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MONITORING IMPACTS OF HUMAN ACTIVITIES ON BOUSKOURA STREAM (PERIURBAN OF CASABLANCA, MOROCCO): 1. PHYSICO-CHEMISTRY

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ABSTRACT The Bouskoura stream (periurban of Casablanca) flows through a highly urbanized and industrialized region where agriculture plays an important role. The installation of important industries on the banks of this stream, the pumping of water for the irrigation of vegetables and cereals crops and the illegal dumping of untreated wastewater have a negative impacts on all levels.

This work presents a global report on the physicochemical situation of the waters of this hydrosystem. Thus, only upstream and near source stations, thus free from pollution, are still close to their original situation. It is in these stations that the lowest biodegradability ratios (COD / BOD_5) were recorded.

Stations receiving untreated liquid discharges from industrial zones and/or urban agglomerations (especially those located downstream) have shown a great variability in their results. The impact of polluting discharges in these stations is reflected dramatically for most of the parameters and thus foreshadowing the difficulties of living conditions of the biocenosis in place. The concentrations of most saprobia parameters and trophic status (nitrogen and phosphorus in particular) in these stations exceed the Moroccan standards for surface water quality and the stream is thus transformed into an open sewer.

The Organic Pollution Index (IPO) has been used to assess organic pollution to assess the organic pollution in the different stations of Bouskoura stream and has highlighted sections of the watercourse with suspicious health conditions that are in poor to very poor quality classes

The typological analysis using principal component analysis (PCA), performed on the averages of the 13 physicochemical parameters recorded in 8 stations, has shown that the hydrochemical situations thus identified are ordered according to a gradient of saprobia (upstream- downstream) represented by the first principal component and a trophic and biodegradation gradient represented by the second component.

KEYWORDS : Water Quality, Physico-Chemical Parameters, OPI index, principal component analysis , typology, lotic system, Bouskoura stream, Morocco.

INTRODUCTION

Situated in the North of the African continent and on the southwestern shore of the Mediterranean Sea, Morocco is characterized by a transitional climate between the Mediterranean climate of Southern Europe and the frankly arid climate of the desert areas of the Sahara. As a result, surface water resources are marked by a wide disparity in their geographical distribution and very irregular hydrological regimes on a seasonal, annual and interannual scale. The hydrological regimes of the rivers are marked by pronounced low flows with often low or even low flows in the summer and strong and rapid floods in the wet season. As a result, Morocco is now expected to face rapid growth in water needs accompanied by risks of degradation of the quality of its water resources linked to the sustained demand of the various user sectors (Jellali, 1997). It is in peri-urban rivers that the degradation of water quality is well illustrated. The hydrosystem of Bouskoura (suburban of Casablanca) is an example. It is home to a dense human population that is divided into several urban and rural population centers. This has led to continual exposure to various types of pollution: agricultural, industrial and urban. Liquid discharges from different activities flow directly (and without prior treatment) into Bouskoura stream and end up in the marine environment after being pretreated at a station near the Atlantic coast (LYDEC Station of El ANK). This results in significant volumes that are dumped at sea while they can be invaluable resources for the Greater Casablanca region, especially since some of the waters of the stream are reused for irrigation of various market garden crops. . quality management is becoming a strategic imperative to avoid degradation of water resources. One of the aspects of management is a qualitative assessment of these resources in order to establish trends in the evolution of the water quality situation and to define the main causes affecting it with a view to its restoration, preservation and enhancement.

STUDY AREA

The study area is located in the Chaouia-Bouregreg Hydraulic Basin, particularly in the coastal Chaouia sub-basin (between the cities of Casablanca and Azemmour). The Bouskoura stream basin is located southwest of Casablanca. It covers an area of approximately 250 km². It is delineated by the geographical coordinates of its outlet (X = 290950, Y = 329730) which is the lowest point and which is next to the exchange office (Figure 1).

The climate, under the influence of the Atlantic Ocean, is characterized by a favorable semi-aridity, whose temperature can reach on average 13 °C in winter and 31 °C in summer. The annual precipitation rate is about 400 mm.

This basin is characterized by a weak urbanization compared to its total surface, concentrated in the centers of Bouskoura and Nouacer and by a dominance of the surfaces intended for agriculture. However, urbanization future of Greater Casablanca is moving southwards by the launch of major projects (Casa Green Town 357 ha, Bouskoura golf city 200 Ha, California Golf Resort 130 ha) and the creation of several industrial parks (Bouskoura Industrial Park 28 Ha , Oulad Salah Industrial Park 32 Ha).

Topographically, the Bouskoura basin has a relief consisting of hills whose altimetry varies between 60 and 240 NGM. Over the years, under the effect of urbanization, the bed of Oued Bouskoura downstream of the basin gave way to the city. But on the southern outskirts of the metropolis, Bouskoura stream is always present and it is its excesses in times of flood that floods the downstream area (goury et chelhaouie, 2013)

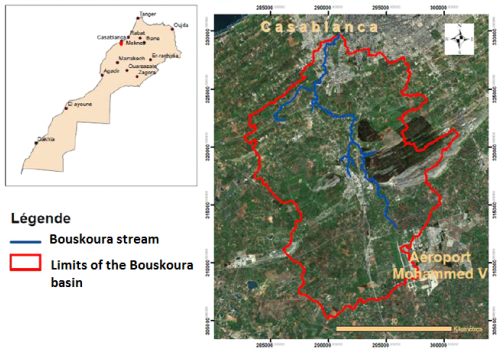

Figure 1 : Map of MOROCCO (a) and Geographical location of the Bouskoura Basin (b) (after GOURY et CHELHAOUIE, 2013)

The Bouskoura Basin has a main watercourse (Bouskoura stream) which is the main source of the flooding problem in the area. It is 10 km south of Casablanca and runs a flow of 10 l/ s in dry weather. Its average annual flow is of the order of 39 l/s. It flows from south to north draining a watershed in the territories of the communes of Nouacer, Bouskoura and Oulad Saleh. After 11 km of course, Bouskoura stream receives the waters of its main tributary: Aïn Joumaa stream. On arrival in the urban area, the Bouskoura stream is channeled in a pipe of small section, allowing a flow of the order of 2 m3/s. The Oued, 20 km long, irrigates 20 ha of agricultural land and is fed by five sources.

