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# Spatiotemporal multivariate analysis by principal component analysis (PCA) of effluent discharged into the municipal slaughterhouse wastewater drained by the Oued Beht (Morocco)

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**ABSTRACT**

*In order to assess the level of pollution caused by waste from the slaughterhouse of the city SidiSlimane, the aim of our study was to perform a statistical study by principal component analysis (PCA) of wastewater drained by the Oued Behtriver (Morocco). To do this, a series of **analysis** physicochemical parameters was carried out from ten urban wastewater collectors (**C1, C2, C3, C4, C5, C6, C7, C8, C9, C10**), tank located inside the slaughterhouse and collector carrying domestic wastewater mixed with wastewater from the slaughterhouse during the period November 2012 and August 2013. The **analysis** performed as COD (chemical oxygen demand), $BOD_5$ (biological oxygen demand), SS (suspended solids),Fecal Coliforms bacteriological parameters (FC) and Fecal Streptococci (FS). For bacteriological parameters, there is increased from upstream to downstream in fecal contamination of fecal coliforms (FC) and fecal streptococci (FS). Statistical analysis provided us according **F1XF2** 60.8% of the total variance and has confirmed a strong correlation between the (physical and chemical parameters - months) (**M1, M2, M3, M11, M12**) to months (**M4, M5, M6, M7, M8**) which results in a decrease in oxygen and an increase in pollution parameters. According **F1 X F2** giving 56.86% also confirms a strong correlation between the (physical and chemical parameters - stations) and informs us that there is more pollution from upstream stations **C1** to **C10** to the downstream stations P2 and**P1** (outfall effluent from the slaughterhouse).*

**Keywords**: Wastewater, slaughterhouse, water courses Assessment Tools (SEQ), multivariate analysis.

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## INTRODUCTION

Among the food processing industry, there are slaughterhouses. They produce effluents that bring body fluids of animals slaughtered in contact with the external environment on the one hand and on the other they use water as a solvent for their cleaning tasks. [1]

Lack of awareness towards environmental protection, lead to a serious ecosystem imbalance and generate pollutants that can affect the physico-chemical and biological quality of aquatic receptors.

In Europe, the waste water discharged volumes are estimated between 6 and 9 liters per kg of beef carcass, and 5 to 11 liters per kg of carcass of pigs [2] .The most studies on wastewater quality slaughterhouses were carried out in Europe [3-6], Australia [7] and the United States of America [8]. In Morocco little research work has been carried out on the characterization and treatment of waste water from slaughter. [9]

The purpose of this study was to evaluate the degree of pollution from wastewater that is drained by the river Oued Beht and offer appropriate treatment to their reuse and reduce the nuisance suffered by the recipient.

However multivariate analysis methodology allows us to extract information and structure of large amounts of data, and also the treatment of environmental data that are useful to confirm the temporal and spatial variations caused by natural and anthropogenic physical factors [10]. Multivariate statistical techniques such as principal component analysis (PCA) were widely used as data analysis methods on water quality. The CPA is a fundamental right and one of the most popular multivariate statistics based monitoring methods [11].

## EXPERIMENTAL SECTION

### 2.1 Study site

The town of Sidi Slimane is located on the southern edge of the Gharb plain, 70 km for from the city of Kenitra. The town is crossed by Oued Behtriver which divides it into two sectors: East and West Sector.

