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Evolution of the Physico-Chemical and Biological Quality of the Waters of Soueir River (Morocco)

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ABSTRACT

As part of the monitoring of water quality of Soueir river, two sampling companions were conducted from April to February during the two periods 2016/2017 and 2018/2019. The study consists of measuring 14 physico-chemical parameters and establishing the inventory of benthic macroinvertebrates upstream and downstream of Soueir river. The physico-chemical parameters were used to calculate the water quality index (WQI) and the exploitation of the results of the fauna inventory allowed us to determine the Shannon - Weiner diversity index (H') and the Belgian biological index (BBI). The comparative study of the results of the two periods shows that during the two sampling periods, the recorded values of the physico-chemical parameters are lower than the admitted standards, except for nitrates and ammonium which present high levels during certain periods of the year, sometimes exceeding the Moroccan standards. These high concentrations can be explained by the excessive use of chemical fertilizers in the activity and the decrease of the water flow. The calculation of the water quality index (WQI) reveals that the water quality varies with a tendency towards degradation from upstream to downstream, the water becomes of poor quality or even non-drinkable. The values of the BBI indicate that the water of Soueir river is not very polluted, and that the quality of the water decreases during the winter period due to the erosion of the substrate and the increase of the matter in suspension. The diversity of benthic macroinvertebrates is greater downstream, due to the diversity of habitats and substrates.The second sampling period reveals a slight improvement in the physico-chemical and biological qualities of the waters of Soueir river, which can be attributed to climatic conditions that were more favorable to the development cycles of benthic macro-invertebrates.

Keywords: Soueir river, physico-chemical parameters, benthic macroinvertebrates, water quality index, biotic index.

INTRODUCTION

Morocco has experienced in recent decades' periods of drought leading to a frequent water deficit which is added to a qualitative and progressive degradation of water resources. It is therefore imperative to monitor the quality of freshwater.

Moreover, the evaluation of water quality is often based on the physicochemical characterization of the environment by determining the values of certain physicochemical parameters of the water and by calculating indices (the water quality index (WQI), the organic pollution index (OPI). However, this evaluation method, called "physico-chemical", only gives a momentary overview of the water quality. Thus, for any more significant evaluation of the quality of the environment, many previous works have resorted to a complementary evaluation to the physico-chemical one. This is the biological assessment, which consists in analyzing the structure of the population of living organisms (biological indicators) such as microorganisms, plants or animals. In addition, this second method of evaluation allows for a more reliable assessment of the biological quality of the environment (Beauger and Lair., 2014). Thus, the concept of integrity or health of ecosystems requires to take into account simultaneously the chemical, physical and biological parameters (Genin *et al*., 2003). Among the animals used in the biological assessment of the environment, benthic macroinvertebrates that are considered good bio indicators, due to their high diversity and sensitivity to pollution and habitat degradation (Fierro *et al,* 2017; Rezouki *et al*., 2021). Benthic macroinvertebrates are particularly good at reflecting the ecological status of the stream by responding very quickly to changes in their environment. Thus, many indices have been developed based on the variation of the specific structure of the benthic macroinvertebrate population. We cite the Standardized Global Biological Index (SGBI) and the Belgian Biological Index (BBI).

In the same spirit of evaluation of water quality in Morocco, we contribute in this work by a double evaluation, physico-chemical and biological, of the waters of Soueir river which is a watercourse located at the north of the Drader-Soueir basin (Morocco). This evaluation is very useful because this watercourse is not sufficiently studied.

MATERIALS AND METHODS

The study area

Soueir river, extends on approximately 15 km. It is one of the main watercourses of the Drader-Soueir watershed which is located in the North-West of Morocco (Figure 1). This basin, with an area of 621 km^2, is drained by two rivers, Drader river and Soueir river; it is widely used for agriculture and eucalyptus plantation.

