



Assessment of the ecological status of the Oum Er-rabie River basin (Central Morocco) through physicochemical, bacteriological parameters and biotic indices

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Abstract

In this work, the assessment of the ecological status of the Oum Er-rabie River basin was carried out by determining the physical-chemical, bacteriological and biological parameters. sampling Benthic macroinvertebrates and water were collected only once during the fourth seasons at the 31 stations upstream to downstream of the streams from spring 2018 to winter 2019. Physical-chemical quality was assessed from the Weighted Index (IP) based on 16 parameters (temperature, conductivity, dissolved oxygen, nitrate, nitrites, Ammonium, biochemical oxygen demand, chemical oxygen demand, turbidity, ortho phosphate, calcium, magnesium, chloride, sulphate) and revealed an average to very poor quality in most stations. The microbiological quality, based on the assessment of the three parameters: fecal coliforms, total coliforms and fecal streptococcus, varies between, good and bad. The values of the biotic indices, Iberian Biological Monitoring Working Group Index (IBMWP), River Habitat Index (IHF) and River Quality Index (QBR), classify the waters of the various prospected stations as good quality waters for upstream stations (S2, S10, S12, S14, S15, S16) and in the medium to very bad quality category for other localities except for two stations (S27, S30) which are downstream but have good qualities.

Keywords IP · IBMWP · IHF · QBR · Water Quality · Oum Er-rabie River basin

Introduction

Morocco has relatively large water resources facing quality and quantity problems. These resources are being altered due to different types of polluting releases. Among the watersheds that clearly detect this deteriorating situation is the Oum Er-rabie River basin.

The Oum Er-rabie has long seen an influx of people who develop around its waterways all possible activities allowing them to ensure an acceptable quality of life. The watershed has the largest demand for water in Morocco: 4.25 billion cubic meters, or 35% of Morocco's total water demand (Abhoer 2007).

The population of the Oum Er-rabie is estimated at 5.1 million and is expected to reach 6.4 million by 2030.

The area is home to the Kingdom's largest mining hub, made up of phosphate industries. Agriculture is the dominant economic activity with an area of more than 300,000 hectares irrigated in a modern way (Abhoer 2012).

Oum Er-Rabie has a wide variety of climatic characteristics, ranging from a semi-arid climate in the meseta to a humid climate in the High and Middle Atlas. The average annual temperature in Tadla is about 20 degrees Celsius and the average temperature is about 10 degrees Celsius. Precipitation is contrasting and more abundant inland. Exposed slopes of the High Atlas generally receive between 800 and 1000 mm; those who are sheltered receive only 600 to 800 mm; Atlas valleys receive only 400 to 600 mm and sometimes less than 400 mm when they sink deep into the massif (Loup 1962).

The industry around the watershed is constantly evolving; agriculture has increased and even modernized (strong use of fertilizers and overexploitation of the soil); households in douars, villages and towns are increasingly populated.

Benthic macroinvertebrates form an important part of freshwater ecosystems. They serve as food for many fish,

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amphibians and birds. It is a very diverse group, and the organisms that make it up have varying sensitivities to different stresses, such as pollution or habitat modification. Macroinvertebrates are the most commonly used organisms to assess the health of freshwater ecosystems (Québec 2010).

In Morocco, they were used to assess the physical, bacteriological and biological quality of the waters of several rivers including those of the watersheds of oued Laou (Errochdi 2015), Martil (Guellaf and Kettani 2020) and others.

Prior to this study, other studies realized in the Oum Er-rabie River basin were conducted by Bitar et al. (2013) and Souilmi et al. (2017) to assess the water quality of the basin based, for the latter's, on physicochemical parameters and benthic macroinvertebrates.

Thus, the aim of our work was to better study the quality and health of the Oum Er-rabie Rivers for a whole seasonal cycle (spring, summer, autumn and winter). A diagnosis of the ecological situation of the watershed was made through the study of physical-chemical variables, bacteriological parameters and biological ones that are essentially based on benthic macroinvertebrates.

Materials and methods

Study area

The Oum Er-rabie zone consists of the Oued Oum Er-rabie basin and the Atlantic coastal basins of El Jadida-Safi. With a total area of 48,070 km², it covers nearly 7% of the Kingdom's area. It is home to 65 urban centers and 254 rural municipalities, spread over 12 provinces, 6 of which are in the study area in their entirety: Beni Mellal, Khouribga, Azilal, El Jadida El Kelaâ des Sraghna and Safi; much of the provinces of Khenifra and Settat are in the study area (Abhoer 2012).

Wide varieties of geological formations are present: the primary lands first meet at the foot of the Middle Atlas; they mainly include shale and quartzites, with Autunian conglomerates in the Khenifra region, some limestone layers, and permo-triassic basalts. The lands of the Middle Atlas and the High Atlas are mainly limestone.

The origin of pollution in the Er-rabie watershed is due to urban concentration in cities and urban centers. The region experiences intense agricultural activity with the highest consumption per hectare in Morocco in addition to the area's highly polluting industries. Degradation of the aquifers (particularly the Tadla aquifer) and sections of the Er-rabie Um (between Kasba-Tadla rejection downstream and Dar Ouled Zidouh rejection downstream) is likely to increase; these are the area's most strongly affected by the combined effect of industrial releases (Bitar et al. 2013).