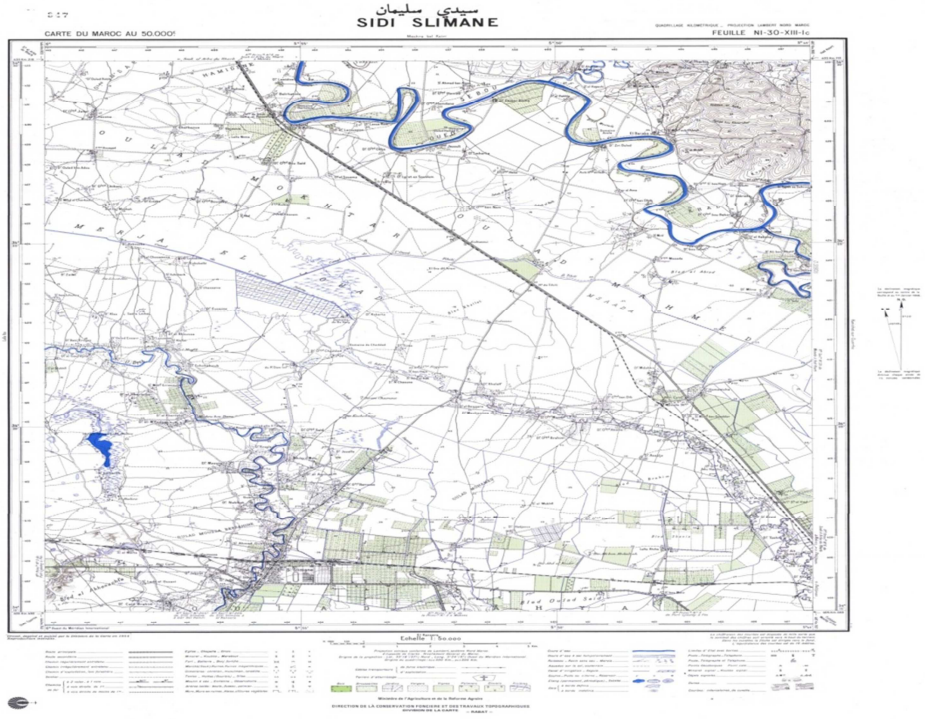



**Figure 1: (map of the town of Sidi Slimane. ORMVAG)**

It is located in the irrigation sector of the river Beht which is 30 000 ha, the area is served by the dam of El Kansra 30 Km au way from Sidi Slimane. The predominant crop in the area are beets, oranges, cotton, vegetable gardening and cereals. The right area of the city of Sidi Slimane has a unitary type sewerage system: in other words, wastewater and storm water channeled. While the left area has a mixed network, the main collectors and part of the secondary collectors operate in single mode, and the rest of the network is in pseudo-separative mode. The total length of the sewerage system is 150 Km, serving approximately 86% of the population. The remaining uses of individual sanitation systems are cesspools or septic tanks. In 2012, the red meat production is 970 tonnes consisting 60% from cattle, 40% of ovine. Wastewater from this rejection are charged by solid waste, fats, plenty of organic material (debris rumen) and concentrated by the blood of slaughtered animals.

The town of Sidi Slimane has a slaughter house to enable where the receipt and control of animals before slaughter and the quality inspection of meat for final consumption.

### 2.2. Physico-chemical analysis

The samples were taken at ten collectors of urban wastewater (**C1, C2, C3, C4, C5, C6, C7,C8, C9, C10**), tanks located inside the slaughterhouse and tank P1 collector carrying domestic wastewater a mixed with wastewater from the slaughterhouse tank P2 the time period between November 2012 and August 2013. The wastewater samples are collected in polyethylene bottles of 1 liter and 500 ml by AFNOR [12].

All physicochemical parameters have been recommended by the method of (Rodier, 2009) [13] as the pH with a pH meter type CONSORT C831 equipped with a probe measuring the temperature. The electrical conductivity was measured by a conductivity meter type CONSORT K912. The TSS (Total suspended solids) are determined by filtering a volume of wastewater on borosilicate glass fiber filter. The chemical oxygen demand (COD) was

determined by the colorimetric method (by oxidation in an acid medium by potassium dichromate). The biochemical oxygen demand ($BOD_5$) was determined by the method OxiTop. Nitrates, ammonium, chloride, total nitrogen and total phosphorus were determined by the continuous flow method.

**Description of study sites**

Figure 2 shows the block diagram of the sampling points.


**Figure 2: Block diagram of sampling points**

- **C1**: Output collector located 31.41 meters, coordinated (X = 450495.2704, Y = 406335.4496). It is a point of domestic waste in the city of SidiSlimane.
- **C2**: Output collector located 36.15 meters, coordinated (X = 450639.0516, Y = 406515.0719). It is a point of domestic waste in the city of SidiSlimane

**C3**: Exit manifold located 36.93 meters, coordinated (X = 450679,517, Y = 406505.618). It is a point of domestic waste in the city of SidiSlimane.