The water supply of Soueir river is ensured by rainwater and water from the Drader-Soueir aquifer. These waters are then discharged into the Merja Halloufa. The flow of water is variable, but sporadic measurements allow us to estimate its average low flow, a period of low flow, from 200 to 250 L/s. In addition, a small rustic diversion structure supplies water to part of the Bargha agricultural estate located on the right bank, downstream (ABHS, 2017). From a geological point of view, the upstream of Soueir river is characterized by a bed made up of sands, silts and clay, as well as by the abundance of small springs whose water analysis allows to estimate the quality of deep waters. Downstream, the bed is of a silty-clay nature.

Sampling and analysis techniques

Sampling

The collection of a water sample, which cannot be repeated, is therefore a delicate operation to which the greatest care must be taken, as it conditions the analytical results and the interpretation that will be given (Loire-Brittany Water Agency, 2006). The water samples are taken bi-monthly during two periods: from April 2016 to February

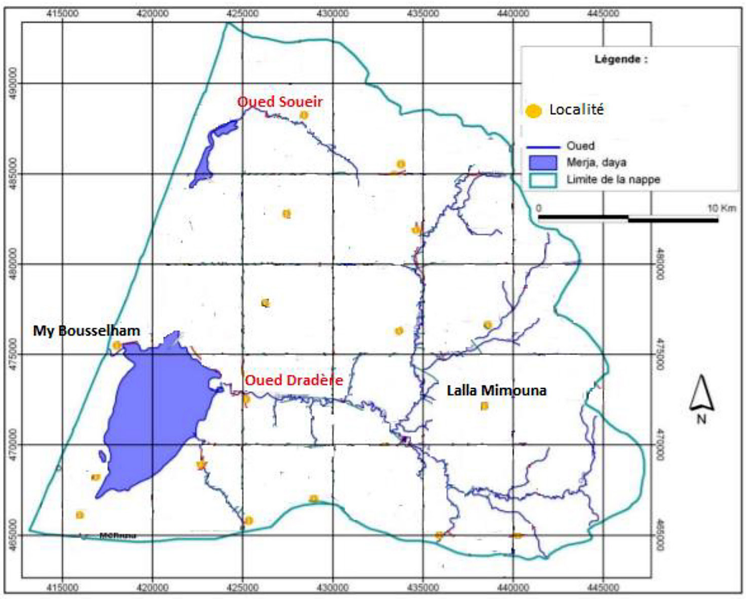

Figure 1. Location of Soueir river in the Drader-Soueir basin

2017 and from April 2018 to February 2019, upstream (station S1) and downstream of Soueir river (station S2). Collected water was packaged in opaque bottles and kept cold until arrival at the laboratory (Rodier *et al.,* 2016).

Physical and chemical parameters measured

Three physical parameters were measured on site with a HACH multi-parameter, model HQ40d. These were water temperature, pH, and conductivity. Eleven chemical parameters were measured. These are calcium, magnesium, carbonates, sulfates, nitrates, ammonium, orthophosphates, BOD_5, COD, suspended matter (SM) and dissolved oxygen (DO).

Calculation of the Water Quality Index

The index WQI used makes it possible to classify the quality of the water by referring to international standards or Moroccan standards of nine physicochemical parameters (pH, DO, CE, T°C, SO_4^{2-}, BOD_5, PO_4^{3-}, $N\text{-}NH_4^+$ and $N\text{-}NO_3^-$) (Table 1 and 2). This index has been used for this purpose by many authors including (Chatterji and Raziuddin, 2002; Yidana *et al*., 2010; Talhaoui *et al*., 2020). Moreover, in this approach, a numerical value called relative weight (Wi), specific to each physico-chemical parameter, is calculated (Table 3) according to the following formula:

$$W_i = \frac{k}{Si} \tag{1}$$

where: k – proportionality constant and can also be calculated using the following equation:

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

where: n – number of parameters, Si – maximum value of the Moroccan standard for surface waters (Aher et al. 2016) of each parameter in mg/L except for pH, T°C and electrical conductivity.

The quality assessment scale (Qi) is calculated for each parameter by dividing the concentration by the standard of the said parameter and multiplying the whole by 100 as in the following formula:

$$Q_i = \left(\frac{Ci}{Si}\right) \times 100 \tag{3}$$

where: Q_i – quality assessment scale for each parameter, C_i – the concentration of each parameter in mg/L.