Macroinvertebrate samples for biological studies and water samples for physical-chemical and bacteriological analysis were collected during four field surveys between 2018 and 2019 at 31 sampling sites (Fig. 1; Table 1) spread over the main tributaries upstream to downstream. The selection of the stations was based on the sustainability of water at some stations providing a biotope for macroinvertebrate communities, the health monitoring of streams over time, the availability of geological and plant diversity and the assessing of the effect of agglomerations on water quality.

Physical-chemical and bacteriological study

The physical-chemical approach makes it possible to characterize disturbances by their causes, by looking for the presence of certain chemicals in water, at a specific time (Mebarki 2001).

Temperature measurements, dissolved oxygen, pH, salinity and electrical conductivity were carried out in the field using a multi-parameter device.

As for the other parameters (ortho-phosphate, nitrite, nitrate, turbidity, sulphate, DBO₅, DCO) and bacteriological parameters (total coliforms and fecal streptococci), they were analyzed at the laboratory of the El Jadida Autonomous Electricity and Water Distribution Authority (RADEEJ) located in El Jadida, according to the methods described by Rodier et al. (2009).

The index of a parameter is obtained by weighting and the index of an alteration is the lowest index obtained for all the parameters characterizing the said alteration (IP). The overall quality index is the lowest index obtained for all the alterations considered. The general surface water quality grid sets five quality classes, each defined by a set of threshold values that the different parameters must not exceed (SEEE 2002, 2008).

Indeed, the values of the ranges set by the new grids to assess water quality are transformed into unitless figures ranging from 0 for very poor quality to 100 for excellent quality (SEEE 2008).

Macroinvertebrate sampling and identification

The sampling of benthic fauna from watercourses was done with hand nets type Surber and/or others. The purpose of the present method was therefore to establish a faunal list, as exhaustive as possible, of the families present and their abundance in all available habitats with a rapid field method. Each time, the net was placed against the current and the substrate was stirred for 30 s so that the organisms are carried away by the current into the net. The different types of micro-habitats existing in the rivers, were thus inspected. All samples were stored in vials filled with alcohol and labelled. Subsequent laboratory phase concerned the identification of

