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RESEARCH PAPER

Assessment of water quality of Oum Er Rabia River by Microbiological Quality Index and Water Quality Index

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ABSTRACT
Water resource management requires simple tools to enable managers to make decisions. This is the case for water quality indices that provide access to clear, synthetic and well-targeted information. In this study, we have chosen two indices based on two different approaches, the Microbiological Quality Index (MQI), which is determined from bacteriological analyses of water, and the Water Quality Index (WQI), which is based on physicochemical parameters. The Water Quality Index (WQI) shows a longitudinal upstream-downstream variation and ranges from is between five (5) (Null Faecal Contamination) at sampling point P1 and 3.4 (Moderate Fecal Contamination) at P2. The Water Quality Index (WQI) ranges from a low of 14.08 (excellent water quality) at the P1 level to a high of 93.05 at the P2 level (poor water quality) receiving wastewater discharges. The WQI results for P3 and P4, show that the water is of good quality (downstream of P2), which shows the degree of self-purification of the Oum Er Rabia River, regardless of the sampling period. Finally, the results of the MQI corroborate those obtained with the WQI for the water quality of the different sampling points.

KEYWORDS: Water resource, management, quality, Oum Er Rabia River.

INTRODUCTION

Water is the most vital element among the natural resources, and is critical for the survival of all living organisms including human, food production, and economic development (Halder, 2015) In Morocco, as in the global context, water demand is increasing substantially as result of the demographic (Ghavidelfar et al., 2017) increase and various socio-economic activities that consume water, mainly agriculture, industry, tourism (Okadera et al., 2005; Garcia and Servera, 2003; Ynthia et al., 2004) and irrational use of water. Coupled with climate change impacts (Ouhamdouch, 2017) and different pollution generated (Zhang, 2006; Chihabi et al., 2002; Hahid and Saba, 2018; Kubicz et al., 2018) by anthropogenic activities such as the discharge of water without treatment in several regions, water resources in Morocco as in the global are becoming increasingly scarce and ranking the country among the areas in water stress (Ceoworld, 2019).

With its hydroelectric production, highly productive agricultural land and tourist attractiveness, Oum Er-Rabia water basin is among Morocco's strategic basins thanks to its extensive river network, which is part of the long-run flow of its large Oum Er Rabia river who is the second life artery of Morocco and represents the main freshwater resources needed

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for drinking, industrial and irrigation water. The latter originated in the Middle Atlas, crosses several regions before entering the Atlantic in El Oualidia near El Jadida town of (Figure 1). Unfortunately, water of this great second river in Morocco suffers from negative impacts of pollution from different origins mainly domestic, agricultural and industrial in different places (Benamar et al., 2019), which impacts water quality and endangers species that need clean water (Adejumoke et al., 2018) and human health (Derradji et al., 2007; Maamri, 2017; Hefni, 2016). Therefore, it is very important to assess the potential impact of fecal pollution, originating from both anthropogenic and zoogenic sources, on the profile of microbial communities in natural water environments. Monitoring of water quality becomes an obligation in order to determine its use and treatment for defined purposes (Dahunsi, 2014; Ayenuddin Haque et al., 2019). Water resource management requires simple tools that enable managers to make decisions. Therefore, assessment of water quality in terms of physicochemical and microbial aspects can help to take effective management decision to prevent those (Ayenuddin Haque et al., 2019; Behbahaninia et al., 2009). This is the case for water quality indices that provide access to clear, synthetic and well-targeted information (Hefni, 2016). In this study, two indices were selected based on two different approaches: Microbiological Quality Index (MQI), which is determined from bacteriological analyses of water (Curcic and Comic, 2002) and Water Quality Index (WQI), which is based on physicochemical parameters of water and depicts the composite influence of different water quality parameters and communicates water quality information to the public and legislative decision makers (Shweta et al., 2013; Bhadja and Vaghela, 2013; Benamar et al., 2019). Water quality index stands out to be a very useful approach in valuation and management of water quality (Ranjith et al., 2019) and, can therefore be utilized to assess programs to enhance water quality. These two indices can be combined to provide the Biological and Physicochemical Quality Index of Water (BPQI). (Hébert, 1997).

