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Monitoring Impacts of Human Activities on Bouskoura Stream (Casablanca, Morocco): Bacteriology and Parasitology

Suivi des impacts des activités humaines sur le cours d'eau de Bouskoura (Casablanca, Maroc): Microbiologie et parasitologie.»

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Abstract. The present study, conducted between August 2015 and July 2017, aims to assess the load of pathogenic microorganisms carried by the waters of Bouskourastream in relation to physical and chemical parameters.The results of the physicochemical analyses of these waters showed a deterioration of the water quality following a gradual mineralization accompanied by a strong organic load in downstream stations with oxygen deficiency and maximum COD means BOD and NTK. In addition to this mineralization and this organic load, there is a high load of total choliforms (3.58.10^6 CFU/100 ml), fecal coliforms (4.79 10^5 CFU/100 ml) and fecal streptococci (3.88 10^5 CFU/100 ml). An average of 5.82 10^3 CFU/100 ml of *Pseudomonas aeruginosa* has been determined in the Ain Joumaa station, where bathing activities are carried out. The microbiological quality index (MQI) made it possible to map the microbiological quality of Bouskoura stream; The origin of faecal contamination, determined using the CF / SF report, highlighted the diversity of pollution sources along this hydrosystem. Parasitological analysis of the waters revealed the following parasitic taxa: *Ascarissp, Trichuris sp., Ankylostoma sp., Hymenolepis nana, Taenia sp*. and *Fasciola hepatica* with a significant predominance of *Ascarissp* eggs. (100% positive samples). This diversity of parasites testifies to the diversity of sources of water contamination. The average parasite load (189.36 helminth eggs/l) greatly exceeds those observed in many similar national aquatic environments.

The number of pathogenic microorganisms (Bacteria and Helminths) of Bouskoura stream exceeds the values indicated by the World Health Organization guidelines for water intended for non-restrictive irrigation of crops and the Moroccan standards in force. The microorganisms encountered may be at the origin of a health risk. Thus, it appears necessary in order to preserve the water resources of this hydrosystem and the public health in particular, to treat these waters before their reuse.

Keywords: water quality, physicochemistry, bacteriology, parasitology, Bouskoura stream, Morocco.

Résumé. La présente étude, menée entre août 2015 et juillet 2017, vise à évaluer la charge en microorganismes pathogènes transportés par les eaux de l'oued Bouskoura en fonction des paramètres physiques et chimiques. Les résultats des analyses physicochimiques de ces eaux ont montré une dégradation de leur qualité suite à une minéralisation progressive accompagnée d'une forte charge organique dans les stations en aval qui enregistrent un déficit prononcé en oxygène, et des valeurs maximales en DCO, DBO et en azote total de Kjeldahl.

En plus de cet impact de la minéralisation et de la charge organique, il existe une forte charge en coliformes totaux (3.58.10^6 UFC/100 ml), en coliformes fécaux (4.79 10^5 UFC/100 ml) et en streptocoques fécaux (3.88 10^5 UFC/100 ml). Une moyenne de 5.82 10^3 UFC/100 ml de *Pseudomonas aeruginosa* a été déterminée dans la station d'Ain Joumaa, où les activités de baignade ont lieu. L'indice de qualité microbiologique (IQM) a permis de cartographier la qualité microbiologique du ruisseau Bouskoura; l'origine de la contamination fécale, déterminée à l'aide du rapport CF/SF, a mis en évidence la diversité des sources de pollution le long de cethydrosystème.

Une analyse parasitologique des eaux a révélé les taxons parasitaires suivants: *Ascarissp, Trichurissp., Ankylostomasp., Hymenolepis nana, Taeniasp*. et *Fasciola hepatica* avec une prédominance significative des oeufs d'*Ascaris sp* (100% d'échantillons positifs). Cette diversité de parasites témoigne de la diversité des sources de contamination de l'eau. La charge parasitaire moyenne dans les stations avales (189,36 œufs d'helminthes/l) dépasse largement celle observée dans de nombreux environnements aquatiques nationaux similaires. Le nombre de microorganismes pathogènes (bactéries et helminthes) du cours d'eau de Bouskoura dépasse les valeurs indiquées dans les directives de l'Organisation mondiale de la Santé pour les eaux destinées à l'irrigation non restrictive des cultures et aux normes marocaines en vigueur. Les microorganismes rencontrés peuvent être à l'origine d'un risque pour la santé. Ainsi, il apparaît nécessaire pour préserver les ressources en eau de cethydrosystème et la santé publique en particulier, de traiter ces eaux avant leur réutilisation.

Mots Clés: Qualité des eaux, physicochimie, bactériologie, parasitologie, Ruisseau Bouskoura, Maroc.

INTRODUCTION

The economic development of many countries is leading to a steady increase in demand for water in the industrial, agricultural and domestic sectors. This demand is even greater in countries characterized by an arid to semi-arid climate such as Morocco, where the water balance and water resources are conditioned by several factors such as: rainfall, air temperature and extreme weather events (especially droughts episodic). In addition, human activities can change the quality of water and make it unsuitable for different uses.

Like the Mediterranean countries, more than 90% of the renewable water resources available in Morocco are used in agriculture (Observatoire National de l'Environnement 2015) which creates a considerable lack of this foodstuff. In order to mitigate this water deficit, the indirect reuse of unconventional water, that is to say, the capture of water from watercourses receiving wastewater, is a common practice. The reuse of these waters (especially in most of the peri-urban areas of developing countries where these lotic environments very often serve as liquid and solid waste weirs) allows an environmental valorisation of «these wastes» (preservation resource, environmental protection by reducing effluent discharges into the receiving environment, etc.) and socio-economic (use of nitrogen and phosphorus from wastewater as fertilizer in agriculture, limitation of rural exodus, job creation, etc.) (Shatanawi *et al*. 2005), but it can lead to negative consequences for:

* The environment by increasing soil salinity, or by impacting groundwater or causing eutrophication of surface water (WHO 2006).

* Public health because these contaminated waters areconsidered the origin of health problems with deadly consequences in a large part of the globe (Benoit *et al*. 2011). Indeed, by trying to reclaim the uses of rivers, the local population is exposed to health risks related to the presence of pathogenic microorganisms that cause diseases such as cholera, typhoid, gastroenteritis, amoebic dysentery, poliomyelitis, hepatitis, meningitis, diarrhea, vomiting, giardias, and many others (WHO & Pond 2005).

The analysis of epidemiological data has made it possible to develop guidelines based on criteria that are no longer microbiological but epidemiological (Shuval *et al*. 1986a, WHO 1989, Coquet 2000). Guidelines on recycling and reuse of wastewater are essential. They help protect public health, increase water availability, prevent water pollution and improve water resources. Many countries have adopted wastewater criteria based on (WHO 2006) guidelines, which are more flexible (Shatanawi *et al.* 2005). In Morocco, which is one of these countries, great importance has been attached to the quality control of wastewater and mixed water intended for recycling (especially in agriculture). Water resource managers have come to recognize the usefulness of this practice, both for nutrient conservation and recycling, and to prevent surface and groundwater pollution. For example, it has been suggested that tests or examinations should be carried out to find: Protozoan cysts and helminth eggs, fecal coliform bacteria, viruses and chemicals, including organic substances existing in the body trace state to decide on the conformity of these waters for agricultural purposes.

The city of Casablanca (economic capital of Morocco) better illustrates this problem of reuse of mixed wastewater. Indeed, population growth as well as accelerated urbanization and industrialization generate significant quantities of wastewater. In the suburbs of this city (Boukoura region in particular where the industrial units are much diversified: Metallurgy, textile, cosmetics and hygiene, food, etc), connections rainwater/wastewater and connections illegal sewage are raised (Mounjid *et al*. 2014a, Mounjid *et al*. 2014b). A large part of this water is discharged into the rainwater pipes intended to be evacuated directly in Bouskourastreamperiurban of Casablanca city. This contributes to the degradation of the water quality of this hydrosystem and thus generates a release of harmful odors. The city is faced with the problems of wastewater management and the protection of the quality of water resources. The Bouskoura stream is currently under threat. The capture of water from the stream receiving wastewater for agricultural, public works, livestock, recreation and other goods and services could present a potential danger for human health and the environment (Nahli 2017). The objective of this study is to make a diagnosis of the physicochemical, bacteriological and parasitological quality of the waters of this hydrosystem with a view to deciding on their conformity. This diagnosis will make it possible to give recommendations concerning the measures to be taken in relation to the different uses of mixed waters of the Bouskoura, especially since no study concerning the specific research of *Echerichia coli*, *Pseudomonas aeruginosa* and that of helminth eggs has been carried out performed to date in this hydrosyteme.

MATERIAL AND METHODS

Study Area

Geographical Setting

Bouskourastreamis a part of the hydrographic network of the Bouregreg and Chaouia watersheds, which includes three sub-basins: the Bouregreg sub-basin (10.210 km²), the coastal Atlantiques streamssub-basin (5.415 km²) and the Plaine of Chaouia sub-basin of which Bouskourastreamis a part (Fig. 1). This plain covers an area of (4.845 km²) with a total drainage network of 424 km (ABHBC 2004).

The Bouskoura streamwatershed, which covers an area of 272.9 km^2, is located 10 km from Casablanca and it is delimited by the geographical coordinates data which are as follows: X = 285000 to 295000 and Y = 330000 to 320000). The development of the city of Casablanca caused the removal of the Bouskoura stream outlet towards the sea up to the level of the El Jadida road; the current evacuation of floodwater from the stream is through the sanitation network of the city (Super Collector West). This basin is characterized by a weak urbanization compared to its total surface (concentrated in the centers of Bouskoura and Nouacer towards the South as well as that of Lissassfa-Sidi Maârouf in the North-East) and by a dominance of surfaces intended for agriculture.