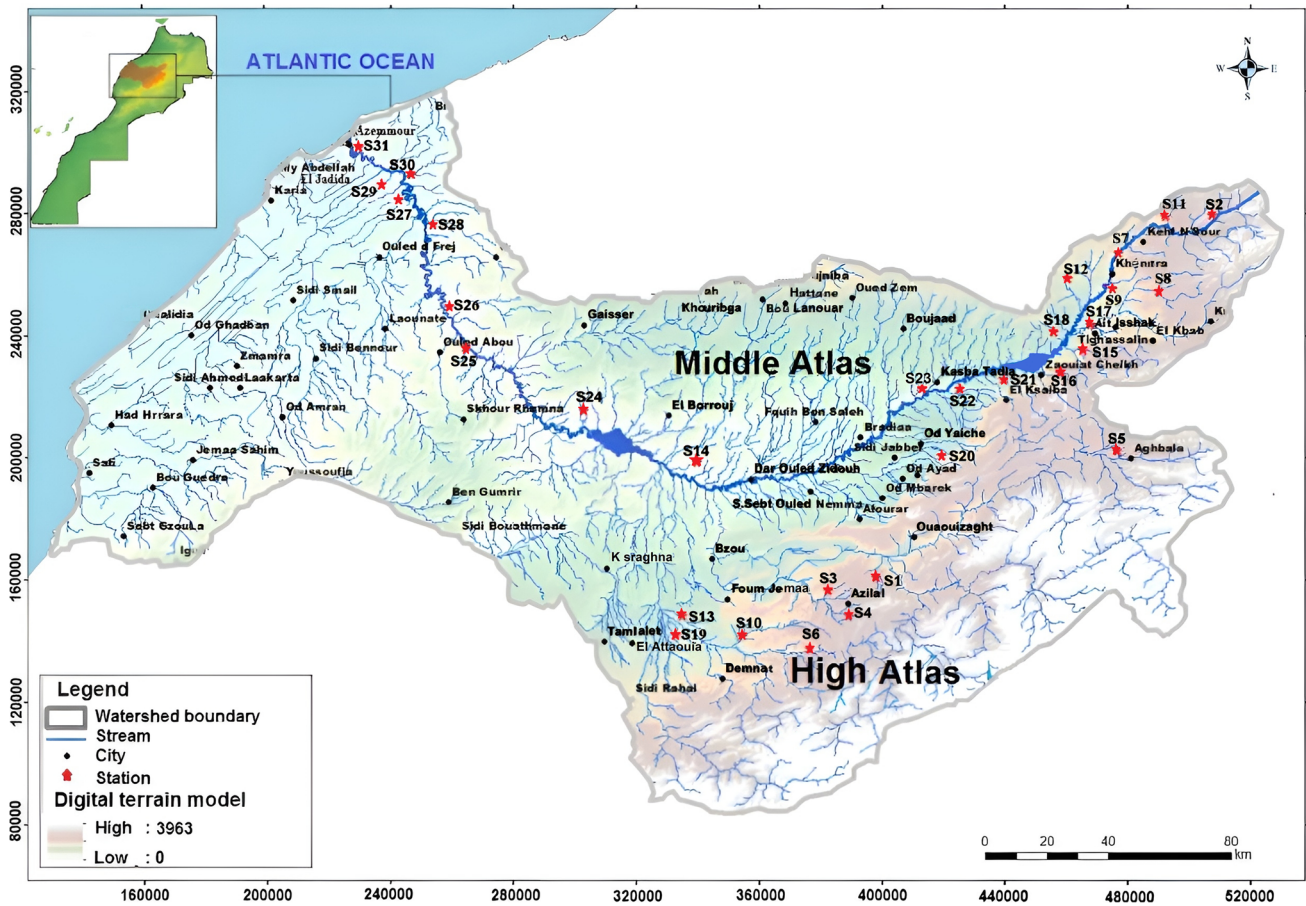


Fig. 1 Location of the stations studied within the Oum Er-rabee River basin

the collected material at the family level based on identification keys such as that of Sansoni (1992) and/or that of Tachet et al. (2002).

Biotic indices

Three biotic indices have been applied that follow the protocol for assessing the ecological status of Mediterranean rivers such as:

- The river Habitat Index (IHF) was used to assess the physical habitat of the aquatic ecosystem, its heterogeneity and its dynamics that influence the structure of benthic communities (Pardo et al. 2004). This index evaluates relations between habitat heterogeneity and physical variables of the stream channel (frequencies of riffles, flow velocity, depth regime, substrate diversity and substrate inclusion in riffles, percentage of shade in the riverbed and aquatic vegetation coverage), which are influenced by hydrology and substrate composition (Acosta et al. 2009; Villamarín et al. 2013). IHF scores, which vary between 0 and 100 points (Garófano-

Gómez et al. 2011), fall within three classes: good habitat quality (Class I: $IHF > 60$), moderate quality (Class II: $40 < IHF < 60$) and bad quality (Class III: $IHF < 40$).

- The Waterfront Quality Index (QBR), used to assess the quality of riparian vegetation (Munné et al. 1998). This provides a rapid assessment of the overall condition of the riparian zone using four aspects (total riparian vegetation cover, cover structure, cover quality and the degree of naturalness of the stream channel). These components or sub-indices are measured in a simple quantitative way (Munné et al. 1998; Villamarín et al. 2013). The index scores range between 0 and 100 points, classifying riparian quality into five classes, namely, Class I of excellent quality ($QBR \geq 95$), Class II of good quality ($90 > QBR > 75$), Class III of moderate quality ($70 > QBR > 55$), Class IV of poor quality ($50 > QBR > 30$), and Class V of bad quality ($QBR \leq 25$) (Garófano-Gómez et al. 2011).
- The Iberian Working Group on Biological Surveillance (IBMWP) index, used to assess biological water quality based on macroinvertebrates (Alba-Tecedor et al. 2002). A score ranging from 1 to 10 which reflects the tolerance

Table 1 Geographical location and characteristics of the main stations studied in the hydrographic network of the Oum Er-rabie river basin

Code	Station	Municipality	Latitude	Longitude	Elevation (m)
S1	Oued Azilal	Azilal	31°57'29"N	6°32'06"W	1450
S2	Oyon Oum Errabie	Ifrane	33°03'04"N	5°24'42"W	1290
S3	Amrssid	Azilal	31°55'24"N	6°37'47"W	1221
S4	Tighajdadamte	Azilal	31°55'49"N	6°36'58"W	1210
S5	Aghbala	Beni Mellal	32°32'27"N	6°00'40"W	1190
S6	Tissakhete	Azilal	31°58'15"N	6°40'50"W	1001
S7	El Borj	Khénifra	33°00'59"N	5°37'32"W	888
S8	Bouzakoum	Khénifra	32°54'44"N	5°40'02"W	834
S9	El Fara	Khénifra	32°54'51"N	5°40'28"W	821
S10	22 Sources	Azilal	31°59'23"N	6°42'50"W	819
S11	Aassa	Khénifra	32°49'38"N	5°36'55"W	811
S12	Boymizdaoun	Khénifra	32°56'18"N	5°44'39"W	800
S13	Cascade Ouzoud	Azilal	31°59'49"N	6°42'53"W	799
S14	Centre Rokia	El kalaa Sraghna	32°00'47"N	6°42'57"W	782
S15	Habacha	Khénifra	32°40'38"N	5°52'00"W	751
S16	Ain Tamda	Beni Mellal	32°38'30"N	5°54'45"W	718
S17	Ouaoumana	Khénifra	32°42'42"N	5°48'23"W	712
S18	Chekaf	Khénifra	32°41'50"N	5°50'43"W	697
S19	Source Ouzoud	Azilal	32°01'11"N	6°43'32"W	661
S20	Ain Asserdoun	Beni Mellal	32°19'35"N	6°20'17"W	611
S21	Affluent Hanssali	Beni Mellal	32°40'33"N	5°53'58"W	598
S22	Zraib	Beni Mellal	32°35'22"N	6°14'48"W	479
S23	Moulay Ismail	Beni Mellal	32°35'39"N	6°16'44"W	474
S24	Affluent Massira	El kalaa Sraghna	32°29'29"N	7°38'57"W	226
S25	Machraa Ben Abou	Settat	32°38'39"N	7°48'10"W	192
S26	Imfoute	Settat	32°44'20"N	7°56'27"W	155
S27	Ain Meryam	Settat	33°13'13"N	8°13'36"W	40
S28	Sidi Said Maachou	El Jadida	33°08'34"N	8°06'34"W	31
S29	Bahani	El Jadida	33°15'56"N	8°17'29"W	13
S30	Mhiwla	El Jadida	33°12'46"N	8°11'57"W	12
S31	Bab Jyaf	El Jadida	33°15'46"N	8°19'55"W	7

of the families of macroinvertebrate to pollution is given. A low score is given for the most tolerant and a high score for the sensitive taxa (Mustow 2002). The total score obtained for each study site indicated the ecological quality of the water by class, categories ranging from very bad (0–15), bad (16–35), poor (36–60), moderate (61–100) to good (> 100) (Nguyen et al. 2017).