The output of this research can be used by water managers to make decisions to protect human health and the ecosystem biodiversity enjoyed by this large and important river in Morocco. In addition, these results can be used as a bibliography for further studies.

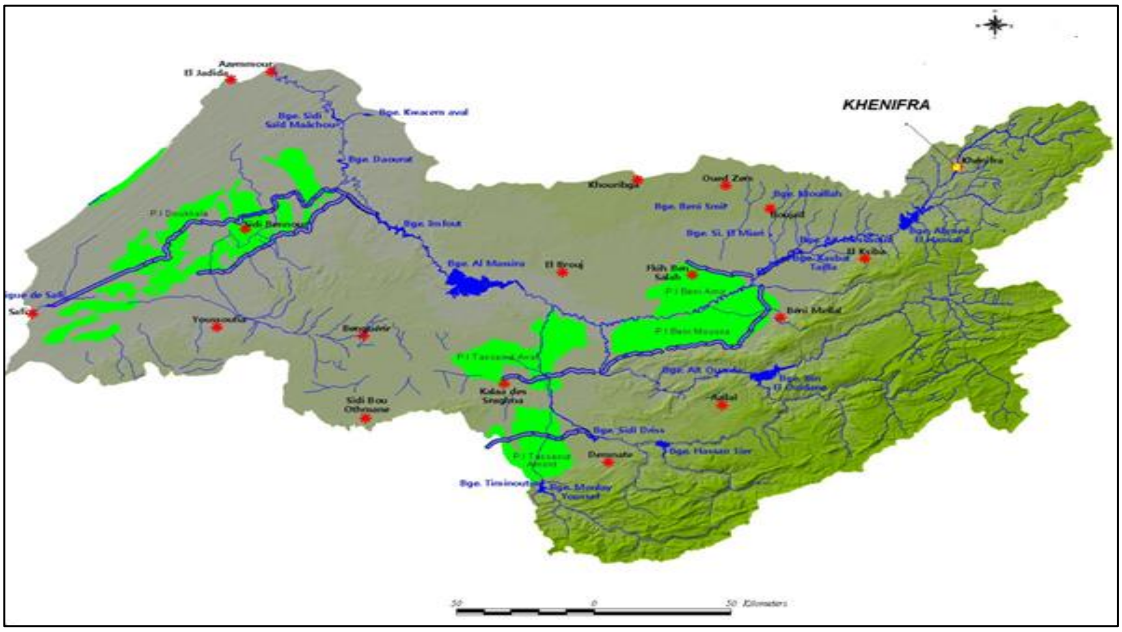

Fig. 1. Oum Er Rabia Hydraulic basin

MATERIAL AND METHODS

Khenifra city, with a high altitude, is surrounded by mountains with an altitude of more than 1200 m with a continental cold winter, warm and dry climate in the summer. Winter temperatures can reach -5 °C, while summer is very hot with temperatures up to 40°C. Average annual temperature is in the order of 10°C and rainfall varies between 400 to700 mm peer year. The rains are quite abundant in each place, with storms that are quite frequent causing significant damage. Since the 1980, the region has been experiencing climate disturbances like any other region in Morocco. The spatial distribution of annual precipitation across the Oum Er Rabia watershed, in terms of precipitation, shows that the study area is well watered over the entire watershed. The Hydrogeological of the province of Khénifra is characterised by lakes Tigalmamine, Aguelmame Azegza and Lake Ouiouan, which are fed in the same way as the sources of the river Oum Er Rabia by a common underground river in the North East - South West direction. Emergence of the waters at the sources Oum Er Rabia and lakes are linked to abnormal contacts of Liasic limestone geological formations belonging to the pleated Middle Atlas massif and based on an impermeable substratum of the salt clays of the Trias (Kirat et al., 2016).