Three soil types exist on the study area: iron sesquioxide soil, hydromorphic soil and calcimagnetic soil. The land use of the Bouskoura basin is very varied (Casablanca city and its suburbs, isolated buildings, Mohamed V airport, Bouskoura forest, agricultural areas) with agricultural dominance.

The industrial units are very diversified (metallurgy, textile, cosmetics and hygiene products, agro-food, etc ...) (BOUDAOUD and HADINE, 2013)

Hydrologically, the study area is located in the Chaouia Basin where groundwater resources are low given the hydrogeological nature of the environment.

MATERIAL AND METHODS

1) SAMPLING STATIONS

Following the work of Mounjid (2014) on the Bouskoura watercourse, we undertook this work by establishing in this hydrosystem a water quality monitoring network with 8 stations located upstream (P1: sources of water). Bouskoura) downstream (P7: Industrial Zone Lissassfa-SidiMaarouf) through the reference station P0 (Source Ain Joumaa). The geographical coordinates of the selected stations are given in table 1. and their geographical location in the Oued Bouskoura basin is shown in figure 2. These sampling stations were chosen according to the nature of the water (wastewater, natural waters), the morphological structure of the hydrological course of the Bouskoura watercourse, the nature of the bed and substrate, the proximity of urban and rural population centers and the possibilities of access and collection offered.

Eleven to twelve samples (depending on the stations) were conducted over a period of two years (August 2015 to July 2017).

TABLE 1: THE GEOGRAPHICAL COORDINATES OF THE STATIONS PROSPECTED AND CHARACTERISTICS OF SAMPLING STATIONS IN BOUSKOURA STREAM.

Stations	Lambert Coodinates		distance between station (km)	Total distance (km)	Type of pollution
	X	Y			
P0 (Aïn Joumaa Source)	286190	322244	-	-	-
P 1 (Bouskoura Source)	291150	318980	-	0	-
P 2 (Noukhayla)	291364	319230	0,353	0,353	Domestic and industrial pollution
P 3 (Laghchiwa Bridge)	291933	322716	4,726	5,079	Agricultural pollution
P 4 (Oulad malek)	288948	323808	3,91	8,989	Agricultural pollution domestic pollution
P 5 (Sidi Ayyad)	288830	325255	2,44	11,429	Agricultural pollution
P 6 (Nassim Agglomerations)	289582	327110	3,006	14,435	Domestic pollution
P 7 (Lissasfa-Sidi Maârouf Industrial Zone)	289733	328117	1,112	15,547	Industrial pollution

FIGURE 2: LOCATION OF THE PROSPECTED STATIONS IN THE BOUSKOURA WATERCOURSE

2) ANALYSIS METHODS

In situ measurements of temperature, pH, dissolved oxygen, and electrical conductivity were performed using a mercury thermometer, a WTW pH meter (1/100), an EUTCH TN-100, a WTW oximeter (1/100) and a WTW conductivity meter (1/100) respectively.
The samples of water to be analyzed are directly carried out in polyethylene bottles of 500 ml, previously rinsed with the water sampled, then kept in a cooler at 4 °C and transported to the laboratory for analysis.

The chemical analyzes mentioned in table 2 are carried out upon arrival at the laboratory. The methods used are standardized according to Afnor standards.

TABLE 2: PHYSICO-CHEMICAL ANALYSIS METHODS OF BOUSKOURA STREAM'S WATER.

Paramètre analyzed	Abbreviations	Units	Standards
Chemical oxygen demand	COD	mg O2/l	NFT 90-101
Biological oxygen demand ()	BOD_5	mg O2/l	NF EN 1899.1
Ammonia	NH_4+	mg N /l	NFT 90-015.1
Nitrites	NO_2-	µg N/l	NF EN ISO 13395
Nitrates	NO_3-	mg NO3-/l	NF EN ISO 13395
Total Kjeldahl Azote	TKN	mg N/l	NF EN 25663
Orthophosphates	Po_4^{2}-	mg PO43-/l	NF EN 1189
Total Phosphore	TP	mg P/l	NF EN 1189
chlorophylle a	Chl a	mg Chl a/l	NF T 90 117
Suspended Matter	SM	mg/l	NF EN 872

3) DATA ANALYSIS

a) Organic Pollution Index (OPI)

As a first step, we used a synthetic index revealing OPIorganic pollution (LECLERCQ & MAQUET, 1987). This index makes it possible to estimate overall organic pollution in the study stations and to clearly visualize its spatial evolution. Four physico-chemical parameters were used for this method: BOD_5, ammonia, nitrites and orthophosphates. To calculate the IPO, it is sufficient to average the classes obtained for the four parameters of Table 3.

TABLE 3: CLASSES OF THE ORGANIC POLLUTION INDEX (OPI).

Paramètres Classes	BDO_5 mg–02/l	ammonia mg –N/l	nitrites µg-N/l	phosphates µg-P/l
5	< 2	< 0.1	5	15
4	2 – 5	0,1– 0.9	6 – 10	16 – 75
3	5.1 – 10	– 2.4	11 – 50	76 – 250
2	10.1 – 15	2.5 – 6.0	51 – 150	251 – 900
1	> 15	> 6	> 150	> 900

The values of the OPI are divided into five classes representing pollution levels corresponding to standard colors and ranging from the least polluted (class 5) to the most polluted (class 1) (Table 4).

TABLE 4: OPI CLASSES, POLLUTION LEVEL AND CORRESPONDING MAPPING

Average class number of the 4 parameters	Level of organic pollution	**mapping**
5.0 – 4.6	zero	**blue**
4.5 – 4.0	low	**green**
3.9 – 3.0	moderate	**yellow**
2.9 – 2.0	strong	**orange**
1.9 – 1.0	Very strong	**red**

b) Principal Component Analysis (PCA)

The Principal Component Analysis method was used to interpret the hydrochemical data globally and to characterize the stations typology of this hydrosystem. It makes it possible to extract the most marked trends in the matrix of data (variables, stations) by transforming the initial quantitative variables, all more or less correlated, with each other, into new uncorrelated quantitative variables, called Principal Components (Foucart S. 1982). The PCA was performed using the STATISTICA software (version 6.0). The database used for PCA analysis and statistical processing consists of annual averages of 13 variables and 8 stations. These physicochemical variables are: temperature (T), hydrogen potential (pH), electrical conductivity (EC), dissolved oxygen (O_2), biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), nitrites (NO_2-), ammonia (NH_4+), total phosphorus (PT), orthophosphate (PO_4^{3}-), total Kjeldahl nitrogen (NTK), suspended solids (MES) and chlorophyll a (Chl a).