Statistical analysis

In order to analyze the existing correlations between the different stations, all the data were processed by the ACP Main Component Analysis using SPSS software, in order to highlight the relationship between the studied stations and the physical-chemical, biological and bacteriological parameters to facilitate the interpretation of the results and assess the quality of the high Oum Er-rabie River basin.

This method is widely used to interpret hydrochemical data (Fekhaoui 1990; Ezzaouaq 1991; El Amrani-Pazza et al. 1994; Bennasser 1997; Jadal et al. 2002; El Blidi et al. 2006; El Morhit et al. 2008; Errochdi et al. 2012).

This technique is a water resource management tool for rapid solutions to pollution problems (Vega et al. 1998; Ouyang 2005; Swaine et al. 2006; Felipe-Sotelo et al. 2007; Shrestha and Kazama 2007; Mencia and Mas-Pla 2008).

Results

Physico-chemical and bacteriological study

The results obtained reveal a deteriorated overall water quality in the Oum Er-rabie River basin, caused mainly by high levels of nitrogen materials excluding nitrates, phosphate

materials, microorganisms, organic and oxidable matter, suspended materials and mineralization.

In order to assess the water quality of selected streams at the Oum Er-rabie River basin, we adopted calculations of the percentage by quality class of weighted indices for all surveyed stations.

Analysis of the data in Fig. 2 shows that during the spring of 2018, 35% of the stations showed good quality and 32% reported average quality. While in autumn 2018 and winter 2018 these values decreased to 29%, for the good class for both seasons and, 38% and 35% respectively, for the middle class. This deterioration was accentuated during the summer of 2018 when only 9% of the stations recorded good quality and 33% showed average quality.

Biotic indices

The river habitat index assesses the ability of physical habitat to accommodate a particular fauna based on seven parameters: substrate, current, depth, shade, presence of heterogeneity elements, and vegetation (Pardo et al. 2004). This index showed that the quality of the stations varies between good and bad (Fig. 2).

The results of this index show that quality depends on seasonality and altitude with 45% of stations ranging from 1450 m to 661 m that recorded good quality during the spring (S2, S3, S5, S6, S7, S12, S13, S14, S15, S18, S19, S26, S27, S30). For the wrong class, we have a total of 3% (S11, S31) of stations during the spring, 6% (S28, S31) during the summer, 9% (S9, S29, S31) during the winter and 12% (S11, S24, S28, S31) in autumn. As for

the two remaining classes, the index revealed approximate scores between the three seasons (autumn, spring, winter) while in summer the number of stations with good quality decreases and reaches 18%.

Biological quality results obtained through the IBMWP Index, applied to 31 study stations along the Oum Er-rabie River basin, generally reveal very good to deficient scores (Fig. 2).

The minimum values were recorded during the two seasons, autumn and winter, with a percentage of 3% for both downstream stations of very poor quality, while the spring season experienced the maximum value of quality in 29% of the stations with an excellent score, followed by 22% of stations in winter and 19% in autumn.

During the summer, the IBMWP index recorded low scores, with 25% of stations posting average quality and 7% of stations, quality is poor, with a decrease in stations (5%) of excellent quality; 48% of the remaining stations were dry.

As for the ripisylves quality index (Fig. 2), values range from 21 as a minimum value, recorded at a single S31 station downstream of the study area during all seasons of very poor quality, to 115 as maximum value. The latter attests to excellent quality but with different percentages, 35% of resorts in spring, followed by 25% during the winter, 22% in autumn and only 12% in summer.

Indeed, the quality of vegetation along the river systems of the Mediterranean region tends to decrease from the upstream of the watersheds to their downstream parts (Suàrez and Tsutsui 2004).

