water rich in organic matter and nutrients.

Conclusion

The quantity and quality of urban waste water depend mainly on the amount of water used, the percentage of the amount that ends up to reach sanitation network influenced by climatic conditions, living standard of the population connected to the sanitation public network, social habits and habitat type.

The monitoring of degree of physico-chemical pollution of urban wastewater from the city of Khenifra (Morocco) allowed us to identify a set of information regarding quality as a direct discharge into the receiving environment, for later reuse in agriculture. The major physical and chemical parameters of wastewater exceeds relatively the general limits of direct discharges to the receiving environment which will raise negative influences for the growth of bacteria and market gardening, also harms the environment and especially to the current state of the river Oued Oum Errabia.

According to the evaluation of the degree of organic pollution, we can see that all the studied parameters (COD, BOD_5 and TSS) located Khenifra wastewater in high concentrations slice. The coefficient of COD / BOD_5 confirms that the raw wastewater from the city of Khenifra is heavily loaded with organic material that can be inferred that these effluents are domestic dominant character.

The Principal Component Analysis of physico-chemical data allowed us to highlight the correlation between the different parameters and differentiate a typology of the quality of domestic release to the study site. PCA showed that high TSS is in favour of a large organic matter load of BOD_5 and COD (a positive correlation, highly significant), which may signify that the TSS dominated by oxidizable organic matter. While the wastewater flow rate negatively affects TSS rate (negative correlation) due to the effect of dilution. Discharge of urban wastewater without treatment can have a significant environmental impact. At the end of improving the situation and for good preservation of the receiving environment a wastewater treatment project is required to respect Standard Moroccan Direct Discharges and limit the impact on the quality of water resources and human health.

References

1. Aziz F., Farissi M., *Ann. W. U. T-Ser. Bio.2* (2014) 95.
2. Akpor O. B.and Muchie M.,*Afr J Biotechnol.* 10 (2011) 2379.
3. Newburn. D. A.,Berck, P.*Agr. Resource Econ. Rev.*, 3 (2011) 375.
4. Harrison M., Stanwyck E., Beckingham B., Starry O., Hanlon B., *Newcomer. J.*, 29 (2012) 483.
5. BioWater.,(*dimensionnemen, Etude de conception et dimensionnement des ouvrages STEP de la ville de KHENIFRA*), (2010) Rapport, p56.
6. Boutayeb M., Bouzidi A., Fekhaoui M., *Bulletin de l'IS, Rabat, section Sciences de la Vie*, 34 (2012) 145.
7. Rodier J. et al., L'analyse de l'eau, 9^eme^éditon. DUNOD (éditeur), Paris, France. (2009), p 1579.
8. Maliki A.M., *Thèse de Doctorat Fac*. Sci. Sfax, (Tunisie). (2000) p301.
9. Ministère de l'environnement du Maroc (2002) « *Normes Marocaines, Bulletin officiel du Maroc* », N° 5062 du 30 ramadan 1423. Rabat.
10. Rassam A., Chaouch A., Bourkhiss B., Ouhssine M., Lakhlifi T. et El Watik L., *Les Technologies de laboratoire*, 7 (2012), 70
11. Hama Maiga A., *Sciences de l'eau / Journal of Water Science*, 21 (1998) 399.
12. Demba N'Daiye A., Ould Sid' Ahmed Ould Kankou M. et Ibno Namr Kh. *ScienceLib*, 3 (2011)748.
13. El Khokh K., Belghyti D., El Kharrim Kh., Kbibch A., Chentoufi M., Belghyti R. *ScienceLib*., 3 (2011) 2111.
14. Rochd R., *Mémoir d'Ing. D'Etat Fac. des Sci. et Techniques*, Mohammedia. (2014) p 115
15. Gaid A., *Techniques de l'Ingénieur. Mise a jour du texe de J. Sibony*, (1993) p 2
16. Ouazzani N., *Thèse d'Etat de l'Université Cadi Ayyad*, Marrakech, (1998). p221.

17. El Guamri Y., Belghyti D., Cisse M., ElKharrim Kh., Sylla I., Raweh S., Barkia H., *Agronomie Africaine* 19 (2007) 251.
18. Kbibch A., Belghyti D., Elkharim K., et El Khokh. K. (2011). *Science Lib*. 3 (2011)110203.
19. Agence des États-Unispour le développement international (USAID)., Revisión Des Normes de Qualitédes Eaux Usées Traitées. Compétitivité économique du Maroc « *Ebauche de révision des normes de qualité des eaux usées traitées destinées à l'irrigation des cultures et l'arrosage des espacesverts*. (2013) 58.
20. Serediak N.A., Prepas E.E. and. Putz G.J., *Environmental Geochemistry*.11 (2014) 305.
21. Hajji Ch., Bendou Abd., Hassou Moh., *Revue Internationale d'Héliotechnique*, N°45 (2013) 29.
22. Ouali M. S., *Office des publications universitaires*, *Ben Aknoun*, Alger (2001)10.
23. ONEP. *Approche de la typologie des eauxuséesurbainesauMaroc*. ONEP et GTZ. Rabat (1998) p78
24. Hamaidi F., Zahraoui R., Hamaidi M.S., Megateli S. *Science Lib.* 4 (2012)73.
25. Belghyti D., El Guamri Y., Ztit Gh., L.Ouahid My., Joti My B., Harchrass A., Amghar H., Bouchouata O., El Kharrim Kh., Bounouira H., *Afrique SCIENCE*. 05(2) (2009) 199.

(2015) ; http://www.jmaterenvironsci.com/