RESULTS AND DISCUSSION

Spatial evolution of physicochemical parameters

In order to evaluate the physicochemical quality of Bouskoura stream water and the impact of human activities on this aquatic environment, the results of physico-chemical analyzes have been confronted with Moroccan standards of surface water quality recommended by SEEE (2002).

TEMPERATURE (T)

The temperature of the water varies according to the sites and sampling periods. The averages of the temperatures obtained vary between 20.45 °C at the station P2 and 21,33 °C at the station P0 (Figure 3). The average temperature of the watercourse would be of the order of 20,88 ° C. The minimum (11,0 °C) and maximum (27,8 °C) temperatures are recorded in the same station (P5) respectively in February 2016), and in September 2016.

The temperatures measured in all of the study stations in stream Bouskoura therefore belong to the middle class with excellent quality (SEEE, 2002). These values are in line with international standards for surface water, which provide for a maximum value of 25 ° (RODIER, 2009). These data indicate that the temperature of the study area is favorable to aquatic life.

The temperature differences between the seasons can be significant and the coefficients of variation vary between 14-15% in the P0 stations (Bouskoura sources) and P1 (Ain Joumaa) and 21% in P3 (Oulad Malek) and P6 (Nassim agglomerations).

Lastly, the temperature variations at the study site level follow those of the region's climate, which is consistent with the work of Mounjid (2014) and Nahli (2017) who worked on peri-urban watercourses in the region Grand Casablanca.

HYDROGEN POTENTIAL (pH)

The pH recorded at the level of the study area is maintained within a range of 7,24 at the P1 station and 8,05 at the P7 station, with an average for the whole of the stream of about 7,69 (Figure 3).

In general, the waters of the studied hydrosystem will be slightly basic. Indeed, Golterman (1971) reports that at slightly alkaline pH the total carbon dioxide in water occurs essentially as bicarbonates. The constancy of the pH can therefore be attributed to the buffer phenomenon of the complex carbonates-bicarbonates.

During the study period, the recorded pH data show small variations since the maximum standard deviation (measured at the P3 station) is only 0,27 (corresponding to a coefficient of variation equal to 3,52%). the pH values would be in accordance with the moroccan standards of the quality of surface water recommended by SEEE (2002).

Electrical conductivity (EC)

In general, the curve illustrating the electrical conductivity shows an uptrend. The average values of the conductivity recorded in the Bouskoura stream vary between 1302,00 µS/cm at the P0 station and 6088,64 µS/cm at the P7 station (Figure 3). These results are consistent with other research that has demonstrated that in rivers there is a growing gradient of upstream to downstream conductivity (Nisbet and Vernaux, 1970). The average for all stations in the watercourse would be 3964,68 µS / cm.

The minimum value is recorded at the station Ain Joumaa in December 2015 with a conductivity of 945,00 µS / cm against the highest value (7750,00 µS / cm) is recorded at the P7 station in August 2015.

Seasonal differences in electrical conductivity are significant and standard deviations are low in upstream stations and high in downstream stations (at P4 and P7 the standard deviation is 1102,03 µS / cm which corresponds to a coefficient of variation equal to 18.10%).

According to Zerouali et al. (2001) and Oubraim (2002) the variations of the average values of the electrical conductivity can be attributed to both the lithological nature of the leached soils (particularly calcareous soils) by the runoff water as well as the polluting load discharged by the domestic illegal collectors sewage and industrial wastewaters accentuated by the strong sunshine and the absence of vegetal cover in some stations. In fact, these wastewaters are potabilized at the origin and the chlorides they contain contribute to the increase of the mineralization of the waters.

According to the SEEE (2002), the waters of Bouskoura stream can be classified, in the middle class to very bad.

These results corroborate those of ABHBC (2004) and Mounjid and al. (2014a), which confirm the strong mineralization of the sub-Chaouia coastal watershed to which the bouskoura watercourse belongs.

DISSOLVED OXYGEN (O_2)

The analysis of dissolved oxygen concentration shows a gradual decreasing spatial evolution from upstream to downstream of the study area. Mean oxygen concentrations range from 0,64 mg O_2/l at the P7 station to 8,07 mg O_2/l at the Bouskoura sources. The curve illustrating dissolved oxygen describes a decay from upstream to downstream. The most remarkable falls are those recorded in P2, P6 and P7 where there is a deficit in dissolved oxygen (respectively 1,73; 1,29 and 0,64 mg O_2/l) (Figure 3). Indeed, these stations receive the waste water a loaded with organic matters and oxydables whose degradation by the microorganisms consumes oxygens. Also note that the coefficient of variation in P2 and P5 stations are 70% and 50%, respectively.

The average of the study area is of the order of 4,35 mg O_2/l; according to Moroccan standards for surface water quality (SEEE, 2009), this value places the waters of this ecosystem in class III (average quality). At the P5 station, there is a slight improvement testifying to the

presence of a natural self-purification. This could be due to the contributions of the source ain jamaa good quality but also this could be attributed to the photosynthetic activity of aquatic plants and the phenomenon of turbulence which creates a mixing of atmospheric oxygen with water.

Finally, it should be noted that during the study period the dissolved oxygen concentrations never reached the values reported in the Bouskoura watercourse (11,48 mg O_2/l) by Mounjid (2014a) and Merzeg (10,00 mg O_2/l) by Mounjid (2014b) and also values of this order in Hassar stream by Nahli et al (2015) and Nahli (2017). This would illustrate the year-to-year dissolved oxygen deficit in this hydrosystem as a result of liquid pollutant releases.

BIOLOGICAL OXYGEN DEMAND (BOD5)

The curve illustrating the spatial evolution of the average BOD_5 describes an upward trend; thus, the average BOD5 equal to values close to the detection limit, ie 2,41 mg O_2/l at the stations P0, P1 and P2. This parameter increased to an average value of 37,38 mg O_2/l at the station P7 (Figure 3). the maximum value was recorded in March 2017 at P7 and is equal to 59,00 mg O_2/l. According Moroccan standards of water, the quality of the water would be good to excellent upstream of the Bouskoura stream (P0 and P1); it becomes mean downstream at P3 and P4 then very bad downstream at the P6 and P7 stations.