- **C4**: Output collector located 36.98 meters, coordinated (X = 450733.7578, Y = 406503.0397). It is a point of domestic waste in the city of SidiSlimane.
- **C5**: Output collector located 37.58 meters, coordinated (X = 450794.8863, Y = 406515.0719) .It a point of domestic waste in the city of SidiSlimane.
- **C6**: Output collector located 36.73 meters, coordinated (X = 450847.4051, Y = 406528.909). It is a point of domestic waste in the city of SidiSlimane.
- **C7**: Output collector located 35.29 meters, coordinated (X = 450893.0363, Y = 406555.5516). It is a point of domestic waste in the city of SidiSlimane.
- **C8**: Output collector located 34.93 meters, coordinated (X = 450915.4214, Y = 406569.3025). It is a point of domestic waste in the city of SidiSlimane.
- **C9**: Output collector located 34.13 meters, coordinated (X = 451020.4591, Y = 406766.4913). It is a point of domestic waste in the city of SidiSlimane.
- **C10**: Output collector located 32.69 meters, coordinated (X = 451174.0068, Y = 407020.5231). It is a point of domestic waste in the city of SidiSlimane.
- **P1**: Output collector of raw water municipal slaughterhouse in the town of SidiSlimane, located 30.40 meters, coordinated (X = 451136.2833, 407153.3868 Y =).
- **P2**: Output collector located 30.66 meters, coordinated (X = 451108.0987, Y = 407152.8075). It is a point of domestic waste mixed raw water municipal slaughterhouse in the town of SidiSlimane.

**2.3. Bacteriological analysis**

The bacteriological analysis focused on germs indicators of pollution which include the Fecal Coliforms (FC) and Fecal Streptococci (FS) as bacteria (Rodier, 2009)[13]. Each dilution series of 100 ml was filtered through a membrane filter (d = 0,45µ) and then placed in a specific culture medium to Fecal Coliforms (FC). These bacteria

are recognizable by a bulging yellow appearance (Tergitol agar medium). These germs are incubated at 44 °C for 48h for the FC. Fecal Streptococci (FS) have a red brick appearance after incubation at 37 ° C in a culture medium (yellow Slanetz).

### 2.4. Statistical analysis

We performed a PCA (Principal Component Analysis) to study the spatial and temporal variations of the physico-chemical parameters. The principal components analysis was one of the most used methods by other authors [14]. The multiple component analysis (MCA) has been developed to study the relation between bacteriological and environmental parameters of the study sites, using the same software.

## RESULTS AND DISCUSSION

In order to establish a relationship between physicochemical parameters and to better assess the impact of human activities on the quality of wastewater drained by the Oued Beht, a CNPA statistical treatment (CPA) was applied to all parameters in the wet season and dry season

This statistical method allows transforming the initial quantitative variables, all more or less correlated with each other in new quantitative variables, uncorrelated, called principal components. [15]

This method is widely used to interpret the hydrochemical data. [11].

PCA was performed on a data matrix consisting of 10 samples (12 X 1 stations wet season) and 10 samples (12X1 stations dry season).

13 in which the variables (water temperature, pH, conductivity, Total suspended solids, biochemical oxygen demand, chemical oxygen demand, chlorides, phosphates, and ammonium nitrate) were measured.

### 3.1 Descriptive analysis of the physico-chemical and bacteriological parameters per month

Descriptive analyzes of the physicochemical parameters of the water quality of the river Beht following months (Table 1).

**Table 1: Physical-chemical and bacteriological parameters of the waters of the Oued Beht per Month**

| Parameters | Observations | Minimum | Maximum | Mean | Standard deviation |
|---|---|---|---|---|---|
| **T °C** | 10 | 16,867 | 21,225 | 18,501 | 1,476 |
| **pH** | 10 | 7,291 | 7,612 | 7,519 | 0,097 |
| **Conductivité** | 10 | 1267,333 | 1579,083 | 1379,933 | 103,990 |
| **$NO_3^-$** | 10 | 2,076 | 3,613 | 2,931 | 0,437 |
| **$NH_4^+$** | 10 | 39,223 | 55,647 | 47,423 | 5,468 |
| **Ntot** | 10 | 70,089 | 113,117 | 99,174 | 11,647 |
| **$Cl^-$** | 10 | 183,000 | 254,250 | 219,783 | 20,293 |
| **Ptot** | 10 | 14,890 | 22,485 | 17,796 | 2,448 |
| **$BOD_5$** | 10 | 673,333 | 783,658 | 723,949 | 40,286 |
| **COD** | 10 | 1560,042 | 1707,771 | 1633,226 | 50,221 |
| **TSS** | 10 | 339,750 | 472,833 | 413,436 | 40,045 |
| **FC** | 10 | 6,686 | 7,132 | 6,891 | 0,159 |
| **FS** | 10 | 5,923 | 6,708 | 6,424 | 0,223 |