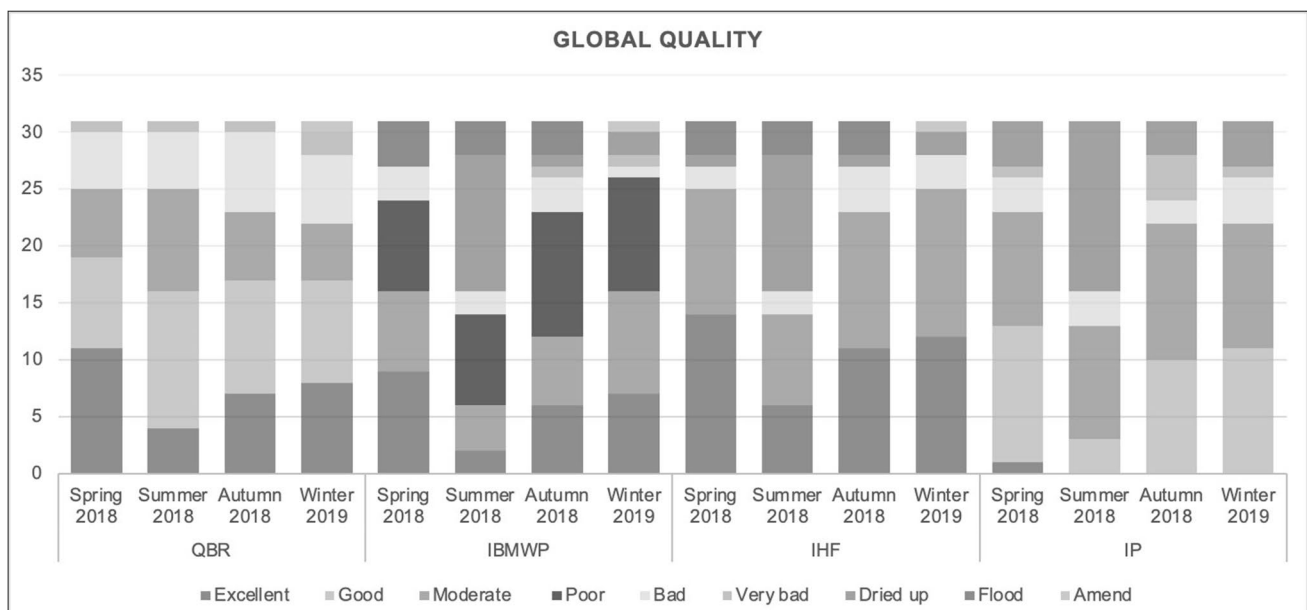


Fig. 2 Evolution of the overall quality of the stations in the Oum Er-rabie basin according to the seasons

Macroinvertebrate assemblies

The biocenetic composition that populates the aquatic habitats of the Oum Er-rabie River basin revealed 28,714 benthic fauna individuals collected and identified at the 31 studied stations (Table 2). They belong to 15 orders (Rhynchobdellida, Gastropoda, Veneroida, Amphipoda, Decapoda, Oligochaeta, Lepidoptera, Isopoda, Ephemeroptera, Plecoptera, Odonata, Hemiptera, Coleoptera, Trichoptera and Diptera) and 86 families (Table 2). Arthropoda are found to be the most abundant, accounting for 81.12% of families, followed by mollusca with 14.44% and Annelida with 4.44%.

The wildlife settlement recorded along the surveyed stations during the sampling period shows a clear dominance of families belonging to the Diptera order with 20.9% (18 families), followed by Coleoptera, which represent 15.11% (13 families) and Mollusca representing 12.79% (11 families). Trichoptera, Odonata, Hemiptera, Ephemeroptera and Plecoptera comprise 11.62% (10 families), 8.13% (7 families), 8.13% (7 families), 4.65% (4 families) and 4.65% (4 families) respectively. The other groups are represented by only small percentages (Rhynchobdellida with 2.22%, Veneroida with 2.22%, Amphipoda with 2.22% and Isopoda characterized by only 1.11%).

Abundance and diversity revealed significant seasonal variations (Fig. 3). Spring was the most diverse season in terms of number of families, especially for Diptera (14 families). Diptera, Coleoptera and mollusca are the most represented groups over the four seasons throughout the study period.

The maximum number of taxa (41) was seen in spring in Oued Oyon Oum Er-Rabie (station S1). Whereas Bab Jyaf (station S31) recorded the smallest total of taxa (3 families) during all surveying campaigns. Furthermore, Simuliidae proved to be the most abundant family with 4201 individuals, followed by Baetidae and Chironomidae, with 4015 and 3782 individuals respectively. All three, were the most abundant families during the four sampling seasons.

Statistical analysis

The analysis of the graph obtained by the main component analysis resulted in a significant organization composed of four different groups (Fig. 4).

Group 1: consisting of the S2, S10, S12, S14, S15 and S16 stations, with altitudes ranging from 1209 m (S2) to 718 m (S16), except for the S30 station, which is downstream of the basin with an altitude of 12 m. The group has very good quality for all the four indices (IP, IHF, IBMWP, QBR), as well as low levels of nitrites and nitrates. The hydrological characteristics (permanent flow, strong flow and relatively strong current) of these

sites contribute to a kind of dilution of water with respect to the various sources of contamination and condition a continuous renewal of the waters and the maintenance of a good overall quality. The ripisylve observed along the river of the group has a conserved appearance in terms of continuity and density. However, in terms of diversity, few species represent shoreline vegetation for Station 14. Group 2: formed by the S1, S3, S5, S7, S13, S19 and S27 stations, located at medium to high altitudes; they are characterized by significant mineralization and a high rate of nitrogen material. Most of the streams studied are permanent, biological indices have good quality indicating that the habitat is well constructed.

Group 3: represented by the S6, S8, S17, S18, S21, S25, S26 and S29 stations that form the middle courses of the basin; their waters are moderately oxygenated with high levels of organic matter and ammonium with a relatively large development of microorganisms that recorded poor quality. The shoreline is heavily deforested, and the river flow pattern is directed downstream.