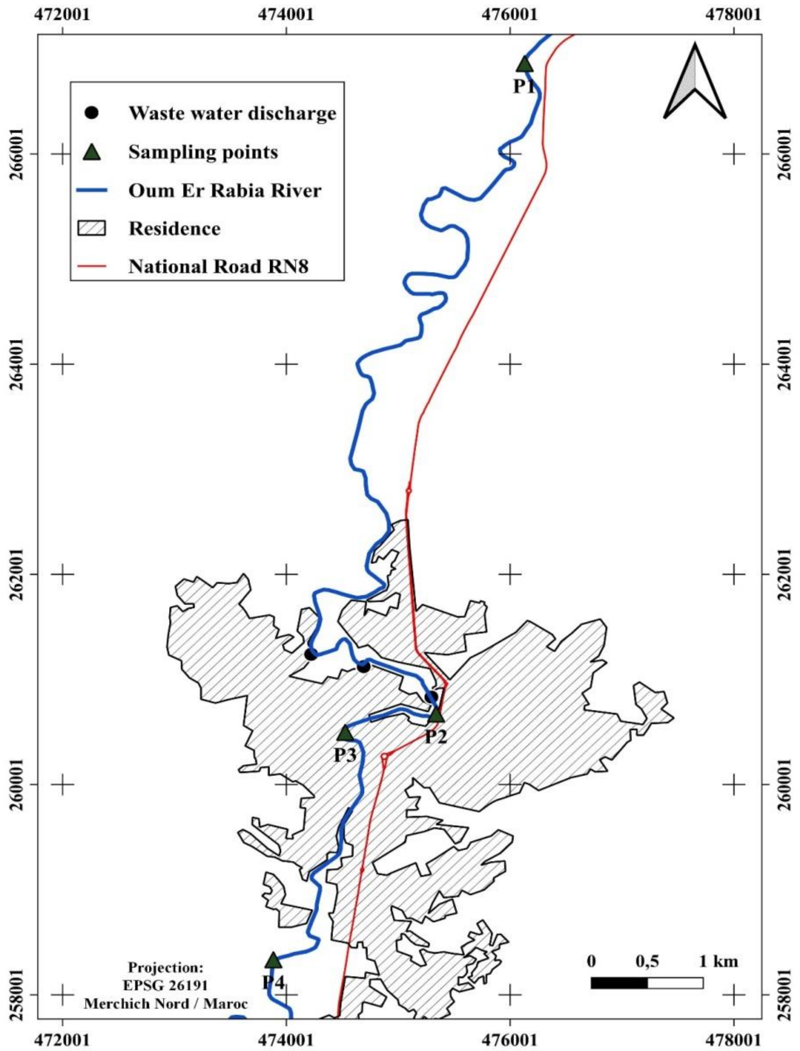

Fig. 2. Location of the different sampling points in the study area

The sampling points chosen in this study (Figure 2) meet our objective of assessing the microbiological and physicochemical characteristics of the water from the upstream part of the Oued Oum Er Rabia, which receives wastewater without treatment. As part of the chosen objective, four sampling points were retained upstream and downstream of domestic water discharge points from areas not connected to the liquid sewerage system in the city of Khénifra. In front of domestic water discharges, station P1 can be considered as a reference station. From sampling points just after wastewater discharges, these are points P2 and P3, both stations can tell us about the microbiological characteristics and the polluting load spilled into the river that can affect water quality and therefore biodiversity and human health. Point P4 tests can provide us with information and assess the self-treatment rate of the Oued Oum Er Rabia.

Table 1. Coordinates of sampling points

Sampling stations	X	Y	Altitude (m)
P1	476130.31	266861.35	929.853
P2	475337.8	260672.72	882.370
P3	474526.21	260498.15	914.296
P4	473884.34	258334.21	899.743

Water samples were taken during the flood and dry weather. Some parameters are measured in situ by a Multi parameter Hach HQ40 device (pH, T°C, dissolved oxygen (O2) and Electrical Conductivity (EC). Water for bacteriological analyses, Total Coliforms (TC), Fecal Coliforms (FC), Fecal Streptococci (FS) and E. Coli who is a member of the Fecal Coliform group and is a more specific indicator of fecal pollution than other Fecal Coliforms are sampled in glass sterilized bottles. The method for processing microbiological data is based on the Fecal Contamination Index (MQI) (Bovesse and Depelchin, 1980), whose principle is to divide the values of the polluting elements into 5 classes and to determine from its own measurements the corresponding class number for each parameter to average them (Table 2). for total coliforms, the concentration was not determined during the flood period.