Geological and Pedological Framework

The geology of the study area consists of a primary base on which unconformably low tertiary and quaternary coverage is based (Fakir 2001). Paleozoic is formed of completely impermeable or very low permeable soils in the weathered upper fringe. The predominant formations of the primary, strongly folded by the Hercynian orogeny, are shales and quartzites with sandstone. All of these lands are attributed to the Acadian and the Ordovician (Zerouali *et al*. 2001).

The subhorizontal Cretaceous cover, of varying thickness and undeveloped in the region appears, in the region of Casablanca, in the form of limestones, yellow marl-limestones and yellow marl. It is limited by the quartzite bar of Al Hank. The Plio-Quaternary consisting of a thin film of silts and silty sands extends over most of the plain (Rafik 2015).

Three soil types exist in the study area: iron sesquioxide soil, hydromorphic soil and calcimagnetic soil (Stoffnerr-GIZ 2013). The land use of the Bouskoura basin is very varied (Casablanca city and its suburbs, isolated buildings, Med V airport, Bouskoura forest, agricultural areas) with agricultural dominance. (Chelhaouie & Goury 2013, Boudaoud & Hadine 2013).

Hydrogeology

The Bouskoura basin has particular characteristics: a weak hydraulic gradient (Zerouali *et al*. 2001), the presence of pools in places, a degraded hydrographic network and

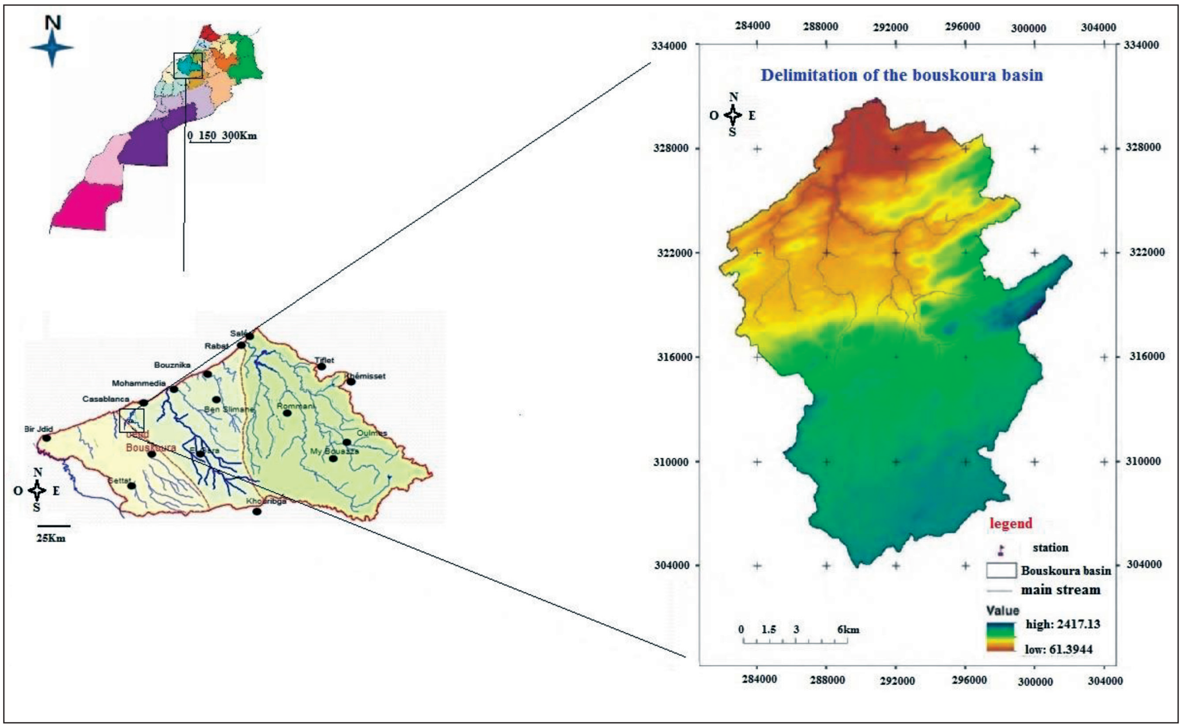

Figure 1. Bouregreg-Chaouia watershed hydrographic network and Bouskoura stream basin (after ABHBC 2004, Chelhaoui & Goury 2013 modified) and Location of sampling stations in Bouskoura stream

little marked notably upstream. The Bouskoura water table (which is the natural extension of the coastal Chaouia aquifer extending over 1260 km^2) has a heterogeneity characterized by the thickness of the sandstone limestone of the plio-quaternary and the depth of alteration of the schisto-sandstone complex of the primary as well as having high salinity. It is also characterized by very low piezometric levels, varying between 8 and 20 m and a potential of 52 million m^3 (Ministry of Agriculture 2018). The reservoir is composed of formations of the sandstone features of the Plio-quaternary are the place of large circulation, the thickness of this formation is however often not sufficient for a continuous sheet can develop there. Their good permeability facilitates, however, the infiltration of rainwater. In terms of quality, the water table has a clear degradation following an intensification of human activities (urbanization, agriculture, industry, ...). The Bouskoura basin has main watercourse consisting of the main watercourse: Bouskoura stream, which starts south of Casablanca and flows at a flow rate of 10 l / s in dry weather; its average annual flow is about 39 l / s (Boudaoud & Hadine 2013) and the average total inflow over the 1939-2016 period was about 4.73 Mm3/year (El Akrout 2017). It runs from south to north draining a watershed in the territories of the communes of Nouacer, Bouskoura and Oulad Saleh. After 11 km of course, streamBouskoura receives the waters of its main tributary: AïnJoumaâ stream. On arrival in the urban area, the streamBouskoura becomes channeled, 20m deep, in a pipe of 8m section. Bouskoura stream, 20 km long, irrigates 20 ha of agricultural land and is fed by five sources. However, the future urbanization of Greater Casablanca is moving southwards by the launch of major projects and the creation of several industrial parks (Boudaoud & Hadine 2013).

Climate

The prevailing climate in the Casablanca region is of the Mediterranean type characterized by the influence of the Atlantic Ocean. The bioclimatic stage corresponds to the semi-arid winter temperate. The temperature can average 13°C in winter and 31°C in summer (Ministry of Agriculture 2018). Rainfall is marked by spatial and temporal fluctuations (annual and interannual). They hardly exceed 400 mm and undergo interannual variations dependent on the climatic irregularities which characterize Morocco in its Mediterranean geographical context for several years (Nahli 2017).

Sanitation of the Area

The study area is equipped with a segregated and unitary sanitation system that has been in operation since 1987. The wastewater collection joins the sanitation network of the city of Casablanca. The rainwater is evacuated towards Bouskourastream by means of a network of a length of 24 km and a diameter between 400 mm to 1600 mm (after internal report of the LYDEC Company).

Sampling Stations

On the Bouskoura watercourse, we have established in this hydrosystem a water quality monitoring network comprising 8 stations distributed in the upstream-downstream direction (Fig. 2). Two of them (P2 Noukhayla and P5 Sidi Ayyad) are part of the monitoring network of the Bouregreg-Chaouia Hydraulic Basin Agency. The geographical coordinates of the selected stations are given in table 1. The choice of these sampling stations is based on the nature of the water (wastewater, water natural features, ...), the morphological structure of the Bouskoura watercourse, the nature of the bed and substrate, the proximity of urban and rural population centers and the opportunities for access and collection offered.

11-12 samples (depending on the stations) were conducted over a 2 years period (August 2015 to July 2017) (Tab. 2).

Physicochemical Analyses

Measurements of temperature, pH, turbidity, dissolved oxygen and electrical conductivity were made in situ respectively by