Group 4: assembling the lower-grade S4, S9, S11, S20, S23, S24, S28 and S31 stations, which are poor to very poor in quality; their waters are highly turbid, with very high values of nitrogen and microorganisms.

Discussion

The water quality assessment of the Oum Er-rabie River basin revealed overall excellent to critical qualities depending on the geographical location of each station and the degree of impacts of human or industrial activities.

The reorganization of benthic assemblages results in changes in community structure in terms of quality and quantity between the different sites that have been identified and between sampling campaigns conducted according to the annual cycle (Mesa 2012). Thus, the diversity and abundance of macroinvertebrates were significantly greater in the spring than in other seasons (Guellaf and Kettani 2020).

In agreement with several studies, indices based on macroinvertebrates have shown significant responses to water quality degradation (Karaouzas et al. 2011; Munyika et al. 2014). The families of Plecoptera, like that of Capnidae, Perlidae and Perlodidae, Ephemeroptera (Ephemeridae, Heptageniidae, Leptophlebiidae) or Trichoptera, including Polycentropodidae and Sericostomatidae, all have a high score in the IBMWP index, given their high indicator value of good quality waters (Lenat 1988; Hilsenhoff 1988; Plafkin et al. 1989; Klemm et al. 1990; Bode et al. 1991; Lenat and Crawford 1994; Resh et al. 1996; Cayrou et al. 2000; Lamri 2009; Slimani 2018). Their representatives were collected at most stations except those downstream of settlements or near farmland.

Table 2 List of Macroinvertebrate taxa with indication of their occurrence (+) in the 31 sampling stations of the Oum Er-rabia River basin visited in the present study

Taxa	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30	S31	Abundance				
Arachnida																																				
Hydracarina				+																															40	
Plecoptera																																				
Perlidae	+	+			+																													7		
Perlodidae	+	+	+		+																	+												15		
Capniidae				+	+				+																									65		
Nemouridae							+																												94	
Chloroperlidae																																			2	
Taeniopterygidae				+																															1	
Leuctridae																																			6	
Coleoptera																																				
Dryopidae	+	+	+						+																										80	
Dytiscidae	+	+	+	+			+		+																										257	
Elmidae	+	+	+	+	+		+		+																										165	
Gyrinidae				+	+				+																										786	
Halplidae	+			+	+				+																										81	
Helophoridae																																			15	
Hydraenidae	+	+	+						+																										120	
Hydrophilidae	+	+	+	+					+																										174	
Noteridae							+															+													27	
Heteroptera																																				
Corixidae				+					+																											750
Gerridae				+	+				+																											251
Hydrometridae									+																											73
Mesoveliidae																																				110
Nepidae				+	+																															25
Notonectidae				+	+				+																											64
Ochteridae									+																											1
Veliidae							+																													47
Diptera																																				
Athericidae					+																															25
Blepharicidae																																				1
Ceratopogonidae																																				21
Chironomidae	+	+	+	+	+		+		+																											3782
Culicidae	+	+	+	+	+		+		+																											1253
Dixidae					+		+																													51
Dolichopodidae																																				1
Empididae	+			+				+																												35
Ephydriidae																																				17
Limoniidae	+						+																													21

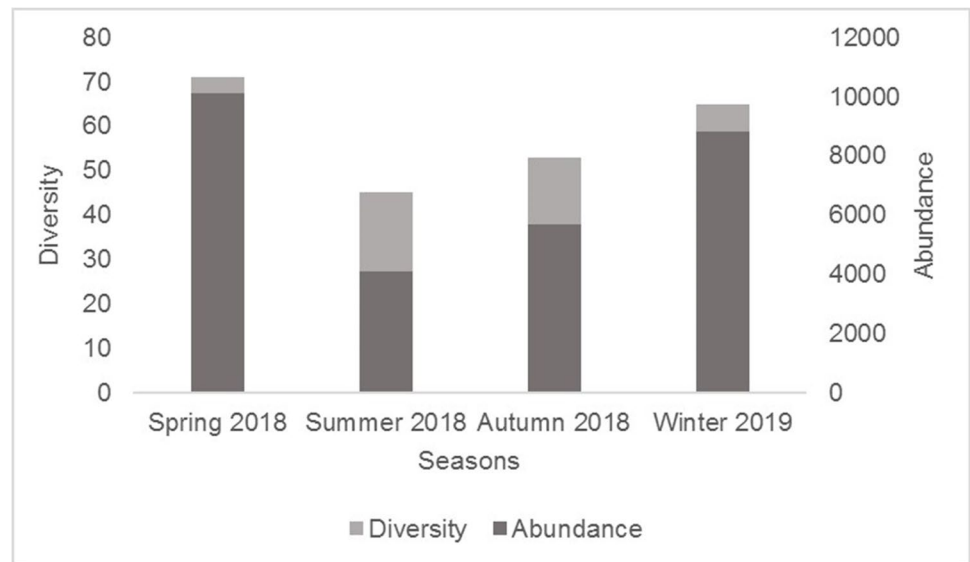
Table 2 (continued)