Table 2. Class limits by MQI index (Bovesse and Depelchin, 1980),

Classe N°	TC/ml	FC /ml	FS/ml	MQI	Fecal Contamination
5	<2000	<100	<5	4.3-5.0	Null
4	2000-9000	100-500	5-10	3.5-4.2	Low
3	9000-45000	500-2500	10-50	2.7-3.4	Moderate
2	45000-360000	2500-20000	50-500	1.9-2.6	Strong
1	>360000	>20000	>500	1.0-1.8	Very strong

Relations Fecal coliforms and fecal Streptococci is an indicator of the origin of fecal pollution in urban and rural water. In regard to the determination of the animal or human origin of the contamination, we are determined ratio R=FC/FS (Table.3) (Borrego and Romero, 1982).

Table 3. Origin of fecal pollution (Borrego and Romero, 1982).

R=FC/FS	Origin of fecal pollution
< 0,7	Animal contamination
0,7 <R<1	Pollution is mixed (human and animal),
1 < R < 2	Predominantly animal pollution
2 < R < 4	Mixed Origin predominantly human
R > 4	Pollution is mainly human

Table 4. Weight of physicochemical parameters and Moroccan Standard of Surface Water Quality (NMQE, 2002)

Parameters	Moroccan Standard	Si: maximal value standard	1/Si	Wi
pH	6,5-9,2	9	0.111	0,031
T°C	20-30	30	0.033	0.009
EC (µs/cm)	720-2700	2700	0.000	0.000
O2 (mg/L)	3-5	5	0.200	0.056
NH4+ (mg/L)	0.1-0.5	0,5	2.000	0.560
NO3- (mg/L)	< 50	50	0,020	0.006
SO4 2- (mg/L)	100-250	250	0.004	0.001
PO4 3-(mg/L)	0.2-1	1	1.000	0.280
BO5D (mg/L)	3-5	5	0.200	0.056
	Σ (1/Si) = 3,568	K= 1 / Σ (1/Si) = 0,280		

For chemical parameters (Ca^{2+}, Mg^{2+}, Cl^{-}, SO_4^{2-} NH_4^{+}, NO_2^{-}, NO_3^{2-} , PO_4^{3-}, COD, BOD_5, oxidability, turbidity, alkalimetric title…) that provide information on the ecological status of the aquatic ecosystem (Abba et al., 2012; Curcic and Comic, 2002), for the parameters used in this study such as NH_4^{+}, NO_2^{-}, NO_3^{2-} , PO_4^{3-} , COD and BOD_5, samples are taken from polyethylene bottles and taken back to a glacier. The sampling protocol and the various analyses were carried out by approved methods (Rodier, 1994). The determination of the physicochemical quality of water is based on the WQI. This index is determined using the weighted arithmetic index method according to several authors (Brown et al., 1972; Chaterjee and Raziuddin, 2002; Yogendra and Puttaiah, 2007; Tran and Pham, 2020). A numerical value called Relative Weight (Wi) (Table 4), specific to each physico-chemical parameter, is calculated according to the formulae (1).

$$Wi = k\ Si. \tag{1}$$

The proportionality constant K is determined according to the Equation (2).

$$k = 1 \sum_{i}^{n} (1/Si) \tag{2}$$

where; **n:** number of physicochemical parameters;

Si: maximum value of the Moroccan Standard for Surface Waters in mg/L (NMQE, 2002) (Table 4). Then, a quality assessment scale (Qi) is calculated for each parameter according to the equation (3).

$$Qi = (Ci/ Si) \times 100 \tag{3}$$

where : **Qi**: Quality assessment scale of each parameter

Ci = Concentration of each parameter in mg/L.

Equations 1, 2, and 3 are finally used to determine the WQI according to the equation (4).

$$WQI = \sum\nolimits^{n}_{i=1} Qi \times Wi \,/ \sum\nolimits^{n}_{i=1} Wi. \tag{4}$$

Water quality according to WQI class is presented in the table 5.