Finally, the overall water quality index is calculated by the following equation.

$$WQI = \sum_{i=1}^{n} Qi\ X\ wi / \sum_{i=1}^{n} Wi \tag{4}$$

Table 1. Classification and possible use of water according to the WQI (Chatterji and Raziuddin, 2002; Aher *et al.*, 2016)

IQE class	Type of water	Possible use
0 – 25	Excellent quality	Drinking water, irrigation and industry
>25 – 50	Good quality	Drinking water, irrigation and industry
>50 – 75	Bad quality	Irrigation and industry
>75 – 100	Very bad quality	Irrigation
>100	Non-drinkable water	Appropriate treatment required before use

Table 2. Weight of physico-chemical parameters and Moroccan surface water quality standard (NM., 2002)

Parameters	Moroccan standards	S_i (standard maximum value, Morocco)	$1/S_i$	W_i
pH	6.5 – 9.2	9	0.111	0.031
T (°C)	20 – 30	30	0.033	0.009
EC (μS/cm)	750 – 2700	2700	0.000	0.000
DO (mg/L)	3 – 5	5	0.200	0.056
NH_4^+(mg/L)	0.1 – 0.5	0.5	2.000	0.560
NO_3^- (mg/L)	<50	50	0.020	0.006
SO_4^{2-} (mg/L)	100 – 250	250	0.004	0.001
PO_4^{3-}(mg/L)	0.2 – 1	1	1.000	0.280
BOD_5 (mg/L)	3 – 5	5	0.200	0.056
			3.569	
		$K=1/\Sigma(\frac{1}{Si})$	0.280	

Sampling of benthic macroinvertebrates

Benthic macroinvertebrate samples are taken with the same frequency of water sampling intended for physico-chemical analysis, upstream (station S1) and downstream of Soueir river (station S2) (Figure 2). The sampling of the studied fauna and water was carried out during two periods 2016/2017 and 2018/2019. The fauna samples were collected using turbid net in calm water and Surber net, 300µm with one square foot of bottom surface (1/10 m^2), in running water. The collected samples were fixed directly with 10% formalin. The determination of benthic macroinvertebrates was carried out with reference to the works of Tachet *et al*. (2000); Wichard *et al*. (2002); Gagnon *et al*. (2006), and Moisan (2010). The taxonomic unit chosen is the family for the different faunal groups.

Method for quantitative and qualitative study of benthic macroinvertebrates

To monitor the biological quality of the waters of Soueir river Shannon and Weaver index were calculated:

$$-H' = -\sum_{i=1}^{s}(pi)(\log 2\ pi) \qquad (5)$$

where: p_i – the relative abundance of a taxon, p_i – n_i/N with n_i – number of individuals of species i, N – the total number.

The Shannon and Weaver index provides information on faunal diversity, based on the relative abundance of the various taxa. The Belgian Biological Index (BBI), which combines a quantitative measure of diversity with a qualitative measure based on the presence or absence of pollutant-sensitive macroinvertebrates (Guerard, 2003).

RESULTS AND DISCUSSION

The measurements carried out are grouped in Tables 3 and 4.

Comparative study of the physicochemical parameters of Soueir river waters

pH

The results show that during the study periods, a significant increase in the pH of the water from upstream to downstream. The minimum value is recorded in S1 in October 2016 (7.52) and October 2018 (7.49 mg/L). The maximum value is recorded in S2 in October 2016 (9.06 mg/L) and October 2018 (9.02 mg/L). This alkalinity of the waters can be attributed to the marly nature of the substrate (Hbaiz *et al*., 2022; Rezouki et al., 2021).