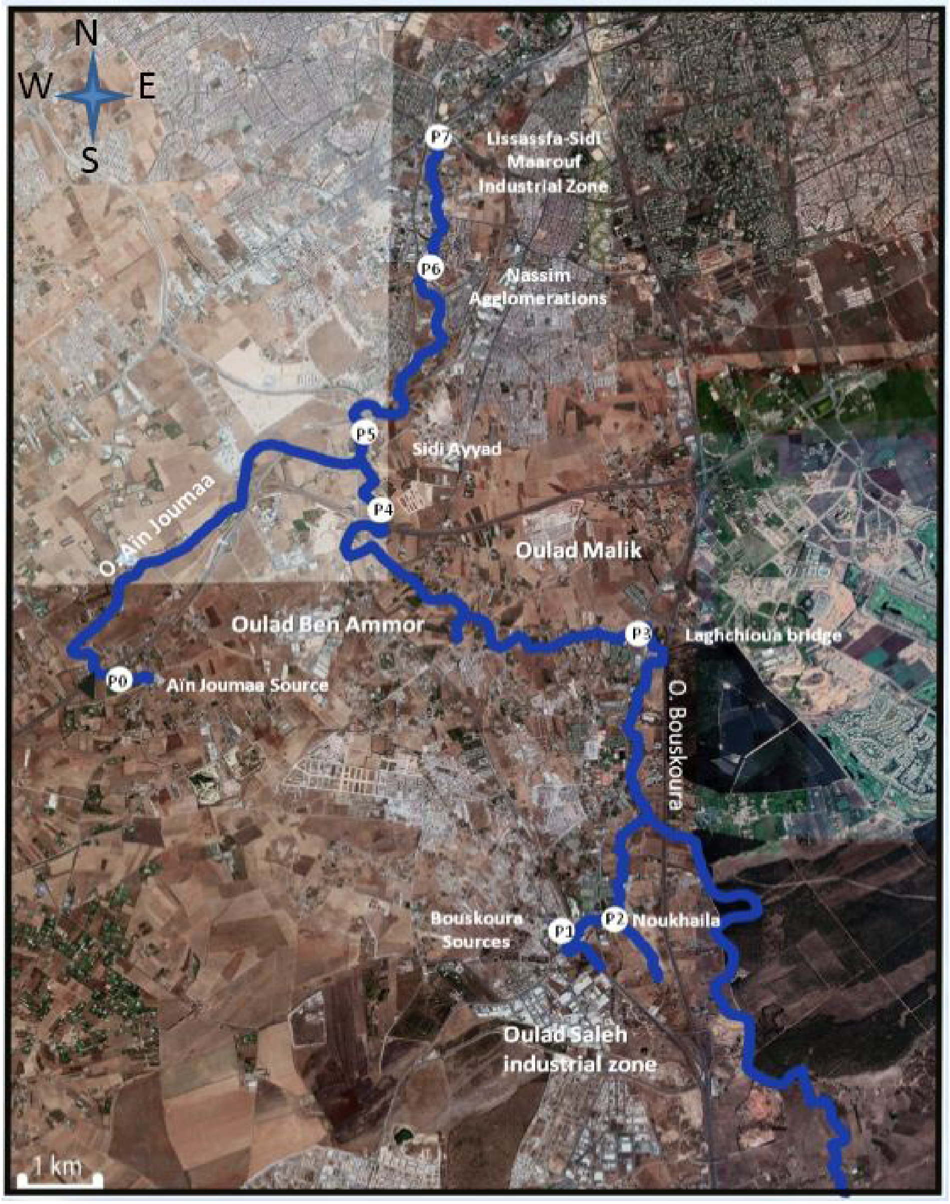

Figure 2. Location of sampling stations in Bouskoura stream.

Table 1. Lambert coordinates, characteristics and type of activities in monitoring stations Bouskoura stream.

Stations	Lambert Coodinates		distance between station (km)	Total distance (km)	Type of pollution
	X	Y			
P0 (Aïn Joumaa Source)	286190	322244	-	-	Bathing activity -
P 1 (Bouskoura Source)	291150	318980	-	0	Reference station
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

Table 2. Total number of samples per parameter at Bouskoura stream stations

Stations	Number of samples by parameters		
	Microbiological analysis	physicochemical analysis	Parasitological analysis
P0 (Aïn Joumaa Source)	11	11	11
P 1 (Bouskoura Source)	11	11	11
P 2 (Noukhayla)	12	12	12
P 3 (Laghchiwa Bridge)	12	12	12
P 4 (Oulad malek)	12	12	12
P 5 (Sidi Ayyad)	12	12	12
P 6 (Nassim Agglomerations)	12	12	12
P 7 (Lissasfa-Sidi Maârouf Industrial Zone)	12	12	12

a mercury thermometer, a WTW pH meter (1/100), a WTW oxymetrer (1/100) and a conductivity meter. WTW (1/100).

Physicochemical parameters analyses grouped in table3 are performed on water samples taken from 500 ml polyethylene bottles, previously rinsed with the water of the area studied, then transported to the laboratory stored at 5 ± 3°C. All sampling and analysis methods used are standardized according to AFNOR & ISO standards (NF 2011).

The results of the water physicochemistry have been confronted with the Moroccan standards (NM 2002) for the quality of surface water in order to check their conformity.

Table 3. Standard Methods used in analyses of water physicochemical parameters

Parameters	Abbreviations	Units	Standars
Chemical Oxygen Demand	DCO	mg O_2/l	NFT 90-101
Biology Oxygen Demand	DBO_5	mg O_2/l	NF EN 1899.1
Ammonium	NH_4^+	mg N /l	NFT 90-015.1
Nitrites	NO_2^-	µg N/l	NF EN ISO 13395
Total Kjeldahl Nitrogen	NTK	mg N/l	NF EN 25663
Orthophosphates	PO_4^{3-}	mg PO_4^{3-}/l	NF EN 1189
Total Phosphorus	PT	mg P/l	NF EN 1189
Chlorophyll a	Chl a	mg Chl a/l	NF T 90 117
Suspended matter	SM	mg/l	NF EN 872

Bacteriological Analyses

Bacteriological Parameters

The study of bacteriological parameters focused on the quantification of indicator parameters of fecal contamination: Total coliform (TC), Fecal coliform (CF), *Echerichia coli* (E. coli) and Fecal streptococci (SF). The search for *Pseudomonas aeruginosa* is being undertaken in this study as bathing activities have been reported in some stations of this watercourse.

All samples were taken according to the requirements of the specific standard for sampling for microbiological analyses in ISO 19458. Thus, the samples were taken in sterile 500 ml vials and stored at a temperature of 5 ± 3°C, while taking care not to exceed 21 ± 3 hours between sampling and analysis.

All the analyses are carried out with a control and a duplicate to guarantee the absence of acontamination and a good homogenization.

Analyses of bacteriological parameters were performed according to the following standards (Table 4):

Analyses of bacteriological parameters were performed according to Afnor and ISO standards (NF 2011).

The results of the bacteriological analyses of waters were confronted with the Morocco standards (NM 2002) relating to the quality of surface water and irrigation to verify compliance.

Especially for the P0 station (source Ain Joumaa) where there is a bathande activity, the quality of the water quality was evaluated by referring to the national standard of bathing water quality (NM 03. 7. 200), transposed from the EU Directive (76/160 / EEC) (Official Journal of the European Communities, 1976) and the WHO guidelines (WHO 2003) applicable to the sanitary control of bathing waters.

Tableau 4. Standard methods used for wtaer microbiological analyses

Paramètre analysé	Norme française
Total coliform	NF ISO 9308-1
Fecal coliform	NF ISO 9308-1
Echerichia coli	NF ISO 9308-1
Fecal streptococci	NF ISO 7899-2
Pseudomonas aeruginosa	NF ISO 16222

Determination of the Origin of Fecal Contamination

The report Fecal Coliforms/Fecal Streptococci (or R ratio) was proposed as a method of identifying sources of pollution as early as 1969 by Geldreich & Kenner (1969). It is based on the fact that human feces have higher levels of fecal coliforms than fecal streptococci, whereas the reverse is true for animal faeces (Jadas-Hécart *et al*. 2012).

Geldreich & Kenner (1969) therefore proposed that Fecal coliform/fecal streptococci (or ratio R) greater than 4 indicate pollution of human origin whereas a ratio lower than 0.7 indicates pollution of animal origin.

Borrego and Romero (1982) proposed a classification of fecal contamination sources for intermediate classesas follows (Tab. 5):

Tableau 5. Fecal coliform / enterococci ratios and origin of fecal contamination according to Borrego & Romero (1982)

CF/SF	Origin of fecal contamination
R>4	exclusively human
4>R>2	mixed predominantly human
2>R>1	uncertain
1>R>0,7	mixed predominantly animal
0.7>R	mainly animal

Microbiological quality index (MQI)

The principle of evaluation of the MQI index is based on the distribution of the pollutant element values (indicators of bacterial contamination) in 5 classes and the determination of the corresponding class number for each parameter to make it the average (Leclercq & Maquet 1978) (Tab. 6).

Class boundaries were established by Bovesse & Depelchin (1980), In Leclercq (2001).

Parasitological Analyses

A sampling of surface water from Bouskourastream was carried out at selected monitoring stations. Five liters for light water, are collected and preserved by the addition of Formol 10% in sterile flasks.

Considering the large dispersal of parasitic helminth eggs in overloaded natural waters, their concentration becomes necessary to ensure a better count. For this reason, the Bailenger (*In* Rodier 2009) technique strongly recommended by the WHO (WHO 1997) was chosen because of its ease of execution, its low cost as well as its reliability.

Table 6. Class Limitations and Mapping quality after the Microbiological Contamination Index IQM

Classe N°	Tot. Bact../ml	Fecal Coliforms/ml	Fecal streptococci/ml	MQI	Fecal contamination	Mapping
5	<2000	<100	<5	4,3-5,0	null	Blue
4	2000-9000	100-500	5-10	3,5-4,2	low	Green
3	9000 - 45000	500-2500	10-50	2,7-3,4	moderate	Yellow
2	45000 - 360000	2500-20000	50-500	1,9-2,6	strong	Orange
1	>360000	>20000	>500	1,0-1,8	very strong	Red

The pellet obtained after centrifugation in a mixture of aceto-acetic buffer and ether is added to a solution of 33% zinc sulfate (density = 1.18) to allow the parasitic elements to adhere to the upper surface of the blade of Mac Master and facilitate their counting under the light microscope. The identification of helminth eggs was based on the size, shape, and content of these eggs in accordance with the bibliographic descriptions (Golvan 1984). The total quantification of helminth eggs per liter (N) present in two liters of wastewater analyzed is calculated using the following formula: $N = A. X / P. V$

with :

A :Number of eggs counted on the Mac Master blade or average numbers found in 2 or 3 blades.
X: Volume of the final product (ml).
P: Capacity of the Mac Master blade (0.3 ml).
V: Volume of the initial sample of wastewater to be analysed.