It is interesting to note that:

a) downstream of the P4 station, the average BOD_5 is significantly reduced from 10,82 mg O_2/l at P4 to 2,41 mg O_2/l at P5 (an abatement rate); BOD5 equal to 77,73%).

b) the decrease in BOD_5 in P5 is concomitant with the increase of dissolved oxygen levels in this station. Natural dilution phenomenon due mainly to the contributions of the source ain jamaa and the purifying power of the waters (knowing well that the bed of the stream hosts a flora of diatoms and macrophytes) contributed to the improvement of the physicochemical quality.

c) P2 station is located after the confluence between the sources of Bouskoura and the large sewage collector of the industrial zone Oulad Saleh but the BOD5 is extremely weak in this station. This could be explained by the nature of the liquid discharges. In fact, in the field we see that the wastewater from this station contains fats, oils, detergents and probably heavy metals. These pollutants are able to inhibit the self-purifying power of aerobic bacteria present in the water. The spatial evolution of BOD5 therefore depends on the type of discharges in the different stations. Such a remark was made by Nisbet and Vernaux (1970) who reported that downstream of Paris, the BOD5 of the Seine river rarely exceeds 10,00 mg O2/l despite the extreme water pollution, due to the presence of many detergents and toxic various contents in the greywater.

The average BOD5 for the whole Bouskoura stream is 14,96 mg O2/l. The averages obtained in the present study (period August 2015-July 2017) seem to be higher than those obtained by Mounjid and al (2014a) during the period February 2011-March 2012 but they remain much lower than those obtained by Fekhaoui and Pattee (1993) in the Fez stream, Abouelouafa et al. (2011) in Bounaim stream.

CHEMICAL OXYGEN DEMAND (COD)

The chemical oxygen demand represents the amount of oxygen consumed by the chemically oxidizable materials in the water. It is representative of the majority of organic compounds but also oxidizable mineral salts (sulphides, chlorides, etc. ...).

the spatial profile of COD in the Oued Bouskoura waters shows the presence of a large oxidic material load with a gradient increasing from upstream to downstream (Figure 3). In the stations P0 and P1 the average values of the COD are in the limit of detection (ie 2,63mg O_2/l). Then, this average will increase until reaching a value of the order of 153,45 mg O_2/l at the station P7. This station was also recorded in June 2016, the maximum value (205 mg O_2/l). This intense pollution is due to the permanent discharges of the Lissassfa-Sidi Maarouf industrial zone and the agglomerations of Nassim.

It is important to note that the largest standard deviation is noted at the P5 station. This could be attributed to the presence in this station of high levels of chloride (up to 1668,00 mg Cl-/l) which interfere with COD. The presence of chloride ions at high concentrations can lead to an overstated COD (Rodier, 2009).

The average for all stations of stream is 72,21 mg O_2/l; these high COD loads reveal the limits of the self-purification power of the environment with regard to certain forms of pollution received locally.

With the exception of the P0 and P1 stations, the moroccan standards of surface water quality grid classifies the waters of this hydrosystem in the middle to very poor classes (SEEE, 2002).

Ratio (COD / BOD_5) and estimation of organic matter (OM)

The COD/BOD_5 ratio makes it possible to deduce whether wastewater discharged directly into the receiving environment has characteristics of domestic wastewater (COD/BOD_5 ratio less than 3) (ONEP-GTZ, 1999). This COD/BOD_5 ratio accounts for the fraction of easily biodegradable materials among all the oxidizable material. In the case of an urban waste water that contains a majority of biodegradable organic compounds, the COD/BOD_5 ratio is generally between 1,5 and 2,5. For industrial effluents, which may contain a significant fraction of non-biodegradable compounds, it may be considered according to the COD / BOD_5 ratio that the biodegradation ability is more or less favorable to a biological treatment, the following rules being generally retained (Rodier , 2009):

$(COD / BOD_5) < 3$: easily biodegradable effluent

$3 < (DCO / BOD_5) < 5$: medium biodegradable effluent

$(DCO / BOD_5) > 5$: effluent that is not readily biodegradable or even non-biodegradable

The evolution of the averages of the COD/ BOD_5 ratio at the stations of the Bouskoura watercourse shows a bimodal curve with values exceeding 5 and thus reflecting, in the Rodier (2009) sense, a difficulty of biodegradability or non-biodegradability of materials carried in P2 and P5 stations in particular (Figure 4).

* a first mode is observed at the P2 station which receives wastewater from the industrial zone of Oulad Saleh; the ratio of biodegradability is equal to 15,48.

* a second, more important, mode is observed at the P5 station where this ratio is equal to 20,63. However, it is in this station that one noticed several signs of restoration of the quality of the waters of Bouskoura stream; this could be explained by the fact that in this station (P5) the high levels of chlorides interfere with the COD and ricochet there is an increase in the ratio of biodegradability.

According to Rodier (2009), the classification of effluents in France as royalties for water agencies uses COD to determine the oxidizable materials (MO) of water according to:

$$\frac{2\ BOD_5 + COD}{3}$$

Organic matter levels increase from upstream to downstream of Bouskoura stream (Figure 4). The lowest concentrations are found in P0 (2.79 mg/l) and P1 (2. mg/l) while the high concentrations are noted in P6 and P7, the very polluted stations, with respectively 59.36 mg/l and 76.07 mg/l of Organic matter.

NITRITES (NO^-_2)

Nitrites are fugitive forms of nitrogen between nitrates and ammonia ions that result from an incomplete degradation of the organic matter of the water. Nisbet and Vernaux (1970) report that nitrites only persist when the aquatic environment is sufficiently oxidizing and their presence indicates a critical state of organic pollution.

The curve illustrating the evolution of the averages of the nitrites in the different stations of the Bouskoura lotic medium shows no particular tendency (figure 4). The nitrite concentrations oscillate between 0.40 µgN / l in the P5 site and 46.02 µgN / l in the P2 and P7 stations.

The spatial variation of the concentrations of these nitrogenous compounds clearly shows significant differences between stations thus testifying to the variability of the sources of pollution along the Bouskoura stream; the largest differences are observed in the P2 and P7 stations that receive industrial wastewater from the Oulad Saleh and Lissassfa-Sidi Maarouf zones respectively.

The highest nitrite value (113.86 µgN / l) was recorded at the P2 station

in January 2017.