Temperature

The recorded temperatures show that, during the two companions of our study, the water temperature varies seasonally: an increase during the

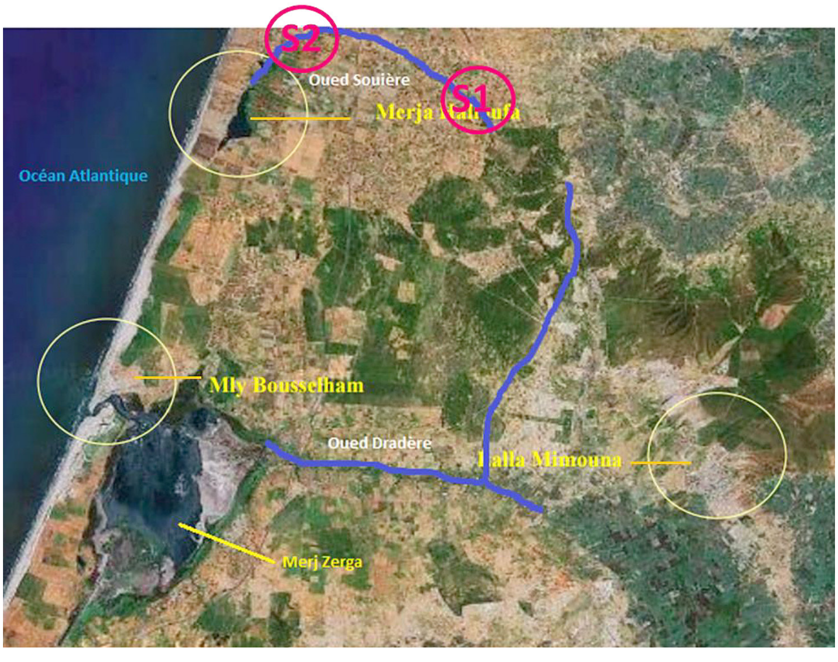

Figure 2. Sampling stations (S1 and S2) of Soueir river

Table 3. Results of the physico-chemical analysis of Soueir river waters during the period 2016/2017

Station	pH	T eau (°C)	EC (µS/cm)	Ca (mg/L)	Mg (mg/L)	HCO_3^- (mg/L)	SO_4^{2-} (mg/L)	NO_3^- (mg/L)	NH_4^+ (mg/L)	$H2PO_4^-$ (mg/L)	BOD_5 (mg/L)	COD (mg/L)	SM (mg/L)	DO (mg/L)
S1 Av	7.75	21.4	1260	122.4	13.6	296.1	105.5	34.6	0.1	0.3	5	11	8	10.22
S1 Ju	7.6	22.8	1174	130	9.8	217	98.3	46	0.3	0.3	4	9	7	8.89
S1 Ao	7.57	28.4	1152	155.6	10.1	201	101	39	0.44	0.2	4	8	7	9.12
S1 Oc	7.52	26.3	1200	170	9.6	172	95	163	1.65	0.7	3	7	4	9.96
S1 Dc	7.78	19.9	1036	128	13.8	360	122	5.6	0.34	0.5	3	5	2	12.11
S1 Fe	7.61	20.8	1066	149	8.3	251	185.3	21.4	0.2	0.2	2	7	6	11.55
S2 Av	7.59	21.6	1132	114	12.8	189	74	43	0.2	0.3	10	19	23	10.04
S2 Ju	7.91	23.9	1078	111.6	11	166	63.4	32.6	0.2	0.3	4	11	8	9.48
S2 Ao	8.17	27.4	922	96.2	8.5	135.2	71	19.7	0.31	0.2	7	23	17	8.25
S2 Oc	9.06	26.8	617	70	7.3	69	65	10.9	1.84	1.2	8	15	19	8.73
S2 Dc	8.12	18	1440	130	7.6	191	120	132	0.32	0.3	38	62	154	10.56
S2 Fe	7.86	19.6	1355	115	9.7	237	94	104	0.76	0.4	24	47	61	10.78

Table 4. Results of the physico-chemical analysis of Soueir river waters during the period 2018/2019