Statistical Analyses

In order to study the variability between the stations, the data collected in this study were analyzed on the XLstat 2014 software by the ANOVA test. A Tukey HSD posterior test was used in cases where the analysis of variance revealed significant differences.

All statistical inferences were made at the 5% threshold.

To account for the structural differences that exist between stations in the study area, we performed a Hierarchical Ascending Classification (HAC) on the basis of the averages obtained during the follow up concerning the bacteriological analyses (TC, FC, *E.coli* and FS), parasitological andphysicochemical. This statistical calculation makes it possible to classify the stations according to their dissimilarity.

RESULTS AND DISCUSSION

Physicochemical Water Quality

The mean values as well as the standard deviations of the different physico-chemical parameters measured in the 8 stations, are presented in table7.

We will limit ourselves in this work to give the summary of the evolution of the environmental indicators studied. For further information on monitoring the physicochemistry of Bouskoura waters, refer to the article by Benhassane *et al*. (2019).

- Average water temperaturesvary between 20.45 ± 3.89°C at the P2 station and 21.33 ± 3.59°C at the P0 station. These data indicate that the temperature of the study area is favorable to aquatic life (Rodier 2009). And they make it possible to classify the waters of the streamBouskoura stations in good quality with values lower than 25°C (NM 2002).

- The average recorded pH values are maintained within the range of 7.24 ± 0.23 pH units at the P1 station and 8.05 ± 0.10 pH units at the P7 station. These values of the pH can therefore be attributed, in the sense of Golterman (1971), to the buffering phenomenon of the carbonate-bicarbonate complex. According to Decree No. 1275-02 of 17 October 2002 (NM 2002) the water quality of the various Bouskoura monitoring stations can be attributed good quality except for the P6 and P7 stations, of which almost 10% of the pH values exceed 8.5 pH units; therefore, they are of average quality.

- On the other hand, the electrical conductivity shows an increasing trend with a minimum average of around 1302.00±892.84 **µS**/cm at the P0 station and a maximum average value of 6088.64±1226.34 **µS**/cm. at the P7 station. This confirms the strong mineralization of the waters down stream because of the different untreated discharges. These results are similar to those recorded in most Mediterranean rivers (Morin 2006, Mouni *et al*. 2009, Oubraim 2002, Mounjid *et al*. 2014a, Mounjid *et al*. 2014b et Nehar *et al*. 2015, etc.).

- Dissolved oxygen (O2) varies in a decreasing manner, with a maximum average value of 8.07 ± 0.02 mgO2/l at the Bouskoura source and a mean minimum value of 0.64±0.4 mg O2/l at the P7 station. Indeed, these stations permanently receive the wastewater from the Lissassfa-SidiMaârouf industrial zone and the Nassim agglomerations, which leads to high consumption of oxygen. The spatial evolution of the dissolved oxygen content in the Bouskoura streamshows that the biodegradable organic matter load of domestic, industrial and agricultural origin discharged and accumulated along with this ecosystem, contributes to a significant fall in the oxygenation of water stream especially in station P2, P6 and P7. Excessive inputs of fermentable organic matter discharged by the various collectors of agglomerations and industrial zones liable to be oxidized, resulting in increased consumption of oxygen and an intermediate drop in its content.

- The average Biological Oxygen Demand (BOD5) and Chemical Oxygen Demand (COD) contents depend on the type of discards in the different stations of Bouskoura stream. The spatial evolution of these two parameters describes an uptrend, with very high values of BOD5 and COD that reflect the importance of the amounts of organic matter received downstream of the stream. The average values of BOD5 vary between a mean maximum value of 37.38 ± 10.45 mg O2/l for the P7 station and a minimum average value of 2.63 ± 0.22 mg O2/l for the P0 station.

Similarly, the COD measurements in this aquatic environment vary according to an upstream-downstream gradient between a mean minimum value of 2.37 ± 0.37 mg O2/ l and a maximum average value of 153.45 ± 31.11 mg O2/l.

According to the Moroccan standards (NM 2002), the water of the P0 and P1 stations upstream of the stream are in the class of excellent quality, on the other hand for the rest of the stations the quality is bad to very bad.

- Analysis of the ammonia profile shows an upward trend with low values upstream 0.07 ± 0.08 mg NH4+/l and maximum values at the polluted sites P6 and P7 with respectively order values. of 10.61 ± 5.64 mg NH4+/l and 15,68 ± 4.69 mg NH4+/l. This makes it possible to classify the water as a lover in excellent quality for stations such as P0, P1. Good quality for P2 and average for P4, P5 while bad to very bad for P3, P6, P7 (NM 2002).

- Nitrites (NO2-) in the different stations of the Bouskoura lotic ecosystem show no particular tendency. 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-SidiMaarouf zones respectively.

- The total Kjeldahl Nitrogen (TKN) is present in all the stations (except P0 and P1) at average concentrations which exceed the limit recommended by Moroccan standards (N.M. 2002), that is to say. 3.00 mg N / l. In the two stations close to the water sources (P0 and P1), the quality of the water is on the other hand excellent.

- The suspended solids content (SM) is between 0.12 ± 0,06 mg/l and 19.73 ± 3.8 mg/l. The highest concentrations were recorded at downstream stations, following spills of different discharges and the type of soil that is muddy. These values make it possible to classify the waters of Bouskourastream in excellent quality, with mean values of less than 50 mg / l (NM 2002).

- Evolution of the average contents of phosphorus compounds shows significant variations between the upstream and down stream of Bouskoura stream.

Total phosphorus (TP) concentrations range from 0.35 ± 0.06 mg P/l in P1 to 5.82 ± 1.54mg P/l downstream at the P7 station. These average grades rank the upstream P0 in the middle category and for the rest of the stations it is poor to very poor (NM 2002).

Orthophosphate (PO43-) contents vary between 0.22 ± 0.07 mg P/l at P0 and 3.97 ± 1.24 mg P/l at P7. The increase in phosphorus compounds may be of domestic and industrial origin but also of agricultural origin; especially since the highest values are recorded during the rainy season when leaching of phosphorus elements is important.

- As for the average levels of chlorophylla (Chla), the high values were recorded downstream of the stream (station P2) with a maximum average of 35.69 ± 7.53 µg/l at P2 (which receive wastewater of Oulad Saleh industrial zone) and a minimum average value of around 0.21 ± 0.15 µg/l at the P0 station. The average chlorophyll values classify Bouskoura waters as excellent for P0, good for P1, P5 and average for P3, P4, P6, while they are of poor quality for P2 station (NM 2002).

The ANOVA statistical test followed by the Tukey HSD posterior test applied to the averages of the physicochemical parameters, shows that the differences observed between the upstream and the downstream stations are significant (P <0.05) for all these parameters except for the temperature. Indeed, the evolution of these parameters illustrates a gradient of mineralization and organic pollution increasing from upstream to downstream of Bouskourastream where the effect of anthropic activities is important.

On the other hand, the strong standard deviations observed show significant intra-site variations.

Bacteriological Monitoring

The study of bacteriological parameters focused on the quantification of indicator parameters of fecal contamination: total coliform, fecal coliform, *Echerichia coli* and fecal streptococci. These indicators are specific to the intestinal flora, they are not necessarily pathogenic, but their presence in large numbers in an aquatic environment indicates the existence of fecal contamination, and therefore a potential epidemiological risk (George & Servais 2002).

Total Coliform

Figure3-A illustrates the spatial evolution of total coliform (TC) loads according to an increasing upstream-downstream gradient of Bouskourastream. We can thus distinguish, along the study site, two peaks of average loads in these bacteria. The first at the station P2 which is of the order of 1.87

Table 7. Averages of the different physico-chemical parameters measured in the 8 stations of Bouskoura stream and results of the ANOVA test followed by the Tukey test

STATIONS		pH	T°	EC	DO	PO_4^{3-}	CDO	BDO_5	TKN	NH_4^+	TP	NO_2^-	MES	Chla
		-	(°C)	(µS/cm)	(mg O_2/l)	(mg P/l)	(mg O_2/l)	(mg O_2/l)	(mg N/l)	(mg N/l)	(mg P/l)	(µg N/l)	(mg/l)	(µg/l)
P0	mean	7,38	21,33	1302	7,88	0,22	3,11	2,63	0,03	0,08	0,36	3,75	0,12	0,21
	SD	0,21	3,59	892,84	0,31	0,07	1,06	0,29	0,02	0,06	0,1	6,59	0,06	0,15
P1	mean	7,24	20,54	1804,75	8,07	0,28	2,37	3,19	0,57	0,07	0,35	0,66	0,12	3,52
	SD	0,23	3,75	55,56	0,2	0,07	0,37	0,73	0,31	0,08	0,11	0,25	0,06	1,54
P2	mean	7,62	20,45	3668,91	1,72	3,2	40,17	2,6	25,41	0,18	5,1	46	14,63	35,69
	SD	0,32	3,89	424,95	1,5	0,94	6,42	0,7	9,68	0,14	1,96	30,29	6,03	7,53
P3	mean	7,3	21,1	4164,91	5,59	1,82	31,98	8,53	27,54	3,79	3,37	10,53	13,33	21,45
	SD	0,31	3,99	1248,34	0,51	0,85	6,25	2,06	5,26	1,31	1,63	2,61	3,09	6,63
P4	mean	8,05	20,99	6088,64	4,54	1,61	35,82	10,82	27,54	0,55	2,17	6,37	19,53	25,7
	SD	0,1	3,57	1287,3	0,63	1,01	6,6	2,62	5,26	0,31	1,1	1,32	4,28	10,83
P5	mean	7,93	20,46	4339,18	5,11	2,87	49,72	2,41	4,86	0,72	2,79	0,4	15,23	9,72
	SD	0,14	4,67	584,55	1,66	1,44	27,99	4,72	8,14	2,93	1,54	10,82	5,78	4,42
P6	mean	7,94	21,19	4260,45	1,29	3,94	122,09	27,07	27,54	10,61	5,82	25,06	19,73	14,73
	SD	0,16	4,16	1264,1	0,44	1,05	13,13	4,4	5,26	5,64	1,46	15,65	3,8	3,73
P7	mean	8,05	20,99	6088,64	0,64	3,97	153,45	37,38	27,54	15,68	5,82	46,02	19,3	6,17
	SD	0,1	3,33	1226,34	0,4	1,29	31,11	13,27	5,43	4,69	1,54	12,02	4,58	1,86
	F	36,3983	0,0905	50,0537	135,7999	12,0848	80,0624	53,7081	30,2015	55,1007	19,2340	27,8845	13,2158	53,1899
	Pr > F	< 0,0001	0,9987	< 0,0001	< 0,0001	< 0,0001	< 0,0001	< 0,0001	< 0,0001	< 0,0001	< 0,0001	< 0,0001	< 0,0001	< 0,0001
	Significatif	Oui	Non	Oui	Oui	Oui	Oui	Oui	Oui	Oui	Oui	Oui	Oui	Oui