Table5. Different water classes according to WQI values (Brown, 1972)

Class WQI	Water quality	Possible uses
0-25	Excellent quality	Drinking water, irrigation and industry
25-50	Good quality	Drinking water, irrigation and industry
50-75	Poor quality	Irrigation and industry
75-100	Very poor quality	Irrigation
>100	No drinking water	Appropriate treatment required before use

RESULTS AND DISCUSSION

The results of microbiological analysis of pollution indicators in flood and dry period are presented in Figures 3A, 3B, respectively.

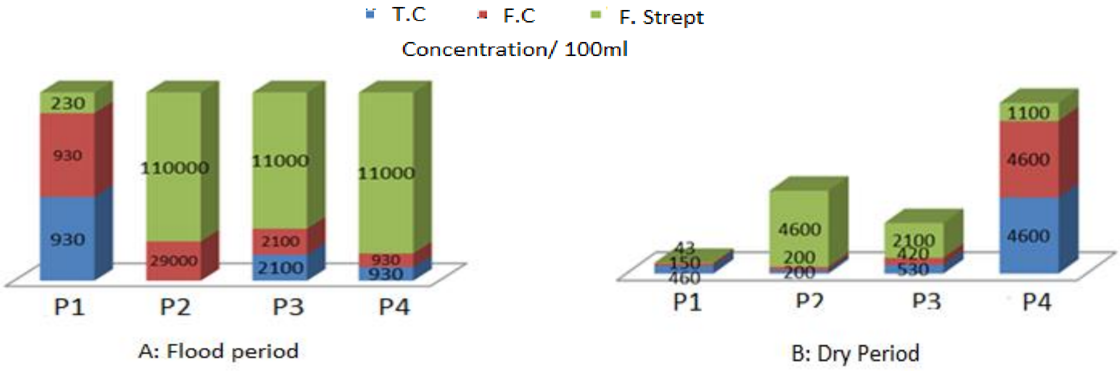

Fig. 3. Concentration of Total Coliforms, Fecal Coliforms and Fecal streptococci in different stations

Based on the results obtained, the mean concentration of germs at the various sampling stations varies from upstream to downstream. Germ concentration was lower at P1 station located upstream (Reference station), then increases significantly at the P2 station and decreases at P3 and P4 levels located downstream. These changes variations in flood period can be explained at P2 and P3 stations by the drainage of wastewater to P2 that is downstream of untreated domestic discharges, which also led to the increase in concentration at P 3 with less importance than P2. According to (Tiefenthaler et al., 2008; Haslay and Leclerc, 1993), suspended matter drained during the flood period may also be the cause of this increase at the P2 and P3 levels. P4 water has the same concentrations of TC and FC as P1 because this sampling point is far from the discharge point.

During dry period, there has been an improvement in the microbiological quality of water, probably due to the increase in ultraviolet radiation, which is potentially harmful to the survival of bacteria Haslay and Leclerc, 1993) and the decrease in drainage of waste water to P2. The MQI calculation (Table 6) classifies the water of the different sampling stations as follows:

Table 6. MQI of different sampling stations of study area

Stations	TC 10^2/ml	FC10^2/ml	FS 10^2 /ml	MQI (Flood period)	MQI (Dry period)
P1	9.3	9.3	2.3	5	5
P2	>1100	290	1100	3.4	4.3
P3	21	21	110	4	4.3
P4	9.3	9.3	110	4	4.3

Table 7. Degree of fecal contamination in different sampling points

Stations	Degree of Fecal contamination (Flood period)	Degree of Fecal contamination (Dry period)
P1	Null	Null
P2	Moderate	Null
P3	Low	Null
P4	Low	Null

The origin of fecal pollution is linked to quantitative ratio R (= FC/FS) of fecal coliforms (FC) to fecal streptococci (FS). Calculating of this ratio R allowed us to determine the source of fecal pollution at each sampling point during the two sampling periods (Table 8).

Table 8. Pollution source as indicated by the fecal coliforms/fecal streptococci (CF/SF) ratio.