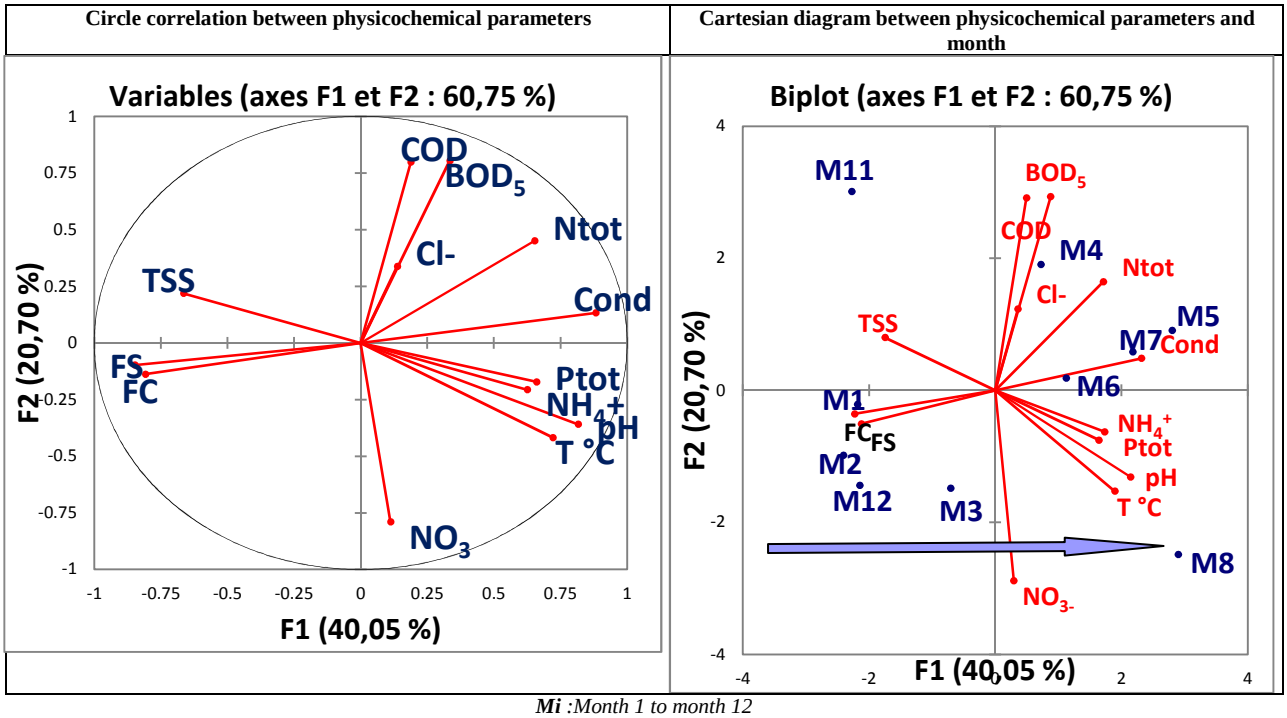
*pH (cond.) conductivity (δ / cm), (TSS) Total suspended solids (mg / L) (Cl) chlorides (mg / L), (Pt) Total phosphorus (mg / L) ($NO_3$) nitrates (mg / L) (Nt) Total nitrogen ($NH_4^+$) Ammonium. (COD) chemical oxygen demand (mg $O_2$ / L), ($BOD_5$) biological oxygen demand (mg $O_2$ / L),fecal coliform (FC) and fecal streptococci (FS), expressed in CFU / 100mL*

### Correlation between physico-chemical and bacteriological parameters per Month

The Cartesian diagram is formed by the F1XF2 axes giving 60.75% of the total information by the axis giving F140.05% and F2 giving 20.70%.

The alkalinity of water is expressed by the high correlation between pH, temperature and bacterial indicators of fecal contamination. According to the axis F1 there is a contrast between polluted water by nitrates and waters polluted by organic matter. [14].

It defines an increasing gradient from left to right pollution from months (**M1, M2, M3, M11, M12**) to months (**M4, M5, M6, M7, M8)** which results in a decrease in the oxygen and increased pollution parameters COD, $BOD_5$, chlorides, phosphates and total nitrogen, this results in a strong mineralization [11].This phenomenon could be explained by the increase in conductivity from left to right along the axis F2, based on data collected monthly by the principal component analysis (Figure 3).




***Mi*** *:Month 1 to month 12*

**Figure 3: Correlation between physicochemical parameters and month**

### 3. 2 Descriptive analysis of the physico-chemical and bacteriological parameters by station

Descriptive analyzes of the physicochemical parameters of the water quality of the river Beht per station (Table 2).