P0 : Ain Joumaa Source; P1: Bouskoura Source; P2 : Noukhayla; P3: Laghchiwa bridge; P4 : Oulad Malek; P5 : Sidi Ayyad; P 6: Nassim Agglomeration; P7: Z.I Lissassfa-Sidi Maârouf zone. // SD : Standard deviation

106CFU/100ml and the second at the station P6 of the order of 3.58106 CFU/100 ml.

The high TC load at the P2 station could be attributed to discharges from the main collector of the Oulad Saleh industrial area. The one recorded at the P6 station reflects the impact of uncontrolled wild discharges of domestic wastewater from Nassim agglomerations. Between these two stations, the average load in TC drops but it remains maintained at a level higher than the self-purifying power of the streamBouskoura. At the P7 station, the drop in bacterial load is probably due to environmental conditions that are unfavorable to bacterial growth, especially the nature of industrial discharges.

Referring to the Moroccan standards (NM 2002) fixing the quality class limits of surface waters one can draw up the following observation: the bacteriological quality of water at the sources of Bouskoura (station P1) and Ain Joumaa (station P0) is excellent (CT ≤50 CFU/100ml); it is, on the other hand, bad to very bad for the other stations (CT >5.104CFU/100ml).

Fecal Coliform

As for the TC, the evolution in average loads in fecal coliforms (FC) or "thermo-tolerant coliforms" illustrates an increasing upstream-downstream gradient of the Bouskourastream (Figure 3-B). In station P1 (Bouskoura source) we note the absence of FC; then, their average concentration goes from 8,58.102CFU /100ml in the Ain Joumaa source (P0 station) to reach 4.79105 CFU/100ml at the P6 station.

It is important to note that from the P3 station to upstream of the P6 station, the landscape is rural and the average CF loads are maintained at high levels, indicating a significant fecal load along from this stream path (personal observations on the study area).This high bacterial load seems to be linked to trampling of the watercourse by domestic animals (cattle, sheep, goat, etc.) whose excrement contaminates this lotic environment by FC. These results are in agreement with the work of Patoine (2011) which states that in general, the higher the animal density, the higher the concentration of fecal coliforms. Similarly, the rural character of the region suggests a contribution of these bacteria from the leaching of agricultural land where the spreading of manure is a very common phenomenon.

Referring to the Moroccan standards (NM 2002) fixing the quality class limits of surface waters we can say that the bacteriological quality of water at the Bouskourasource(P1 station) is excellent, it is good in ainJoumaa source (P0 station where FC ≤2000 CFU/100ml) and bad to very bad for the other stations (FC>2.104 CFU/100ml).

These very high values recorded during our sampling campaign, are on the one hand the direct consequence of the discharges of untreated wild domestic sewage from the douars and agglomerations bordering the Bouskourastreamas well as the effluent collection networks of the industrial units (P2 and P7), and secondly to soil leaching.

In addition, with reference to the National Bathing Water Quality Standard (NM 03. 7. 200), transposed from the EU Directive (76/160 / EEC) (Official Journal of the European Communities1976) and the WHO Guidelines (WHO 2003) applicable to sanitary monitoring of bathing water, the average fecal coliform levels evaluated at the Ain Joumaa (P0 station) exceed the Guide Value (VG) set at 100 CFU / 100ml. As a result, bathing in the waters of this station poses a health risk (especially for schoolchildren who venture from time to time to bathe in these waters when they return from their school or during weekends and holidays).

Echerichia coli

Echerichia coli (E. coli) monitoring conducted during the study period in Bouskoura stations showed the same evolutionary trend as that of fecal coliforms (Fig. 3-C). These follow-ups make it possible to know the percentage of *E. coli* in FC. Except in the P1 station where they are absent, the *E. coli* determined in the 7 stations during two years, from June 2015 to July 2017, represented between 60.02% and 88.47% of the FCs according to the station with an average overall of 79.76%. These *E. coli*/FC ratios obtained are of the same order of magnitude as those presented in the literature for small streams. For example, Rasmussen and Ziegler (2003) found that *E.coli* accounted for an overall mean of 77%; the work of Patoine and D'Auteuil-Potvin (2015) on 36 of the 51 measuring stations in small watercourses in agricultural areas located in different regions in Quebec indicate an average between 43 and 100% of FC.

Fecal Streptococci

The average fecal streptococci (FS) load is zero at the Bouskoura source (P1) and low at the Ain Joumaa source (P0) where it is of the order of 9.25102CFU/100 ml (Fig. 3-D). The maximum mean value is recorded at the P5 level (3.88105CFU /100 ml) which decreases downstream to reach 2.45 105CFU /100 ml at P7. The very high concentrations of bacteria at the monitoring stations (between P3 and P5) could be related to agricultural activities and intensive farming at the borders of Bouskoura stream.

Referring to the regulatory framework for surface waters (NM 2002), the average levels of fecal streptococci obtained in the studied stations allow them to be classified in the same class categories obtained for fecal coliforms (ie excellent class for P1, good for P0 and bad to very bad for the rest of the stations).

Similarly, the bathing activity observed at the Ain Joumaa source poses a health risk for the population in contact with the waters of this station because the average intestinal enterococci load exceeds that recommended by the European Directive (76/160/ECE) (Official Journal of the European Communities 1976) and the WHO Guidelines (WHO 2003) for Bathing Water Sanitation (set at 100 CFU/100 ml).

Bibliographic studies that have examined bathing in freshwaters contaminated with fecal streptococci have shown that the health risk in these waters is significant and low enough for very low levels in these indicator organisms. For example, Dufour (1984) sets a value of 33 SF/100ml and Zmirou *et al*. (1990) a value of 20 FS/ml.

Fecal coliform/fecal streptococci ratio (R)

The Rratio distinguishes four types of fecal contamination sources along the Bouskourastream (Tab. 8):

- Fecal contamination of mixed origin with predominantly animals in the P0 station (R = 0.93),

- Fecal contamination of predominantly human mixed origin in station P2 (R = 3.23),

afecal contamination of mainly animal origin in the P3 station with a CF/SF ratio of the order of 0.57,

andfinallyfecal contamination of uncertain origin in stations P4, P5, P6 with a 1<R<2 ratio.

The FC/FS ratio for the P0 station is 0.93 which means that the origin of fecal pollution is mixed and predominantly animal. Thus, it is likely that livestock watering, found in the field is the source of this value taken by this report.

The P2 station is characterized by an FC/FS ratio which is of the order of 3.25, which means that the fecal contamination source is of mixed but predominantly human origin. This is consistent with our observations on the ground where the presence of domestic wastewater is found in the main collector of the Oulad Saleh area; it would seem that illegal connections or reversals of connections (sewage / rainwater) are taking place in this area.

In station P3, the FC/FS ratio is equal to 0.57 indicating fecal pollution of animal origin. Fecal contamination in this area of the stream could be attributed to the presence of farm animals that can contaminate the water, as well as to the excrement of wild animals and the use of animal manure, which can thus compromise the bacteriological quality of the waters of Bouskourastreamat this station. In the agricultural sector, livestock waste is the main source of bacteriological contamination of water (Geldreich 1976 & Maul *et al*. 1982).

For the rest of the stations (from P4 to P7), the FC/FS ratio does not allow the exact identification of the source of fecal contamination because of the bacterial loads of human origin generated by several uncontrolled wild domestic releases and those of animal origin caused mainly by animal manure and the use of manure in agriculture.

The FC/SF ratio has been able to determine the origin of fecal contamination in the different stations although the interpretation of its fluctuations must take into account several factors. Thus, Edwards *et al*. (1997) reports that FC and FS loads can be influenced by variables such as seasons and flow rate during sampling. Servais *et al.* (2009) reported that intestinal enterococci survive longer than *E.coli* in the natural aquatic environment. Tyagi *et al*. (2009) have many limitations for this relationship (eg, variations in streptococcal concentrations in individuals that are related to different diets, the survival rate is variable among different species of fecal streptococci, difficulties in interpreting intermediate values, etc).

In any case, the human or animal origin of the fecal contamination, once determined, would constitute an important part of the management of the quality of the receiving water and would make it possible to set up.