Station	pH	T eau (°C)	EC (µS/cm)	Ca (mg/L)	Mg (mg/L)	HCO_3^- (mg/L)	SO_4^{2-} (mg/L)	NO_3^- (mg/L)	NH_4^+ (mg/L)	$H_2PO_4^-$ (mg/L)	BOD_5 (mg/L)	COD (mg/L)	SM (mg/L)	DO (mg/L)
S1 Av	7.8	20.9	1275	133.6	14.2	304.9	126	42.62	0.2	0.2	4	12	10	10.33
S1 Ju	7.64	23.4	1131	128	9.4	214.6	115.4	47.6	0.1	0.2	4	9	8	9.02
S1 Ao	7.55	29.1	1166	148.2	10.45	212	122	38	0.34	0.1	3	10	7	8.74
S1 Oc	7.49	27.5	1245	159	8.56	162	98.6	121.3	1.23	0.3	4	7	6	9.12
S1 Dc	7.75	18.3	1103	144.4	12.9	286.7	131.8	14.5	0.1	0.2	3	6	3	10.24
S1 Fe	7.6	20.1	1097	141	11.2	239.1	176.5	23.44	0.2	0.2	5	11	5	10.95
S2 Av	7.63	21.2	1115	123.6	11.92	197	89.4	31.8	0.3	0.3	10	14	19	9.55
S2 Ju	7.87	23.8	1136	114	10.33	170.4	71	41.2	0.3	0.3	4	9	9	9.42
S2 Ao	8.06	27.9	1042	103.7	7.85	156	74.7	28	0.36	0.2	7	13	13	9.04
S2 Oc	9.02	27.1	903	84.5	7.2	96.2	69	30.64	1.55	0.4	6	10	14	8.16
S2 Dc	8.14	18.5	1384	138.2	8.12	191	126.3	72.14	0.2	0.2	26	48	144	10.35
S2 Fe	7.78	19.8	1408	120	10.77	208.3	106	67.53	0.3	0.4	16	31	57	10.47

summer period and a decrease during the winter period. A difference in temperature values between the two companions is also noted. These temperature variations show the determining effect of the air temperature and thus of the climate on the water temperature. Thus, the observed differences in water temperature can be explained by the variation in climate between the two study periods (Rezouki et al.,2021).

Electrical conductivity

Conductivity is a parameter that allows us to assess the degree of mineralization of the waters. As shown in the data in Tables 3 and 4, the values of electrical conductivity oscillate between 617 µs/cm (October 2016) and 1440 µs/cm (December 2016), during the first sampling period, and between 903 µs/cm (October 2018) and 1408 (December 2018) during the second period. These values remain below the Moroccan standard for surface water set at 2700 µs/cm (N.M., 2002). The highest values are therefore recorded in the month of December which is characterized by a more important erosion of the bedrock by water.

Carbonates, calcium and magnesium

During both sampling periods, carbonate content varies spatiotemporally. The lowest values were recorded in October (69 mg/L in 2016 and 96.2 mg/L in 2018) downstream of the stream (S2). The highest values (360 mg/L in December 2016 and 304.9 mg/L in April 2018) in S2. These variations can be attributed to variation in substrate erosion intensity and variation in stream flow. For calcium, the lowest values are recorded downstream (S2) in October (70 mg/L in 2016 and 84.5 mg/L in 2018). The highest values are recorded upstream in October (170 mg/L in October 2016 and 159 mg/L in 2018). These variations can be attributed to the marly nature and calcium richness of the soils in the Drader-Soueir basin and the abundance of water.

The magnesium content of Soueir river waters varies between 7 mg/L and 14 mg/L depending on the study station and the time of the year. These variations can be explained by the nature of the substrate and the climate. The latter factor is the cause of the differences observed between the two sampling campaigns (Hbaiz et al., 2022).

Sulfates

The concentrations recorded in sulfates, in both campaigns, are below the Moroccan standards (250 mg/L). The differences observed between the two sampling periods can be attributed to variations in climatic conditions that affect the erosion of the substrate.

Nitrates

As shown in the results (Table 3 and 4); upstream of the river the concentrations of nitrates are all below the Moroccan and international standards (50 mg/L), except for those recorded in the months of October, which, for the two companions, are high (163 mg/L in 2016 and 121,3 mg/L in 2018) and exceeding the accepted standards. Downstream of the river, nitrate levels exceeding the admitted standards, are recorded in the months of December and February for both periods. In addition, the increase in nitrate levels in the water can be attributed to the leaching of fertilizers used in agricultural soils located in the Drader-Soueir basin.