**Table 2: Average physico-chemical and bacteriological parameters of water Oued Beht by Station**

| Parameters | Mean | Standard deviation |
|---|---|---|
| **T** | 18,630 | 0,638 |
| **pH** | 7,526 | 0,103 |
| **Cond** | 1376,792 | 64,690 |
| **$NO_3^-$** | 2,914 | 0,775 |
| **$NH_4^+$** | 47,051 | 15,388 |
| **Ntot** | 102,307 | 83,260 |
| **$Cl^-$** | 221,625 | 17,265 |
| **Ptot** | 17,747 | 6,076 |
| **$BOD_5$** | 728,723 | 1077,068 |
| **COD** | 1645,926 | 2705,261 |
| **TSS** | 416,318 | 76,325 |
| **FC** | 39114000,000 | 51251535,016 |
| **FS** | 10075408,333 | 10474598,269 |

*pH (cond.) conductivity (δ / cm), (TSS) Total suspended solids (mg / L) (Cl) chlorides (mg / L), (Pt) Total phosphorus (mg / L) ($NO_3$ ) nitrates (mg / L) (Nt) Total nitrogen ($NH_4$+) Ammonium. (COD) chemical oxygen demand (mg $O_2$ / L), ($BOD_5$) biological oxygen demand (mg $O_2$/ L), fecal coliform (FC) and fecal streptococci(FS), expressed in (CFU) / 100mL*

- Figure 4 gives an assessment on the pollution of the various stations (C1 to C10) and (P1 and P2).

We notice that there is a high pollution in organic matter in terms COD and $BOD_5$ for the station P1 which could be due to the discharge point of the slaughterhouse.

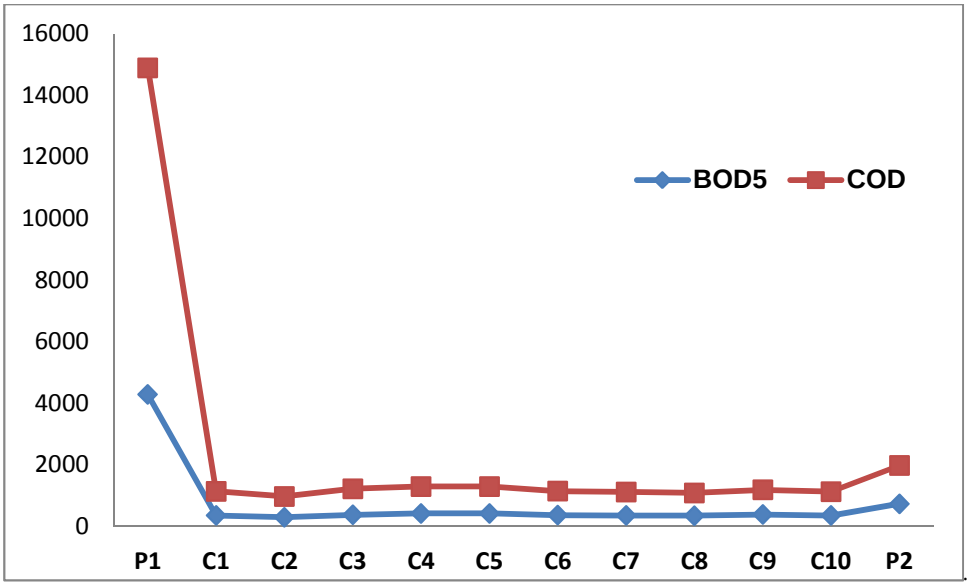



**Figure 4: Graphic representation of the COD and $BOD_5$ according stations**

**Ratio $COD/BOD_5$**

At the level of waste water from the municipal slaughterhouse P1, the ratio COD / $BOD_5$= 2,486 high, which confirm that wastewater drained by this collector are heavily loaded with organic matter (Table 3).

The result is confirmed by the estimation of COD = 10607.048 (mg $O_2$ / l) and $BOD_5$ = 4284 (mg $O_2$ / L), which allows us to deduce that the charge materials organics in the wastewater of this collector is readily biodegradable according Johan [2].

**Table 3: Performance ratios at different stations**

| Station | P1 | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | P2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $COD/BOD_5$ | 2,486 | 2,267 | 2,180 | 2,258 | 2,063 | 2,063 | 2,121 | 2,162 | 2,124 | 2,074 | 2,183 | 1,686 |

**Correlation between physicochemical parameters / Stations**

The Cartesian diagram is formed by the F1 X F2 axes giving 56.86% of the total information by the axis giving F1 31.15% and F2 giving 25.71%.