Comparison of Bacteriology Results at the National Level

The comparison of the results of the means of the indicator bacteria of the fecal contamination of the present work and those obtained for in similar Moroccan peri-urban rivers (Tab. 9) indicates that:

- referring to the work of Mounjid *et al.* (2014a), the Bouskoura stream would be more contaminated by TC, FC and FS during the study period (June 2015 - July 2017) compared to the period February 2011-March 2012.

- in Bouskoura stream, the average loads for each of these three types of germs are also greater than those reported by Aboulkacem *et al*. (2007) in the streams Boufekrane and Ouislaneperi-urban of Meknes, by Mounjid *et al*. (2014b) in the suburban streamMerzeg of Casablanca. On the other hand, they are lower than those reported by El Addouli *et al.* (2008) in the Ouislane & Bouishakstreams of Meknes, by Abouelouafa *et al*. (2002) in the Oujda suburban Bounaïmstream and by Larif *et al*. (2013) in the suburban Boufekranestream Meknes.

Table 8. Spatial evolution of CF/FS ratio in Bouskoura stream

Station	FC/FS report	Source de contamination
P0	0,93	mixed predominantly animal
P1	-	-
P2	3,23	mixed predominantly human
P3	0,57	mainly animal
P4	1,76	uncertain
P5	1,13	uncertain
P6	1,33	uncertain
P7	1,75	uncertain

Pseudomonas aeruginosa

Despite the high burden of indicator bacteria in the above-mentioned fecal contamination, water analysis in Bouskoura showed that only the station located at the source of Ain Joumaa (P0) contained the pathogenic germs *Pseudomonas aeruginosa*. The average bacterial load in these bacteria is of the order of 5.82 103CFU/100ml (Fig. 3-E). This load may be due to water contamination during bathing activities at the source Ain Joumaa.

Microbiological Quality Index (MQI)

According to table.10, the spatial evolution of the Microbiological Quality Index (MQI) varies between 2 and 5, reflecting zero upstream bacteriological contamination and high contamination downstream of Bouskoura stream.

The spatial evolution of the microbiological quality index MQI makes it possible to classify the stations of Bouskoura stream into three quality classes:

- The P0 and P1 stations (close to the sources) in which the waters belong to the quality class 5, of which MQI is between 4.3 and 5.0, thus translating zero bacteriological contamination;

- The P3 station, with an index of about 2.7 which reflects a moderate bacteriological contamination;

- The MQI values in the P2, P4, P5, P6 and P7 stations, which are of the order of 2.3; 2.3; 2.3; 2 and 2.3, respectively, reflect a situation of high microbiological contamination of water.

The low value of the MQI index in P2 indicates high fecal contamination that could be directly related to the discharges of the large domestic and industrial sewage collector in the Oulad Saleh zone. This fecal pollution decreases under the self-purifying effect of the watercourse and fecal pollution become moderate (MQI = 2.7) at the P3 station. Downstream from this station, the MQI index will fall and take lower values indicating strong fecal contamination ($1.9 < MQI < 2.6$); water

Table 9. Comparison of the results of the means of the indicator bacteria of fecal contamination obtained in different Moroccan peri-urban streams.

Authors	Location	Fecal contamination indicators (CFU/100ml)		
		CT	CF	SF
El Addouli *et al.* (2008)	Ouislane & Bouishak streams (peri-urban of Meknes)	10^{7} - 3.10^{7}	$1,8.10^{5}$ - $8,3.10^{5}$	10^{3} - 10^{7}
Aboulkacem *et al.* (2007)	Boufekrane stream (peri-urban of Meknes)	$1,2.\ 10^{5}$ - $5,2.10^{5}$	$2,4.10^{4}$ - $1,03.10^{5}$	$1,5.10^{4}$ - $7,9.10^{4}$
	Ouislane stream (peri-urban of Meknes)	$2,0.\ 10^{4}$ - $7,7.10^{4}$	$8,6.10^{3}$ - $2,4.10^{4}$	$1,6.10^{3}$ - $7,8.10^{3}$
Abouelouafa *et al.* (2002)	Bounaime stream (suburban of Oujda)	$3,4.10^{7}$	$1,8.10^{7}$	$1,7.10^{6}$
Larif *et al.* (2013)	Boufekrane stream (peri-urban of Meknes)	10^{7} -3.10^{7}	$1,8.10^{5}$ - $8,3.10^{5}$	10^{3} - 10^{7}
Mounjid *et al.* (2014)	Merzeg stream (suburban Casablanca)	$2,5.10^{4}$ - $4,2.10^{5}$	$8,9.10^{3}$ - $3,0.10^{5}$	$1,1.10^{3}$ - $3,0.10^{3}$
Mounjid *et al.* (2014)	Bouskoura stream (suburban Casablanca)	$4,0.10^{3}$ - $8,1.10^{4}$	$1,2.10^{3}$ - $1,5.10^{4}$	$0,4.10^{3}$ - $2,3.10^{4}$
This study	Bouskoura stream (suburban of Casablanca)	$1,87.10^{3}$- $3.58\ 10^{6}$	$8.58\ 10^{2}$- $4.79\ 10^{5}$	$9.25\ 10^{2}$- $3.88\ 10^{5}$

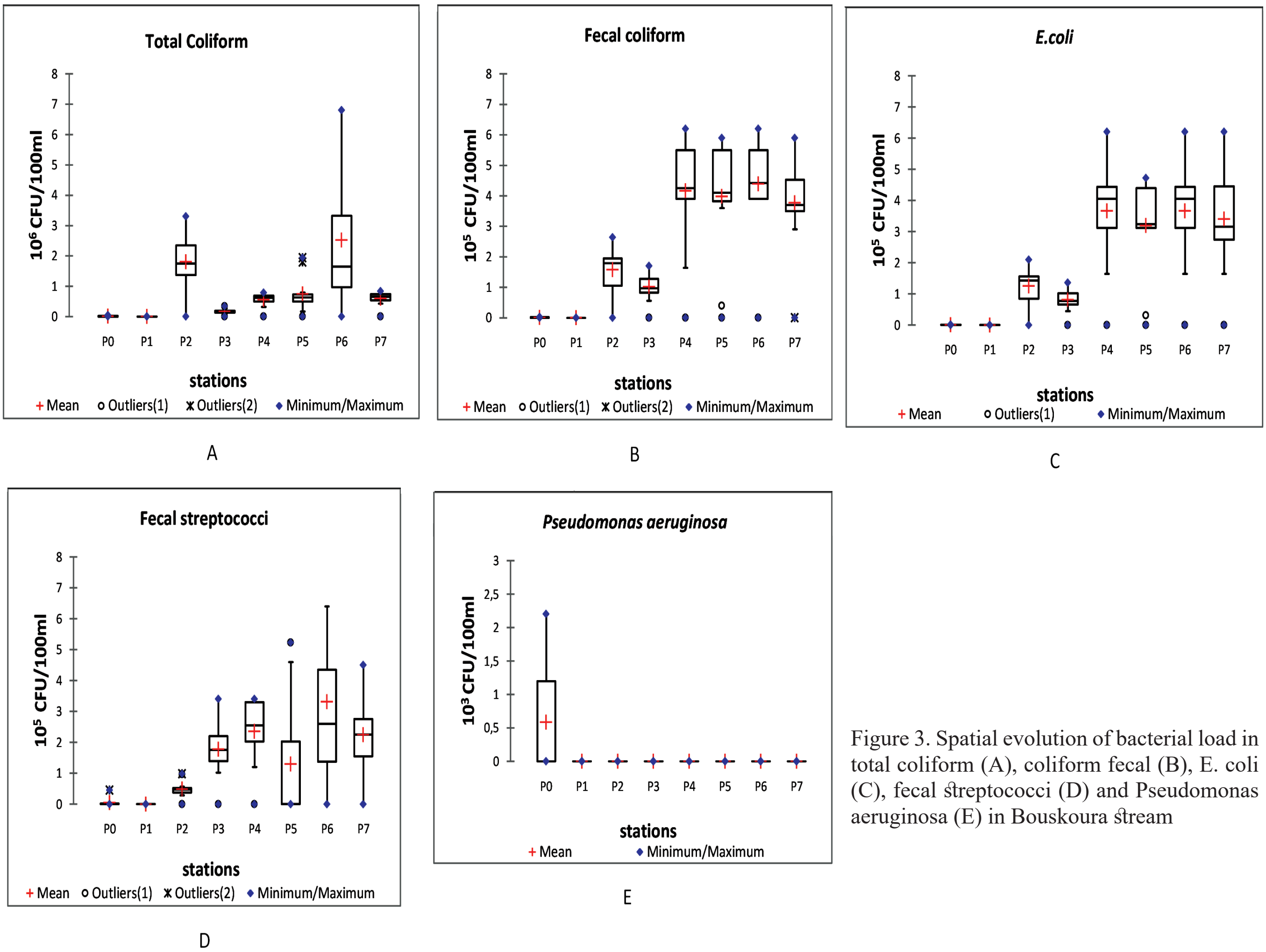

Figure 3. Spatial evolution of bacterial load in total coliform (A), coliform fecal (B), E. coli (C), fecal streptococci (D) and Pseudomonas aeruginosa (E) in Bouskoura stream

quality is no longer improving along the stream, thus testifying to the importance of the pollutant load of fecal nature compared to the self-purifying capacity of the stream.