		Results at dry period		
Stations	**P1**	**P2**	**P3**	**P4**
R= f. C / f. S	3.49	0.04	0.2	4.18
Origin	Animal	Animal	Animal	Human (wastewater)
		Results at flood period		
R= f. C / f. S	4.04	0.26	0.19	0.08
Origin	Human (wastewater)	Animal	Animal	Animal

According to ratio (R= FC/FS), origin of fecal contamination at different sampling stations in study area is animal with the exception of P4 station or origin is human, but at the flood period, only P4 station. During flooding, only station P1 is human, all other sampling points are contaminated by pollution of animal origin. This may be due to the ruining of cattle manure and landfills at the Oued Oum Rabia riverbanks, especially near the military barracks where there has been a wild scrap of horse manure.

Table 9. Concentration of Physicochemical parameters (Ci) during dry period of different sampling points (Pi).

Parameters	**1/Si**	**Wi**	**Si**	**C1**	**C2**	**C3**	**C4**
pH	0.111	0.031	9	7.91	8,04	8.32	8.26
T°C	0.033	0.009	30	21.1	21.5	22.9	23.4
EC (µs/cm)	0	0	2700	2650	2670	2640	2630
O_2 (mg/L)	0.200	0.056	5	9.01	8.71	8.81	8.3
NH4+ (mg/L)	2	0.56	0.5	0.00085	0.142	0.16	0.131
NO_3^{2-} (mg/L)	0.02	0.006	50	7.01	6,49	6.01	7.33
SO_4^{2-} (mg/L)	0.004	0.001	250	65,23	64,61	66.15	63.6
PO_4^{3-} (mg/L)	1.00	0.28	1	0,022	0.04	0.03	0.024
BOD_5(mg/L)	0.2	0.056	5	0.001	56	3	0.003

Table10. Determination of Qi × Wi at different sampling points (Pi) during dry period

Paramètres	**Q1**	**Q1*W**	**Q2**	**Q2*W**	**Q3**	**Q3*W**	**Q4**	**Q4*W**
pH	87.88	2.72	89.33	2.77	92.44	2.87	91.77	2.84
T°C	70.33	0.63	71.66	0.65	76.33	0.7	78	0.7
EC (µs/cm)	98.15	0	98.88	0	97.77	0	94.4	0
O_2 (mg/L)	180.2	10.1	174.2	9.78	176.2	9.9	166	9.3
NH_4^+ (mg/L)	0.17	0.095	28.4	15.9	32	17.92	26.2	14.67
NO_3^- (mg/L)	14.02	0.084	12.98	0.08	12.08	0.07	14.66	0.09
SO_4^{2-} (mg/L)	26.1	0.026	25.84	0.026	26.46	0.03	254.4	0.09
PO_4^{3-}(mg/L)	2.2	0.62	4.0	1.12	3.0	0.84	2.4	0.67
BOD_5(mg/L)	0.02	0.001	1120	62.72	60	3.36	0.06	0.004

Table 11. Concentration of Physicochemical parameters (Ci) during flood period of different sampling points (Pi).

Parameters	**1/Si**	**Wi**	**Si**	**C1**	**C2**	**C3**	**C4**
pH	0.111	0,031	9	8,06	8,2	7,97	8,22
T°C	0,033	0,009	30	16	17,7	17,6	18,3
EC (µs/cm)	0	0	2700	2460	2470	2485	2475
O_2 (mg/L)	0,200	0,056	5	8,71	8,18	8,65	7,99
NH_4^+ (mg/L)	2	0,56	0,5	0,0085	0,072	0,062	0,144
NO_3^- (mg/L)	0,02	0,006	50	6,22	6,05	5,88	6,05
SO_4^{2-} (mg/L)	0,004	0,001	250	62,48	59,11	61,39	62,71
PO_4^{3-}(mg/L)	1	0,28	1	0.03	0,035	0,032	0,032
BOD_5(mg/L)	0,2	0,056	5	0,001	50	3,2	0,025

Table12. Determination of Qi × Wi at different sampling points (Pi) during flood period