Ammonium and orthophosphates

During both periods the concentration of ammonium ion remains low in both stations. However, in the month of October, a value exceeding the accepted Moroccan standard (0.5 mg/L) (N.M., 2002) was recorded. This increase could be explained by the use of soil fertilizers and by the significant decrease in water flow following a long dry period. For orthophosphates, the recorded values are low and below the accepted standard (1 mg/L), except for the value measured in October 2016 in station 2 (1.2 mg/L) which indicates the presence of phosphate pollution during this period.

Biochemical oxygen demand (BOD_5)

During both periods, the values of BOD_5 measured at station 1 are very low, which indicates the absence of organic pollution of the water upstream of river studied. Downstream, for both periods, the values recorded in the month of December, exceed the accepted standard (25 mg/l) (N.M., 2002). These high results can be attributed to the abundance of organic matter, linked to erosion caused by heavy rainfall. It should also be noted that the values recorded between April 2018 and February 2019 are slightly lower than those measured in April 2016 and February 2017, attesting to an improvement in the quality of the waters of Soueir river during this period of the year (Table 3 and 4).

Chemical oxygen demand (COD)

During both periods (Table 3 and 4), the evolution of COD levels is similar to those of BOD_5. The highest values are recorded in station 2 during the months of December and February.

Suspended matter (SM) and dissolved oxygen (DO)

Low levels of SM are recorded in both stations and for both study periods, except for the months of December and February when the values obtained are high in station 2. This increase in SM is explained by the effect of precipitation on the substrate and on the vegetation and the entrainment of this SM from the upstream to the downstream of the river.

The values of DO (Table 3 and 4) recorded during the two periods show the same evolution: higher levels upstream of the river in winters, the maximum values are recorded in December 2016 (12,11 mg/L) and February 2018 (10,95 mg/L), and lower levels downstream in summer the minimum values are recorded in August 2016 (8,25 mg/L) and October 2018 (8,16 mg/L). This can be explained by the effect of water temperature on oxygen dissolution, which increases with decreasing temperature, and the increase in water agitation due to increased water flow in winters.

Water Quality Assessment via WQI

The results obtained show significant variations with a trend towards degradation from upstream to downstream, the water becomes of poor quality or even non-drinkable (unfit for consumption). This would be related to the impact of agricultural activities (Şener *et al.,* 2017). The highest values of the WQI are recorded during the month of October, due to high nitrogen pollution and decreased flow. The water quality improved significantly during the 2018/2019 study period which could be explained by the abundant precipitation (Table 5).

Spatiotemporal evolution of the benthic fauna in the waters of Soueir river

The elaboration of faunal inventories of benthic macroinvertebrates of the two stations S1 and S2, during the two sampling campaigns, allowed us to evaluate the Shannon and Weaver diversity index (H') and the Belgian biological index (BBI). Tables 6 and 7 illustrate the results of this evaluation.

Biological diversity in the waters

The comparison of benthic macroinvertebrate diversity between the two sampling periods, carried out via the calculation of H' (Tables 6 and 7 and Figure 3), shows that it varies from one season to another. This diversity is richer in late spring and summer. However, the evolution of the values of this index in each of these two periods is more or less similar. In fact, the magnitude of the difference in fortnightly values between the two periods is relatively high only during the month of June. This difference can be attributed to the rainfall that was larger and more regular during the 2018/2019 period.

Biological quality of water

Water quality is assessed by determining the Belgian Biological Index (BBI). Figure 4 shows the evolution of this index, carried out in the two stations S1 and S2 during the two periods studied. The results show a similar evolution of the BBI values of the two surveys. The values are higher during the spring and summer periods than those noted in winter. Thus, these high values of RBBI indicate, according to the water classification table that the waters of Soueir river are little polluted during these two seasons. On the contrary, the BBI values are lower in winter, which indicates a degradation of the water quality during winter. This degradation is linked to the effect of climatic conditions, more abundant and more frequent rains, erosion of the surrounding environment, etc. Indeed, in winter, the water becomes more turbid and more loaded with suspended matter.