Given the absence of nitrite in Moroccan standards, we will stick to the classification given by the "SEQ-water" (MEDD and Water Agencies, 2013) which is a system used by French and European agencies for monitoring the physicochemical quality of surface water. Applied to this lotic environment, the "SEQ-water" allows us to classify the water of all the stations (except the station B1) in the class of very bad quality. As for the waters of station B1, according to this evaluation system, they would be classified as bad quality water.

The results obtained remain close to those obtained Fagrouch et al. (2011) at Oued Za and Abouelouafa et al. (2011) in Oued Bounaim.

AMMONIA NITROGEN (NH_4^+)

Ammonia nitrogen exists only in waters rich in decomposing organic matter when the oxygen content is insufficient to ensure its transformation (Nisbet and Vernaux, 1970). It is a good indicator of the pollution of rivers (RODIER, 2009).

The analysis of the ammonia profile shows an upward trend (figure 4). Indeed, in the stations upstream of Bouskoura the ammonia ion load is low and the contents vary between 0.07 mg N/l and 0,18 mgN/l. On the other hand, in the stations located further downstream of the Bouskoura stream the ammonia pollution is relatively extreme with values of the order of 10,61 mg N/l and 15,68 mg N/l (respectively at the level of the stations P6 and P7). It is also in these stations (where the maximum values have been recorded, ie 26.13 mg N/l in December 2015 at P6 and 23,60 mg N/l in April 2016 at P7), that there are the greatest variations during the study period.

The reduction of the ammonia ion charge between P3 and P5 is of the order of 85,45%; Nevertheless, it is important to point out that the very pronounced growth of this chemical parameter downstream from P5 illustrates the limits of the self-purification phenomenon in this section.

Note finally that the average ammonia ion for all stations is 3,96 mg N/l. By referring to the moroccan standards (SEEE, 2002), the waters of this ecosystem would be of poor quality with respect to this chemical parameter.

The concentrations of ammonia ions in Bouskoura waters of this work appear to be higher than those obtained in the same study site by Mounjid (2014) during the period 2011-2012 as well as those obtained on a peri-urban watercourse of Greater Casablanca (in this case oued Hassar) by Nahli (2017). Compared with other results obtained on similar Moroccan water courses, our results seem superior to those obtained by Fagrouch et al. (2011) and Mabrouki et al. (2016) in Za stream, by Kbibch and al., (2011) in Mda stream and by Akil et al. (2014) in Guigou stream but weakly loaded with ammonia nitrogen compared to the work of Abouelouafa et al. (2002) on Bounaim stream.

NITRATES (NO_3^-)

Nitrate ion (NO_3^-) is the main form of inorganic nitrogen found in natural waters. It constitutes the final stage of the oxidation of nitrogen. The nitrate concentrations recorded in the stations P0, P2 and P5 of the Bouskoura watercourse vary between 57,55 mg NO_3^-/l in P5 and 66,42 mg NO_3^-/l in P2 (figure 4).

The maximum value (126,09 mg NO_3^-/l) recorded during the study period was found in station P2, which represents the confluence between the waters of the Bouskoura stream and the wastewater from the Oulad Saleh industrial zone. Note also that all the averages obtained for nitrates exceed 50,00 mg NO_3^-/l. This value makes it possible to classify, globally, the waters of the three bouskoura stations, according to SEEE (2002) in the very bad class.

It should also be noted that the waters of the P0 station are of underground origin and the results of the nitrates in this station corroborate those obtained by Zerouali et al. (2001), ABHBC (2004) and Mounjid (2014) who highlighted the degradation of the quality of the coastal chaouia water table by the high levels of nitrates.

TOTAL KJELDAHL NITROGEN (NTK)

Considered as a major indicator of organic pollution, total Kjeldahl nitrogen presents all the reduced organic and ammoniacal forms (Rodier, 2009).

With the exception of the P0 and P1 stations, where the water quality is excellent with respect to this parameter by reference to SEEE (2002), the total Kjeldahl nitrogen concentrations of all stations in Bouskoura stream exceed 3 mgN / l (Figure 4).

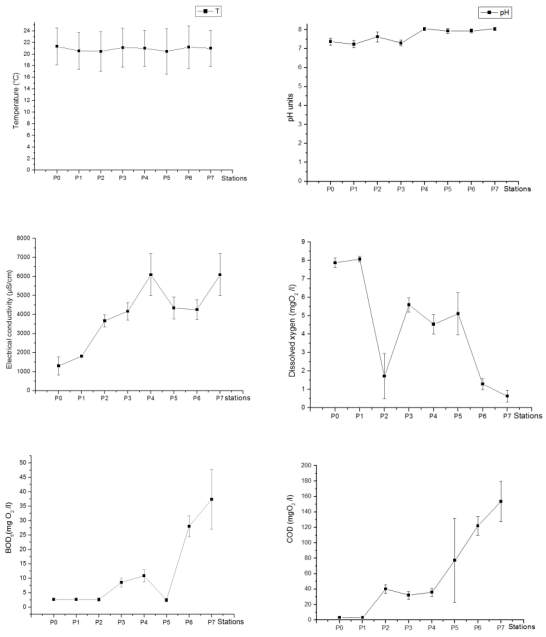

Figure 3: Spatial variations of means of temperature, pH, Electrical conductivity, dissolved oxygen, biological oxygen demand and chemical oxygen demand in stations of Bouskura stream between August 2015 to July 2017.

The Moroccan standards (SEEE, 20002) classify the water of these stations in the category of water of very poor quality. The greatest variations were observed in the S2 station, which receives the industrial wastewater from the Oulad Saleh industrial zone.

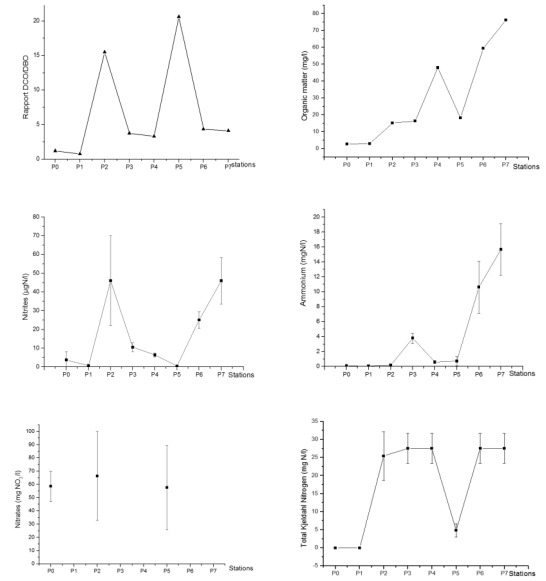

Figure 4: Spatial variations of means of biodegradability ratio (COD/BOD_5) , organic matter, nitrites, ammonium, nitrates and total Kjeldahl nitrogen in stations of Bouskoura stream between August 2015 to July 2017.