Correlation BetweenPhysicochemical and Bacteriological Parameters

Total coliform has significant negative correlations ($p<0.05$) with oxygen and positive correlation with orthophosphate and total phosphorus (household pollution indicators) but no correlation between pH and electrical conductivity (EC) or suspended matter (SM) (Tab. 11). In fact, this group of bacteria is very heterogeneous and according to Servais (2009), since not all species included in CT are specific for the intestinal flora of warm-blooded animals. Indeed, some species are of telluric or aquatic origin and are able to develop in the aquatic environment.

Mean loads of FS, FC and *E. coli* are positively correlated with pH, EC and SM; these correlations are significant ($p<0.05$) for SF, and highly significant ($p<0.01$) for CF and *E. coli*. CF and *E. coli* additionally show positive and significant correlations with orthophosphates (PO43-) parameter and the COD indicators of oxidizable materials. Indeed, the group of FC is mainly made up of the species *E. coli*. This is considered a good indicator of recent environmental contamination by human faeces or warm-blooded animals (Helmer *et al.* 1991, Baudisová 1997). The work of Craig *et al.* (2004) has shown that turbidity and sediment attachment can improve the survival of *E. coli.* in sediments. Their decay is twice as high in the Free State as when they are associated with suspended particles (Garcia-Armisen & Servais 2004) which explains the good correlation with SM.

Parasitological Monitoring

Table 10. Spatial evolution and mapping of the microbiological quality index (MQI) in Bouskoura stream

Stations	**P 0**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**
indice MQI	4,7	5	2,3	2,7	2,3	2,3	2	2,3
Contamination fécale	Null	Null	strong	Moderate	Strong	Strong	Strong	strong

Parasitological analyses of the waters of this hydrosystem have revealed the presence of eggs belonging to two groups of parasitic Helminths (Platyhelminths and Nemathelminths) with a predominance of the latter (Tab. 12**)**. This predominance of Nemathelminths has also been reported by several authors (Stien *et al.* 1987, Stien 1989, Abou el ouafa 2002, El Guamri & Belghyti (2007), Sylla *et al.* 2008, Hamaidi-chergui *et al.* 2016, etc). This predominance was explained by Schwartzbrod *et al*. (2003), Hajjami *et al*. (2012) and Hajjami *et al*. (2013) by the fact that the eggs of the intestinal nematodes are more resistant than those of the cestodes in Wastewater.

Among the Plathelminths found in this watercourse are a trematoda taxon (*Fasciola hepatica*) and two Cestoda taxa (*Hymenolepis nana* and *Taenia sp*.) (Tab.12). The Nemathelminths include the following taxa: *Ascarissp*, *Trichurissp*, and *Ankylostoma sp*. In this inventory, we can note the absence of certain Helminth taxa (especially strongyles and protozoa: *Giardia sp*., *Entamoeba sp*., etc....) often encountered in polluted Moroccan rivers and streams.

The diversity of parasite taxa noted in this study has also been reported in other studies on lotic environments at the national level (Dssouli *et al*. 2001, El Guamri & Belghyti 2007a, El Guamri *et al*. 2007b, Talouizte *et al*. 2007, El Ouali Lalami *et al*. 2014 etc...) and internationally (Stot *et al*. 1997). According to these authors, this diversity indicates that the sources of contamination are of human and animal origin.

It is important to point out:

* that in stations P2 and P6 we note the presence of all six taxa of Helminths;

Table 11. Matrix of correlations between means of the physicochemical and the bacteriological parameters

	CT	**CF**	**E COLI**	**SF**
pH	0,45	0,96**	0,97**	0,77*
T°	0,03	0,02	0,05	0,06
EC	0,23	0,84**	0,85**	0,71*
O_2	-0,71*	-0,70	-0,69	-0,50
PO_4^{3-}	0,71*	0,76*	0,74*	0,68
CDO	0,55	0,73*	0,73*	0,62
BOD_5	0,39	0,60	0,62	0,47
TKN	0,48	0,53	0,55	0,41
NH_4^+	0,38	0,52	0,53	0,45
TP	0,72*	0,62	0,61	0,52
NO_2^-	0,49	0,27	0,28	0,03
SM	0,56	0,89**	0,89**	0,80*
Chl a	0,38	0,20	0,20	0,10

*: Significant correlations at $p<0,05$ ($N = 8$)
**: Highly significant correlations at $p<0,01$ ($N = 8$)

* with the exception of the stations close to the sources (P0 and P1), in all other stations the eggs of *Ascaris sp.* have been identified. The same result was reported by Lamghari-Mubarrad & Assobhei (2007) who reported that these eggs were present throughout the year in the wastewater effluents of the city of El Jadida. These authors also report that the risk attributable to wastewater during transmission of ascaridiosis to exposed children was approximately 17% and boys, particularly those aged 7 to 10, appeared to be the most vulnerable to infection exposure to ascariasis due to their frequentation of the aquatic environment polluted by domestic wastewater.

The spatial assessment of the mean parasite load of Bouskourastream waters reveals large fluctuations in helminth eggs (Fig. 4). Thus, the minimum average parasite loads are recorded upstream of the stream, in particular at the P0 and P1 stations close to the sources) with a total absence of helminth eggs. On the other hand, a first peak at P2 (159.36 eggs / l) and a second peak at the P6 station (189.36 eggs / l) appear in figure 4. These data reveal fecal pollution carried by raw effluents, especially at the level of P2 (discharges from the Oulad Salah region) and P6 (Nassim agglomerations). At these stations, Bouskourastream behaves like an open sewer. According to Bouhoum (1987), Yilmaz *et al*. (1997) and Salama *et al*. (2016), levels of helminth eggs in wastewater are strongly related to demographic status and socio-economic level, which corroborates the results of this study because the population at these two stations is dense and its socio-economic level is low.

The decrease helminth egg levels recorded at the P3, P4 and P5 stations is due to the small number of inhabitants connected to the collectors flowing into the Bouskoura stream; Indeed, the populations of these areas (rural or slum) have septic tanks they drain sporadically in the stream. On the other hand, the drop in the parasite load at the P7 station is mainly due to the dilution by the industrial effluents, which is in agreement with the work of El Guamri & Belghyti. (2007) and Jiménez *et al*. (2002).

The comparison of the results of this study with the scarce data from the literature on similar ecosystems (at the national level)

Table 12. Eggs of the Helminths inventoried in the different stations of Bouskoura stream.

Stations	Mean of total Helminths (eggs/l)	Helminths					
		Platyhelminths	Nematods			Cestods	
		Fasciola hepatica	Ascaris sp.	Trichuris sp.	Ankylostoma sp.	Tænia saginata	Hymenolepis nana
P0	0	-	-	-	-	-	-
P1	0	-	-	-	-	-	-
P2	159,36 ± 35,27	+	+	+	+	+	+
P3	52,18 ± 16,42	-	+	+	+	-	-
P4	51,90 ± 10,78	-	+	-	-	+	-
P5	58,90 ± 21,02	+	+	+	-	-	-
P6	189,36 ± 35,32	+	+	+	+	+	+
P7	86,72 ± 12,14	-	+	+	-	+	+

(+) : present taxon; (-) : absent taxon

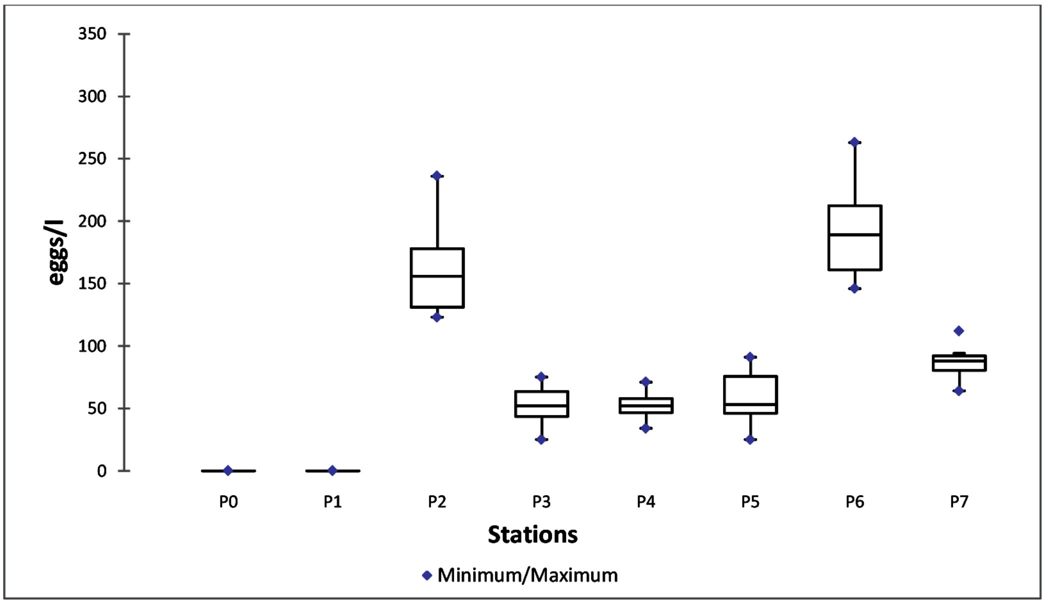

Figure 4. Spatial evolution of parasite load in helminth eggs along Bouskoura stream

indicates that the waters of the Bouskourahydrosystem are highly parasitologically loaded (Tab. 13). Thus, the parasite loads released in the waters of the Ouislane and Bouishak streams (periurban of Méknès) by El Addouli *et al*. (2012) are of the order of 44 and 36 eggs / l respectively; these loads are of the order of 2.5 eggs/l in the Bounaïmstreamperiurban of Oujda (after Dssouli *et al*. 2001) and 32.4 eggs/l in the Fouaratperiurban of Kenitra (according to El Guamri *et al* 2007a).