CONCLUSIONS

The study of the water quality of Soueir river reveals that these waters are not very polluted. Indeed, the measured values of the physico-chemical parameters are lower than the accepted standards with the exception of nitrates and ammonium which sometimes exceed 50 mg/L and 0 .5 mg/L respectively during certain periods of the year. The calculation of the water quality index (WQI) reveals that the quality of the water varies with a tendency towards degradation from upstream to downstream, the water becomes of poor quality or even undrinkable. This pollution can be explained by the impact of agricultural activity. These results are consistent with the study of biological quality via the Belgian biological index, which places the waters of Soueir river in the category of low-polluted waters.

Table 5. WQI values and quality class of the surface waters of Soueir river during the two sampling campaigns

Station	WQI 2016/2017	Quality class	WQI 2018/2019	Quality class
S1 Av	40.43	Good quality	47.97	Good quality
S1 Ju	61.51	Bad quality	26.26	Good quality
S1 Ao	73.61	Bad quality	58	Bad quality
S1 Oc	224.28	Non-drinkable water	165.74	Eau non potable
S1 Dc	72.46	Bad quality	35.07	Good quality
S1 Fe	46.79	Good quality	49.43	Good quality
S2 Av	57.11	Bad quality	67.57	Bad quality
S2 Ju	49.78	Good quality	60.97	Bad quality
S2 Ao	61.3	Bad quality	67.86	Bad quality
S2 Oc	262.49	Non-drinkable water	204.97	Non-drinkable water
S2 Dc	103.92	Non-drinkable water	72.98	Bad quality
S2 Fe	139.85	Non-drinkable water	184.11	Non-drinkable water

Table 6. Faunal inventory and H' and BBI values recorded upstream and downstream of Soueir river. during the 2016/2017 period

Station	S1						S2					
Samples	**1**	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**
Taxa												
Cl. INSECTS												
O.Trichoptera												
Leptoceridae		1						1	1			
Odontoceridae	2						1	2				
O. Ephemeroptera												
Ephemeridae	1	1					2	1		1		1
Baetidae							1	2	2			1
O. Odonata												
Lestidae							2	2	1			1
Libellulidae	2	1	1		1	1	3	2	2	1	1	2
O. Heteroptera												
Notonectidae	1	2		1		1	3	1	1			1
Hydroptilidae							2	2	1			1
O. Coleoptera												
Dytiscidae	1						2	2		1		1
Elmidae							1	2	2			
Sphaeridiidae				1			1		1			
O. Dipteria												
Tipulidae										1		
Chironomidae									1	1		
Cl. GASTEROPODI												
O. Prosobranchia												
Physidae	8	7	7	5	3	4	2	3	1	1	2	4
Lymnaeidae	23	21	18	12	11	14	12	15	16	10	4	5
Cl. BIVALVES												
O. Eulamellibranchia												
Syphridae							2	2	3	2		2
Cl. OLIGOCHAETS												
O. Prosopores												
Lumbricidae	3	5	6	4	2	2	2	3	3	2	1	1
Cl. ARACHNIDS												
O. Hydracarina												
Hydrachnidae		1	2	1				2	2	1		
Total	41	39	32	24	17	22	36	42	37	21	8	20
Nb of taxa	8	8	5	7	4	5	14	15	14	10	4	11
H'	1.27	1.42	1.23	1.35	0.99	1.09	2.12	1.96	2.07	1.77	1.21	1.85
BBI	7	6	4	5	3	4	7	8	7	5	3	6

The determination of the Shannon index shows, for the two sampling periods, a greater diversity downstream compared to upstream which can be explained by the difference in the morphodynamic, abiotic and biotic characteristics of the two stations. Thus, it seems imperative to rationalize the use of chemical fertilizers in order to reduce nitrate pollution and preserve the fresh waters of the drader-soueir basin.