Taxa	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30	S31	Abundance			
Psychodidae							+																										38		
Sciomyzidae																						+											17		
Simuliidae	+	+				+																											4201		
Stratiomyidae	+	+			+																												78		
Syrphidae																																	84		
Tabanidae	+	+	+																														61		
Tipulidae	+	+	+																														41		
Anthomyiidae																																	35		
Ephemeroptera																																			
Baetidae	+	+	+																															4015	
Caenidae	+	+	+																															2140	
Ephemerellidae															+																		45		
Oligoneuriidae								+																											
Heptageniidae	+		+																															350	
Leptophlebiidae																																		8	
Polymitarcidae																																		25	
Odonata																																			
Aeshnidae																																		1	
Coenagrionidae			+																															320	
Cordulegasteridae		+																																3	
Cordulidae																																		21	
Gomphidae	+																																	95	
Lestidae																																		3	
Libellulidae			+																															450	
Trichoptera																																			
Ecnomidae																																			8
Glossosomatidae																																			8
Leptoceridae																																		32	
Brachycentridae																																		1	
Psychomyiidae																																		1	
Potamanthidae																																		17	
Hydropsychidae	+																																	1	
Hydroptilidae	+	+	+																															335	
Limnephilidae		+																																85	
Philopotamidae																																		112	
Polycentropodidae																																		7	
Rhyacophilidae	+	+	+																															1	
Sericostomatidae	+	+	+																															121	
																																		81	

Table 2 (continued)

Taxa	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30	S31	Abundance			
Lepidoptera																																			
Pyralidae				+					+																									2	
Mollusca																																			
Ancylidae	+						+																											56	
Hydrobiidae						+																												61	
Lymnaeidae		+																																1181	
Neritidae		+																																362	
Physidae		+																																1402	
Planorbidae		+																																42	
Sphaeridae		+																																18	
Thiaridae																																		602	
Unionidae																																		108	
Oligochaeta																																		25	
Hirudinae																																			
Erpobdellidae																																		8	
Glossiphoniidae	+																																	51	
Hirudidae																																		34	
Amphipoda																																			
Gammaridae																																			3115
Isopoda																																			
Aseellidae																																			1
Decapoda																																			
Astacidae																																			74
Atyidae																																		470	
																																		28,715	

Fig. 3 Seasonal evolution of diversity (number of families) and abundance (number of individuals) of macroinvertebrate families collected in the Oum Er-rabie River basin stations



However, dipteran families such as Chironomidae, Culicidae and Syrphidae, beetle families such as Dytiscidae, Gyrinidae and Halipilidae, as well as Heteroptera such as Corixidae, Gerridae and Notonectidae, have a high tolerance to pollution. Indeed, these families show a preference for aquatic environments rich in organic matter and macrophytes (Tachet et al. 2002).

Macroinvertebrates, such as Capniidae, Perlodidae, Perlidae, Physiidae, Simuliidae and Heptagenidae, characterized by a high sensitivity to water pollution, recorded significant richness in spring in the stations of Group 1 (Fig. 5) The low levels of nitrites and nitrates revealed by the weighted index, in addition to the very high values of dissolved oxygen and the biotic index, attest to a well-built habitat with unpolluted water, little altered and excellent for the development of macroinvertebrates. The waters also have good biological quality as they come from a nearby groundwater upwelling and do not exhibit organic contamination.

On the other hand, the families Gomphidae, Baetidae, Dryopidae, Dytiscidae, Caenidae, Rhyacophilidae and Hydrophilidae (Fig. 5), not very sensitive to pollution, found an excellent habitat favorable to their development in the stations of the group 2. According to the QBR index, the ecological state of these stations is good. They show weak signs of alteration in urban wastewater discharges, which are not very important, and riparian vegetation is slightly altered. If these discharges were purified and the banks improved, the section could easily reach the ecological status of very good.

In reverse, the weighted index of this group designates an average quality given the high levels recorded for nitrites and nitrates. Indeed, the contamination of the water by these elements could result from diffuse pollution by discharges of wastewater, discharged into the soil or in septic cracks, from dwellings located upstream. Factors such as natural

geology and anthropogenic activities (for example, discharge of untreated domestic wastewater to KasbaTadla and Khenifra) were identified as the main determinants of point pollution events in the basin (Koukal et al. 2004; Skoulidakis et al. 2005).

Macroinvertebrates families, such as Gyrinidae, Gerridae, Psychodidae, Hydroptilidae, Tabanidae and Gammaridae (Fig. 5), resistant to pollution, inhabit the group 3 stations, whose ecological state is poor. The riparian vegetation is extremely altered and only the shrub layer remains. As for the IBMWP index, the decrease in taxonomic richness is caused by all activities such as grazing and the discharges that weigh on these ecosystems.

Indeed, the weighted index showed an average quality for all parameters throughout this study period except nitrogen elements (phosphorated and nitrogen) that exceeded the standards indicated in the quality grid because of polluting activities, especially diffuse pollution of agricultural origin; in the presence of low flow and flow, the ability of these streams to assimilate these nutrients is thus exceeded. This results in oxygen depletion of water due to the resulting eutrophication, which consumes a significant portion of it. Industry, agriculture and households in the douars are the key factors responsible for the degradation of freshwater quality and the environment of the Oum Er-rabie River basin (Bitar et al. 2013).

Known to be poluo-sensitive macroinvertebrates, the Chironomidae, Bithyniidae, Syrphidae and Culicidae (Fig. 5) found their ecological conditions in the stations of Group 4. The heterogeneity of its river habitat is very low due to dam construction and deforestation that causes the extinction of endemic species from these regions.