Another important point to consider: the flow velocity of the waters of the Bouskourastream is low (Mounjid 2014). According to Bouhoum (1996) and Bouhoum *et al*. (1997), reduced water velocities in these lotic media would facilitate the sedimentation of helminth eggs, which would pass mainly from water to sediments. This would increase their bioavailability and thus their health impact.

Helminth eggs, by their great ability to survive in the environment, are very important to consider in the context of irrigating with wastewater. For example, the WHO guidelines (1989) set Helminth contents ≤ 1 egg/l and the national water quality standards for irrigation (NM 2002) advocate the absence of these eggs. In view of the results obtained, it can be said that the waters of the different stations of the Bouskourastream (with the exception of the P0 and P1 stations close to the sources) would be non-compliant with the use in agriculture. The work of Shuval *et al*. (1986a) on a theoretical model of assessing the real risk of infection of the population by irrigating with waste water have shown that the highest risk (among Helminths, bacteria and viruses) is obtained with Helminths (*Ascaris*, *Trichuris*, *Ankylostoma*, *Taenia*, etc.). These Helminths cause diseases such as Ascaridiasis, Trichuriasis, Faciolopsiasis, Ankylostoma, ... Their survival time in the environment is several months (Feachem *et al.* 1983). This risk of contamination of the population concerns: consumers of agricultural products using wastewater as irrigation water, farmers who come into contact with water and people in the vicinity of production sites (Klingel 2001).

Table 13. Comparison of results of mean helminth eggs obtained in different Moroccan streams and aquatiques environments.

Autors	El Guamri *et al.* (2007) a	El Addouli *et al.* (2012)	El Addouli *et al.* (2012)	Dssouli *et al.* (2001)	El Ouali Lalami *et al.* (2014)	This study
Locality	Fouarat (Kenitra)	Ouislane stream (peri-urban of Meknes)	Bouishak stream (peri-urban of Meknes)	Bounaime stream (peri-urban of Oujda)	Wastewater of peri-urban of Fès	Bouskoura stream
Total helminths (eggs/l)	32,4	44	36	2,53	2 à 33	51,91 - 189,36

Hierarchical Ascending Classification (HAC)

The groupings of the obtained stations are represented graphically in the form of a dendrogram which makes it possible to visualize the degree of similarity between stations according to the classes of water quality (Fig. 5). From this

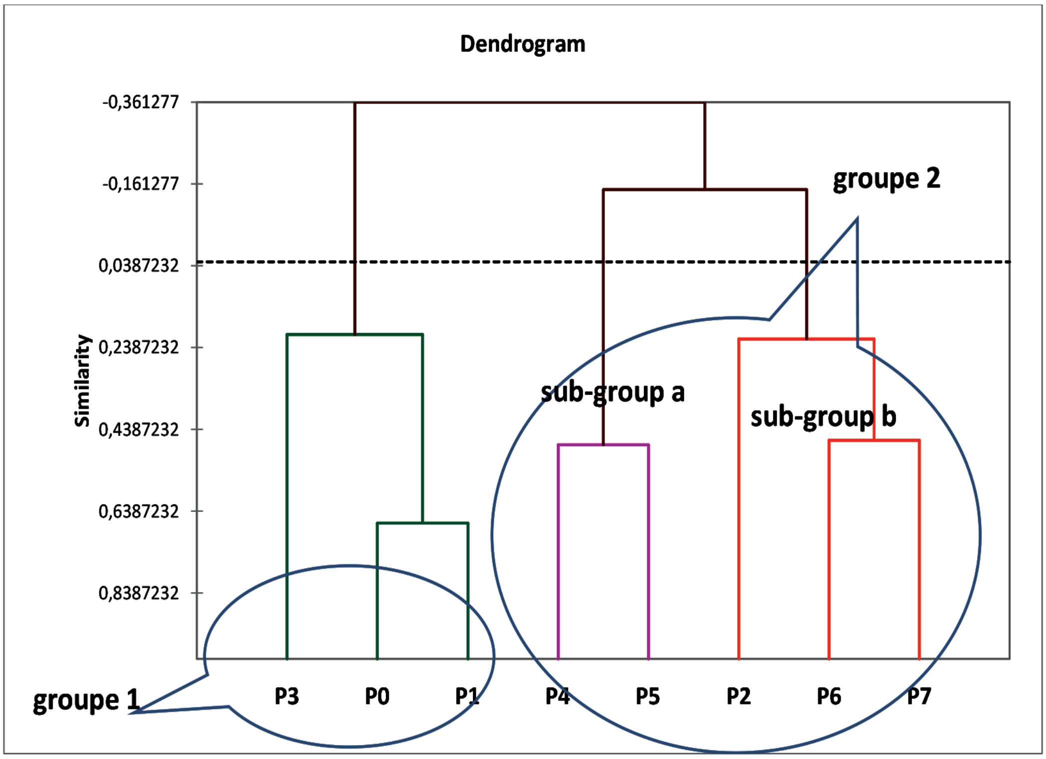

Figure 5. Dendrogram showing clustering of sites of Bouskoura stream based on physico-chemical, bacteriological and parasitological analyses of their water.

figure and from table14it can be deduced that the determining factors in this HAC are organic and oxidizable matter (BOD5 and COD), bacteriological and parasitological quality; the other parameters have less weight in the discrimination of the stations. Thus, two main nuclei (or groups) with different characteristics can be individualized. In each group the number of stations is variable:

- the first group consists of stations in which the organic matter and oxidizable charges (COD, BOD5) and the bacteriological and parasitological loads are the lowest, the water is well oxygenated. This group brings together the P0, P1 and P3 stations located downstream of Bouskoura.

- the second group includes stations (P2, P4, P5, P6 and P7) characterized by different levels of bacteriological, parasitological and organic pollution. This group is subdivided into two subgroups:

* the sub-group “a” groups stations characterized by a moderate bacteriological, parasitological and organic load: P4 and P5 stations where we have a low self-purification power,

* sub-group “b” groups stations with high organic, bacteriological and parasitological pollution: P6 and P7 stations located in the Bouskoura watercourse.

In general, the HAC confirms the existence of a growing gradient upstream-downstream of the deterioration of the water quality of Bouskoura stream from a physicochemical, bacteriological and parasitological point of view.

Table 14. Matrix of data relating to the barycenter of the physicochemical parameters, and bacteriological for the ascending classification hierarchical CAH of the stations of the Bouskoura stream

Class	pH	T°	EC à 20°C	O2	Turbidity	PO_4^{3-}	COD	BOD5	TKN
1	7,30	20,99	2423,89	7,18	4,83	0,77	12,48	4,78	9,36
2	7,87	20,88	4672,67	1,22	13,99	3,70	105,24	22,66	26,83
3	7,99	20,72	5213,91	4,82	16,35	2,24	42,77	6,62	16,20

Class	NH4+	TP	NO2-	TC	FC	*E. COLI*	FS	*Pseudomonas aeruginosa*
1	1,31	1,36	4,98	62672,98	37073,99	29601,97	64762,88	194,44
2	8,83	5,58	39,03	2071515,15	359727,27	302557,58	219545,45	0,00
3	0,63	2,48	3,38	708454,55	444227,27	374600,00	322306,82	0,00

CONCLUSION

The bacteriological, physicochemical and parasitological analysis campaigns carried out in Bouskoura stream between June 2015 and July 2017, highlighted an overall pollution generated by the discharges of raw wastewater. The degradation of the water quality of the stream generally takes place according to an increasing upstream-downstream gradient.

Overall, it appears that, for all forms of pollution observed in Bouskoura waters, only bacteriological and parasitological pollution can be a handicap for any reuse.

The strong standard deviations observed and proved statistically highlight significant intra-site variations. In addition, the spatial variation of the physico-chemical parameters means did not underline the full extent of the deterioration of the water quality (in particular upstream of the stream).

The bacterial load, described in the Bouskoura using bacterial counts (total coliforms, faecal coliforms, E. coli, fecal streptococci), largely exceeds the Moroccan standards of quality of surface water and irrigation and the guidelines of the World Health Organization (WHO) for watering agricultural products likely to be consumed raw. This bacterial load remains high enough not to be able to consider (in the short term) any activity requiring contact with these waters. Compared to previous work, this bacterial load was much amplified during the period of this study.

It is important to note that the absence of germs (TC, FC, *E. coli* and FS) in the stations near water sources implies the absence of contamination of the groundwater. Nevertheless, the detection of *Pseudomonas aeruginosa* in Ain Joumaa station must justify the prohibition of bathing in this station by the authorities and the urgency of treating these waters in order to preserve natural resources in general and public health in particular.

The origin of fecal contamination, determined using the FC/FS ratio, highlighted the diversity of pollution sources along this hydrosystem.

Parasitological analyses also revealed the potential health risk of the irrigation with the waters of Bouskoura stream. The determination of helminth eggs shows a diversity of parasites testifying to a diversity of sources of contamination (human and animal origins). The average parasite load exceeds the applicable national and international regulatory specifications. This charge varies in parallel with the bacterial load.

The recovery of all uses of raw water in the suburban Casablanca should go through a better management of the sanitation system (including the collection of wastewater, rainwater management), the planning of environmental objectives andtakingthe necessary measures to protect the health of consumers, farmers and residents of Bouskoura against epidemics. Such measures would combine the protection of public health with better economic development in the study area.

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