TOTAL PHOSPHORUS (TP) AND ORTHOPHOSPHATES (P_O4^{3-})

Phosphorus, an essential element in the development of all living autotrophic organisms, is naturally present only in very small quantities in continental waters. However, above a certain concentration and when conditions are favorable (low current, adequate transparency, etc.), it can cause excessive growth of algae and

aquatic plants (Vilain, 1989). In both surface water and wastewater, phosphorus is mainly found in the form of phosphates.

Total phosphorus expresses the overall content of organophosphates, condensed phosphates and organic forms of phosphorus present in water.

The analysis of the results shows that the spatial variation of orthophosphates follows that of total phosphorus thus illustrating an upstream-downstream gradient (figure 5). Indeed, the average PT concentrations are of the order of 0.35 mg P/l upstream and reach downstream of the stream (mainly at the P7 station) the value of 5.82 mg P/l ; the average for the entire stream is 3.22 mg P/l. This value makes it possible to classify the waters of this stream in the very bad water category according to SEEE (2002).

In comparison with other streams, PT concentrations in the waters of Bouskoura stream are higher than those obtained by Mounjid et al. (2014a) in the same site but they corroborate with those reported by the same authors in the Merzeg stream (Mounjid et al., 2014b). These results are also lower than those reported by Abouelouafa et al. (2011) in Bounaim stream.

The evolution of orthophosphate contents in the studied waters is very similar to that of total phosphorus. They vary between 0.22 mg $PO4^{3-}$/l at P0 and 3.97 mg $PO4^{3-}$/l at P7 with an average's watercourse of 2.24 mg $PO4^{3-}$/l which makes it possible to classify the waters of Bouskoura stream in the class of poor quality according to SEEE (2002) (Figure 5). It should be noted that the largest variations in orthophosphate are recorded in station P5; this station receives the waters of the Ain Joumaa stream, those of the P4 station as well as the runoff water from the adjacent agricultural lands. Thus, it can be said that the evolution of phosphorus compound contents depends on the type of sources of phosphorus elements (in particular the leaching of agricultural land, the nature of the land crossed and the discharges of untreated wastewater into the aquatic environment).

In comparison with other streams, $PO4^{3-}$ levels in Bouskoura stream are higher than those reported by Fawzi et al. (2001), Fawzi (2002), Fawzi and al. (2002) and Oubraim (2002) at Hassar stream(suburban of Casablanca), by Mounjid and al. (2014a) in the same site. However, they are lower than those reported by Abouelouafa and al. (2011) at Bounaim stream, El Addouli and al. (2009) at the Oued Bouishak and Ouislane.

SUSPENDED MATTER (MES)

Suspended matter consists of solids suspended in water. They come from natural sources, municipal and industrial effluents, agricultural run-off, and suspended atmospheric deposition (Hayzoun, 2014 and Dinh, 2013).

According to the results of this study, the average levels of suspended matter are between 5 and 20 mg / l. The highest values are observed in the downstream stations (P6 and P7) because of the spills of the different discharges (Figure 5). Overall, averages for all stations remain low and lower than those obtained by Fawzi et al. (2002), Nahli (2017) in Hassar stream (peri-urban of Casablanca), by Abouelouafa (2002) in Bounaim stream and by Karrouch and Chahlaoui (2009) in Boufekrane stream. This could be explained by high sedimentation of suspended solids due to the low current in the Bouskoura stream.

CHLOROPHYLL A (Chl a)

The measurement of chlorophyll a is used as an indicator of phytoplankton biomass in Bouskoura stream waters. The evolution of this pigment describes a unimodal curve (Figure 5); a maximum of 36.9 µg Chla /l of this pigment is observed in the eutrophic station P2 and whose water quality is poor in the sense of SEEE (2002). The lowest values are obtained at P0 (0.37 µgChla / l) and P1 (0.39 µgChla / l) stations with a high quality and excellent quality respectively in the sense of SEEE (2002). In the other stations the suality of the waters is globally average.

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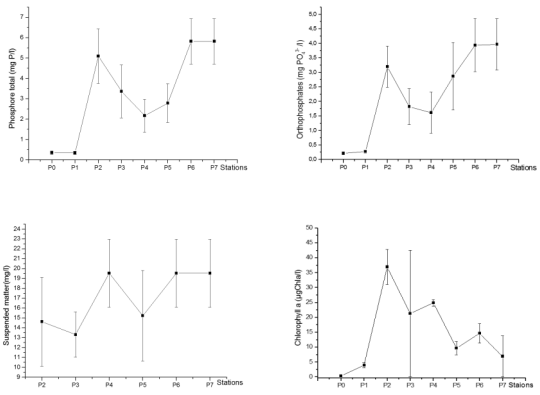

Figure 5: Spatial variations of means of total phosphorus, orthophosphates , suspended mater, and chlorophyll a in stations of Bouskoura stream between August 2015 to July 2017.

SPATIAL EVOLUTION OF THE ORGANIC POLLUTION INDEX (OPI)

In order to globally estimate the organic pollution in the study stations and to clearly visualize the spatial evolution of this pollution, we made use of the synthetic index: Organic Pollution Index "OPI" (LECLERCQ and MAQUET, 1987) . The values of the OPI calculated in the different stations of the Bouskoura stream have been collated in the Table 5 and represented in the figure 6.

The results obtained for the OPIindex indicate a regressive evolution and show a degradation of the quality of the water downstream of the Bouskoura watercourse (Figure 6); the excess of organic matter restricts the process of self-purification in this stream. In fact, in the P0 and P1 stations situated upstream of the watercource where the residual COD concentrations are low and the dissolved oxygen contents are high, the OPItakes the value of 4.25 (low organic pollution). This index will decrease along the stream continuum to reach a low value of about 1.5 (very high organic pollution) which reveals the importance of the pollutant load emitted by the various illegal and legal collectors in the P7 stations. (Lissassfa-SidiMaarouf industrial zone) and P6 (Nassim urban agglomerations zone) whose untreated liquid discharges contribute to a clear degradation of the water quality of this aquatic ecosystem.