➢ According to the axis **F1** (31.15%), on the one hand highly mineralized water rich in chlorides and slightly mineralized waters on the other hand it is associated with such variables COD, $BOD_5$, $NH_4^+$ and Pt which are domestic pollution indicators opposed to oxygenated waters

This axis therefore defines a gradient and mineralization of organic pollution from the left to the right of the component 1.

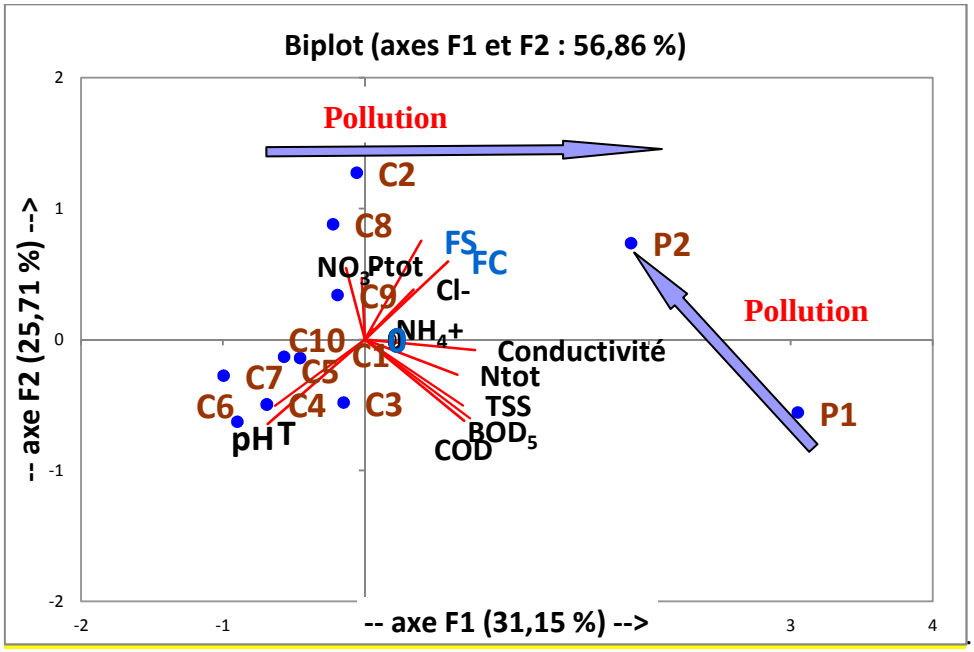
➢ Depending on the axis **F2** (25.71%), it is associated with variables such as TSS and conductivity.

The position of the pH on the negative part of Component 2 is highly correlated with temperature this could be explained by the waters of the river that are more Beht oxygen in the upstream portion away from the impact of slaughterhouse effluents **P1** [16].

**The axis 2** defines an axis of pollution in natural organic and mineral particles carried by the river during the rainy period.

This phenomenon could be explained by the drainage of natural organic matter watershed to the river Beht especially in the upstream study area stations (C1 to C10) which are domestic discharges of the town of Sidi Slimane [17,18].

However, in the downstream part of the stations (**P1** and **P2**) is detected at this point that there is presence of fecal contamination by the presence of bacteria (fecal coliforms (FC) and fecal Streptococci( FS)) that are carried by the water from the municipal slaughterhouses P1 outfall (Figure 5).




*P1: collector output of raw water for municipal slaughterhouse in the town of SidiSlimane.*

**Figure 5: Diagram Cartesian between the physico-chemical parameters and stations**

## CONCLUSION

The results of the physicochemical analysis presented in this work have shown that the pH is close to neutral, a steady average of $BOD_5$= 728.723 (mg $O_2$/L) and COD= 1645.926 (mg $O_2$/L), a monthly average of $BOD_5$= 723.949 (mg $O_2$/L) and COD = 1633.226 (mg $O_2$/L).

An oscillating monthly conductivity between 1,267.333 and 1579.08349 (S /cm).
Thus, the studied physicochemical parameters are loaded are not compatible with the standards of wastewater.

The CPA has allowed us to highlight the influence of stationary and monthly seasonal variations and anthropogenic human activities.

So there are two key factors in this study: the seasonal factor and human factor remains other essential components: such as heavy metals, pesticides…,that need to be clarified.

A wastewater treatment plant should be established to reduce pollution and to strictly follow a sewage waters, is of great necessity to safeguard the ecosystem.

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