Parameters	Q1	Q1*W	Q2	Q2*W	Q3	Q3*W	Q4	Q4*W
pH	89,55	2,77	91,11	2,82	88,55	2,76	91,33	2,83
T°C	53,33	0,5	59	0,53	58,66	0,53	61	0,55
CE (µs/cm)	91,11	0	0	0	92,04	0	91,66	0
O_2 (mg/L)	174,2	9,76	163,6	9,16	173	9,67	159,8	9,95
NH_4^+ (mg/L)	0,17	0,095	14,4	8,064	12,4	6,5	28,8	16,13
NO_3^- (mg/L)	12,44	0,074	12,1	0,073	11,76	0,07	12,1	0,073
SO_4^{2-} (mg/L)	24,99	0,025	23,65	0,024	24,57	0,25	25,1	0,025
PO_4^{3-}(mg/L)	3	0,84	3,5	0,98	3,2	0,9	3,2	0,896
DBO_5(mg/L)	0,02	0,0011	1000	56	64	17,92	0,5	0,028

Table 13. Water quality rating as per arithmetic water quality index method

WQI Value	Rating of water quality	Grading
0-25	Exellent water quality	A
26-50	Good water quality	B
51-75	Poor water quality	C
76-100	Very poor water quality	D
>100	Unsuitable for drinking purpose	E

The result of water quality index (WQI) (Table 14) of the upstream part of Oum Er Rabia during flood and dry period shows that the water quality at P1 sampling point is excellent (WQI= 14.29 and 14.08) and degrades very significantly at P-sampling point P2 or quality water becomes very poor (WQI= = 93.05 and 77.73). These results can be explained by the fact that this P2 station receives wastewater from a part of the city of Khénifra that is not connected to the liquid sewerage system. The comparison of the WQI for the same station (P2) shows that water quality is very degraded in dry time (WQI = 93.05) compared to the flood period (WQI = 77.73). These results are explained by the phenomenon of water dilution following floods. For stations P3 and P4 that are downstream of discharges, water quality becomes good as the EQI is between 27.6 as he minimum value and 38.64 as the maximum value. This improvement in WQI at the two sampling points P3 and P4 and above all at the P4, is due to the self-purifying power of the river, which can reach an average flow rate of 105 m^3/s of water (Benamar et al., 2019). Compared with the results of the stations downstream of those studied and which are located at the level of the other cities crossed by Oum Er Rabia Zawiat Cheikh, Kasbat Tadla and Dar Oulad Zidouh, the WQI values of the water samples ranging from 1063.05 to 438.27 in dry period and, 564.02 to 399.37 in flood period (Benamar et al.2019) These results shows that Oum Ta Bia River received many wastewaters due to the absence of water treatment plants in these towns located downstream of Khénifra.

Table 14. Water Quality index of different sampling points

WQI	P1	P2	P3	P4
Flood period	14.08	77.73	38.64	27.6
Water Class	A Excellent quality	D Poor quality	B Good quality	B Good quality
Dry period	14.29	93.05	35.72	28.39
Water Class	A Excellent quality	D Poor quality	B Good quality	B Good quality

CONCLUSION

Surface freshwaters are the main freshwater resources for recreation, fishing, agriculture, domestic, industry, landscapes and all socio-economic activities. unfortunately, these waters are subject to various types of degradation: human, agricultural, industrial and other sources of pollution, such as water of the Oued Oum Er Rabia. The study carried out on the River is to assess the impact of domestic wastewater discharged directly without any treatment using physicochemical and microbiological parameters over two periods where the climatic conditions and precipitation in the region are different and will assist water managers in making decisions to connect individual wastewaters to the sewerage system for treatment before discharge to the receiving environment. The results show that the Oum Er Rabia River is contaminated by human and animal pollution especially at the level of the station that receives domestic wastewater from the area of the city not yet connected to the treatment station. The WQI shows that water quality is poor at the P2 level in flood and dry period (WQI = 77.73 and 93,05) compared with referential station P1 where the water quality is excellent (WQI = 14.08 and 14,9). These results corroborate with microbiological quality index (MWQ = 3,4). Deterioration in water quality can affect the human health and biodiversity of the aquatic ecosystem, in particular the endemic varicorhinus marocanus species classified in the IUCN Red List.

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CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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