Discharges from the Ouled Saleh industrial zone reduce the OPIin the P3 station to 3.00 (moderate pollution). This degradation will continue at the P3 station, which receives untreated domestic waste from slums and rural settlements in Oulad Ben Ammor and Oulad Malek. These discharges represent both domestic wastewater and rainwater at very variable proportions over time and according to climatic conditions. the OPIin this station reaches 2.25 (strong pollution). Downstream from this station, the water quality of the stream improves (OPI= 3.25) and the pollution becomes moderate thanks to the phenomenon of self-purification and the dilution of this water by the water supplies of the P0 station (source Ain Joumaa) between stations P4 and P5.

TABLE 5: OPI AVERAGE VALUES, LEVELS OF ORGANIC POLLUTION AND MAPPING AT BOUSKOURA STREAM STATIONS DURING THE PERIOD OF AUGUST 2015 - JULY2017

STATIONS	OPI	Level of organic pollution and mapping
P0 (Aïn Joumaa Source)	4,25	low organic pollution
P 1 (Bouskoura Source)	4,25	low organic pollution
P 2 (Noukhayla)	3	Moderate organic pollution
P 3 (Laghchiwa Bridge)	2,25	Strong organic pollution
P 4 (Oulad malek)	3,25	Moderate organic pollution
P 5 (Sidi Ayyad)	3,25	Moderate organic pollution
P 6(Nassim Agglomerations)	1,5	very strong organic pollution
P 7 (Lissasfa-Sidi Maârouf Industrial Zone)	1,5	very strong organic pollution

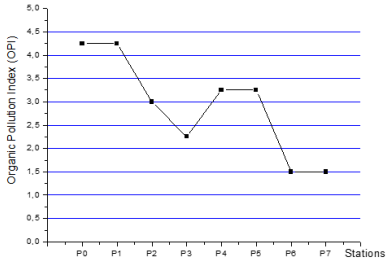

Figure 6: Spatial evolution of the averages of the OPI index at Bouskoura stream stations during the period August 2015 - July 2017

TYPOLOGICAL ANALYSIS OF THE BOUSKOURA STREAM

Taking into account the above-mentioned variability from one station to another of the averages of the physicochemical variables, we considered it interesting to synthesize these results by applying a multivariate statistical analysis: Principal Component Analysis (PCA). This statistical treatment will make it possible to identify the determining phenomena in the functioning of the aquatic system and to obtain, as a result, an overall synthesis of the information given by the data matrix (Angelier et al., 1978, Philippeau, 1986). The PCA was applied to averages of 13 physicochemical parameters recorded during two years in each of the 8 stations surveyed.

The factorial map F1XF2 (figure 7) shows that the first two axes, alone, account for 80.02% of the inertia of the cloud of variable points. The first axis is characterized by a percentage of inertia of 64.21%. Dissolved oxygen (O_2), orthophosphate (PO_4), chemical oxygen demand (COD), total phosphorus (TP), suspended matter (MES), biochemical oxygen demand (BOD_5) and total Kjeldahl nitrogen (TKN) are decreasing order, the parameters best suited to this axis with 61% of the contribution of this axis. Oxygen (11%) negatively structures this axis. At the other end of it, the important contributions are those of variables PO_4^{2-}, DCO and TP with 10% each as well as the MES (9%), the BOD_5 and TKN (8% each)

Axis 1 would clearly translate an enrichment of water into substances related to human activity in all its forms but with organic dominance. The human action on the Bouskoura watercourse is expressed both by biodegradation (with O_2 under-saturation and increase in TP, MES but mainly BOD_5) and by photosynthesis (with O_2 supersaturation and weak concentrations of BOD_5, TP and MES)

The second axis has a percentage of inertia of 15.81%. The high levels of chlorophyll a give it a high relative contribution, but negative (-36%), which oppose temperature (20%), ammonia (14%) and BOD_5 (13%). Axis 2 would clearly represent a gradient that reflects eutrophication that is opposed to biodegradation (which is reflected by the position of the variable points BOD_5 and NH_4^+ produced by human action on the river).

In comparison with other work, it can be said that results of PCA applied to physicochemical data in the same study site by Mounjid et al. (2014a) reveals that the first main component (F1 axis) described the mineralization while the present study highlights the organic and oxidizable charge as the first component. This difference between the results of these two analyzes suggests that pollution is worsening in the Bouskoura watercourse and could be supported by the fact that the data from this study are spread over two years (August 2015-July 2017), whereas for Monjid et al are annual (February 2011-March 2012).

On the axis 1 and 2 of the figure 8 appear groupings of affine stations, that is to say having neighboring physicochemical parameters. The stations P0 (Ain Joumaa source) and P1 (Bouskoura source) located upstream of the different sources of pollution, are characterized by positive values on axis 1. They share high values of dissolved oxygen and therefore significant photosynthesis and absence of signs of pollution. The P6 (Agglomerations NASSIM) and P7 (Lissassfa-Sidi Maarouf industrial zone) stations, which take negative values on this axis, would be highly polluted (high loads in BOD_5, COD and NH_4^+). As for the remaining stations, particularly P2, they would be rich in chlorophyll a (sign of eutrophication) due to discharges loaded with orthophosphate (main precursor of eutrophication in continental aquatic environments.)

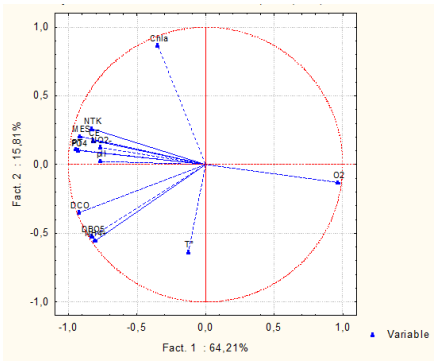

Figure 7: Projection of the 13 mean physico-chemical variables on the factorial plane (1 X 2)

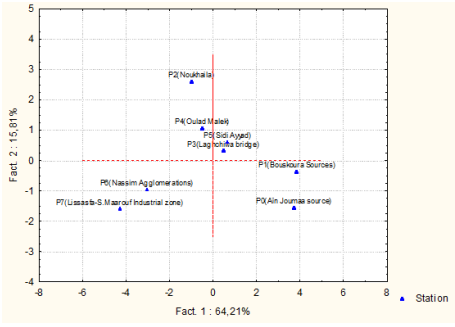

figure 8: Projection of the 8 stations of Bouskoura stream on the factorial plane (1 X 2)

To better refine this multivariate analysis by PCA, we studied the evolution curve of the average of the stationary coordinates on the F1 axis of the PCA as a function of their distance from the Bouskura source (figure 9). It follows that:

* the arrival of polluted water from the Oulad Saleh industrial zone leads to the appearance of negative values on axis 1, for station P2.