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Table 7. Faunal inventory and values of H' and BBI recorded upstream and downstream of Soueir river during 2018/2019

Stations	S1						S2					
Slamps	**1**	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**
Taxa												
Cl. INSECTS												
O.Trichoptera												
Leptoceridae		2						1	2			
Odontoceridae	2	3						2	1			
O. Ephemeroptera												
Ephemeridae	2	3					3	2				1
Baetidae							1	3	2			2
O. Odonata												
Lestidae		2					3	2	1			1
Libellulidae	3	2	1		2	1	4	3	2		1	2
O. Heteroptera												
Notonectidae	2	3	2			1	3	2	2			1
Hydroptilidae							4	2	2			1
O. Coleoptera												
Dytiscidae	1	2					3	3		2		
Elmidae							1	2	2			
Sphaeridiidae			1	2			2	1				
O. Dipteria												
Chironomidae									2	1		
Cl. GASTEROPODI												
O. Prosobranchia												
Physidae	11	8	8	6	5	6	3	4	3	2	1	3
Lymnaeidae	27	24	19	11	13	14	15	17	16	11	5	5
Cl. BIVALVES												
O. Eulamellibranchia												
Syphridae							2	4	2	3		2
Cl. OLIGOCHAETES												
O. Prosopores												
Lumbricidae	4	6	5	5	3	2	3	4	3	3	1	
Cl. ARACHNIDS												
O. Hydracarina												
Hydrachnidae		1	2	2				2	2	1		
Total	52	56	38	26	23	24	47	54	42	23	8	18
Nb of taxa	8	12	8	5	4	5	13	16	14	7	4	9
H'	1.48	1.84	1.44	1.41	1.13	1.13	2.56	3.15	2.22	1.58	1.45	2.098
BBI	7	8	5	3	4	4	7	7	8	3	4	5

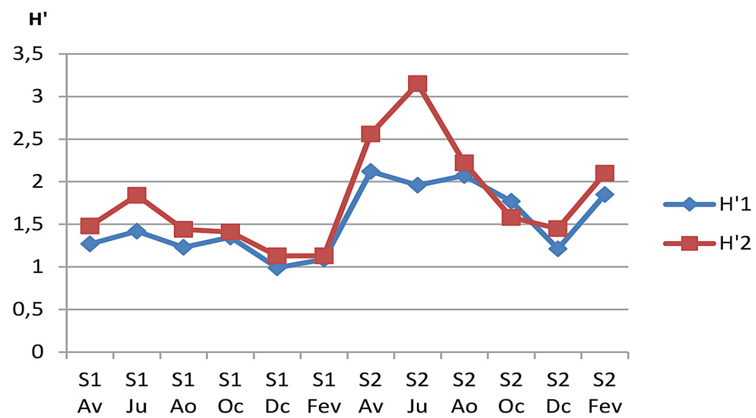

Figure 3. Spatiotemporal evolution of the Shannon index (H') during the two sampling periods of benthic macroinvertebrates in the waters of Soueir river

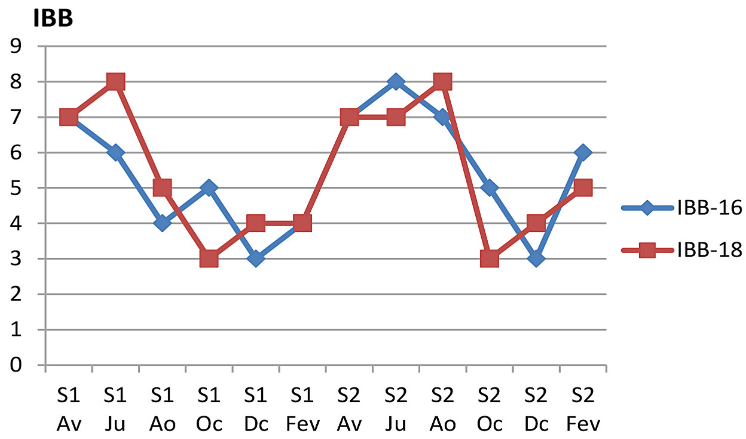

Figure 4. Spatiotemporal evolution of the Belgian Biological Index (BBI) during the two sampling periods of benthic macroinvertebrates in the waters of Soueir river

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