* downstream of P2, the station P3 is again positive on the axis 1; this could be explained by the self-purification phenomenon that takes place in this transect of about 4km. Indeed, between these two stations, the average dissolved oxygen content has tripled. Nevertheless, it should be noted that with the exception of the NO2 abatement yield (77.10%), those of COD, PO_4^{2-}, TP, and Suspended matter remain below 50%.

* In the P4 station, the quality of the water is deteriorating due to the arrival of sewage from the Douars and the agglomerations of Oulad Ben Ammor and Oulad Malek as well as those of agricultural activities in this region. This station P4 is negative in axis 1. This station is characterized by an increase in pH, COD, BOD_5 and SS that reach a maximum.

* The positive position of P5 on the axis 1 could be explained by the dilution of the waters of the Bouskoura stream by those of Ain Joumaâ (on the one hand) and by the purification process of the watercourse (on the other hand). Compared to the P3 station, the yields of the BOD_5, NTK, NO_2^- and suspended matter reductions in the P5 station remain high (respectively 77.74%, 82.37%, 93.76% and 22.02%),

* The P6 and P7 stations have the most strongly negative coordinates due to the untreated domestic pollution caused by the strong agglomeration of the Nassim city in the first station (P6), to which are added the wastewater from the Lissassfa industrial zone. Sidi Maarouf at P7.

As a result, along the Bouskoura watercourse, the discharges of the various anthropogenic activities contribute to the evolution of the hyrochemism of this hydrosystem and that the A. C. P. therefore has the merit of showing the dominance and importance of allochthonous contributions in the functioning of this hydrosystem.

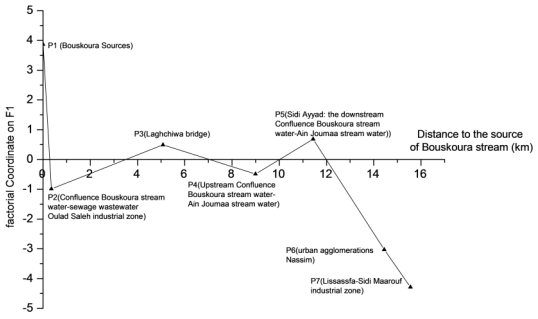

Figure 9: Evolution of the average of the stationary coordinates on the F1 axis of the PCA as a function of their distance from the Bouskura source.

CLUSTER ANALYSIS

The 8 stations were classified according to their physicochemical characteristics into 3 groups by Hierarchical Ascending Classification HAC (Figure 10):

- Group 1 consists of 2 stations (P0 and P1) which are the only ones free of pollution, and thus still close to their original situation. This set is characterized by waters close to neutrality, well oxygenated (O2-contents greater than 7 and very low levels of elements characterizing a pollution in orthophosphates, COD, BOD_5, TKN, TP and MES;

- Group 2 (P4 and P7) groups stations with very mineralized water (conductivity greater than 6000µS / cm) and alkaline water (pH greater than 8);

group 3 (P2, P3, P5 and P6) contains 4 sites having intermediate physicochemical characteristics between groups 1 and 2 with a distinction of station P2 which is further characterized by high chlorophyll and nitrite contents.

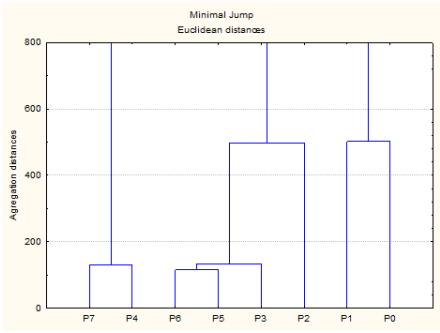

Fig. 10. Dendrogram of 8 sampling sites clustered for 13 physico-chemical variables.

CONCLUSION

The Bouskoura (Casablanca suburban) watercourse is impacted by the different types of anthropogenic activities (town planning, industry and agriculture) which are spread on its slopes. The assessment of these impacts on the water quality of this stream was carried out using physicochemical methods.

The analysis of the spatial evolution of the physicochemical parameters showed that the Bouskoura stream has characteristics that are quite comparable to that of several Moroccan rivers, namely high mineralization and pollution. These two characteristics are related to the geological nature of the lands traversed by the waters, to the great instability of the hydrological regime (pumping for agriculture, especially low water in summer), to the importance of the discharges of domestic or industrial effluents or the runoff of agricultural land amended by fertilizers. This analysis has also shown that the degree of pollution in this hydrosystem varies from one area to another with levels that sometimes exceed those recommended by national standards. In addition, comparison of the results of some parameters with previous work on the same study site (in particular those of Monjid et al (2014a)) showed an intensification of this water pollution. This problem diminishes the potential for good-quality water resources (which the region needs especially for agriculture that suffers from a water deficit) and renders watercourse utilities compromised.

The organic pollution index OPIrevealed the degree of alteration of the physicochemical quality of natural waters in most stations of Bouskoura stream (especially downstream stations). The excess of organic matter in the polluted sites restricts the process of self-purification in this stream and would make the existence of animal and plant species difficult. The contribution of the waters of the unpolluted drain Ain Joumaa is beneficial for the quality of the water of this lotic environment since it allows the dilution of the pollution.

The principal component analysis (PCA) analysis, carried out on the averages of the 13 physicochemical parameters recorded in 8 stations, showed that the hydrochemical situations thus highlighted are ordered according to a pollution gradient represented by the first major component and a trophy gradient and Biodegradation represented by the second component. Similarly, the stations studied on the Bouskoura are grouped according to their common physicochemical characteristics, and in particular tracers of the ecosystem.

This observation underlines the urgency of setting up a system for the control and purification of wastewater before it is discharged into the receiving environment by the responsible authorities.

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