At this level, the QBR biotic index of biological parameters with moderately low scores, shows a rather poor quality

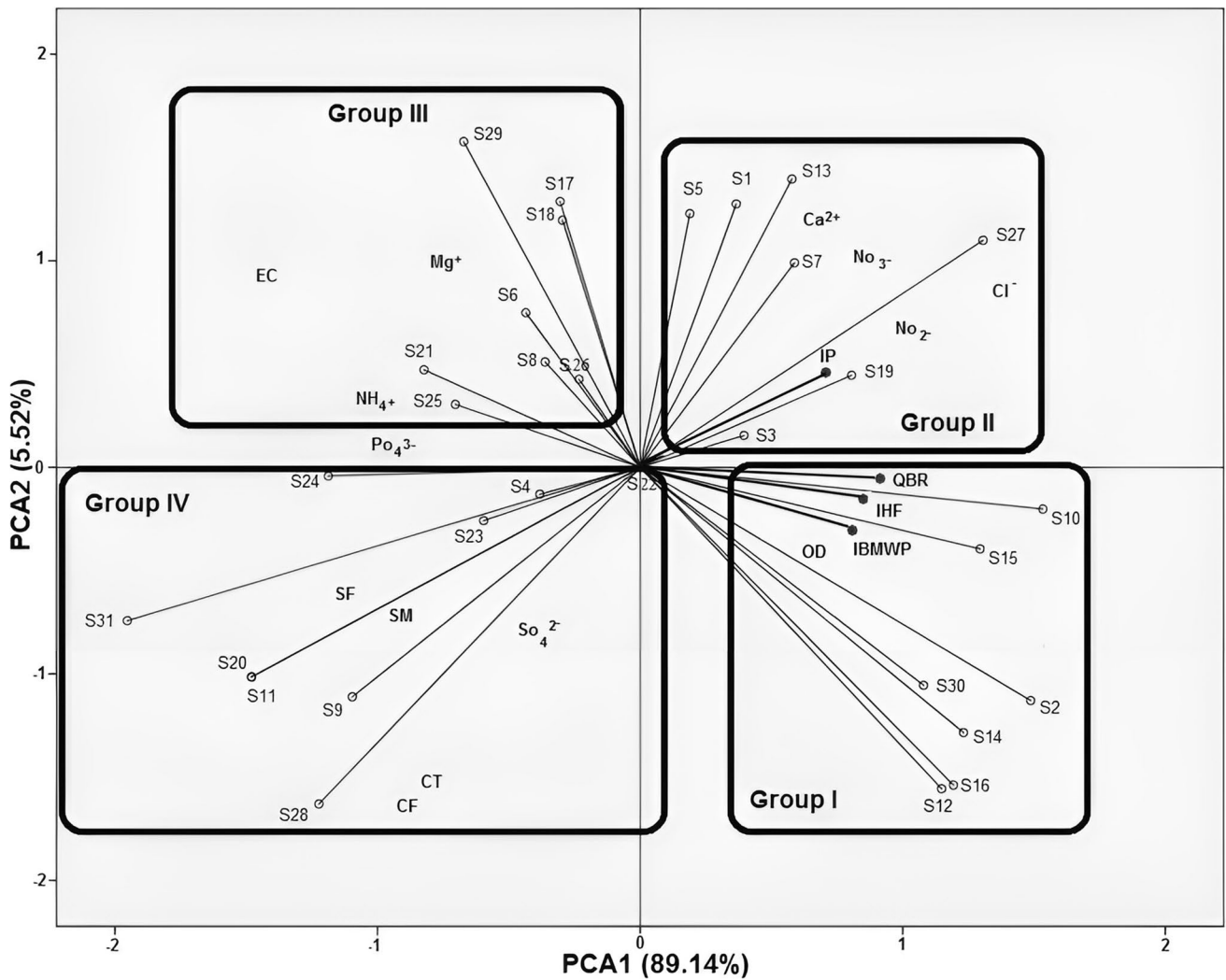


Fig. 4 Projection of weighted index variables based on average values for parameters: magnesium (Mg²⁺), electrical conductivity (EC), dissolved oxygen (OD), Calcium (Ca²⁺), suspended solids (SM), sulfate (SO₄²⁻), nitrite (NO₂⁻), nitrate (NO₃⁻), ammonium (NH₄⁺),

orthophosphates (PO₄³⁻), chlorides (CL⁻), and three biotic indices (IBMWP, QBR, IHF) in thirty-one stations on the PCA1-PCA2 factorial plane

with strong alterations and extreme disturbances suffered by these ecosystems and which ultimately attest to an altered ecological state. The weighted index indicates also a very poor quality due to high levels of total nitrogen and nitrites, and low concentrations of dissolved oxygen, causing the development of poluo-sensitive benthic fauna.

The two banks of the S4, S20, S24 and S28 stations are occupied by agricultural land that is a source of contamination of the water by fertilizers rich in nitrogen and phosphoric elements. We are witnessing diffuse pollution responsible for the eutrophication of riverbeds, which is manifested by a very large development of filamentous algae and macrophytes, thereby reducing the levels of dissolved oxygen in the water. The anthropogenic pressures on the various study stations have a negative impact on biological communities in

river ecosystems (Gregory et al. 1991; Allan 2004; Burcher et al. 2007; Bruno et al. 2014).

In addition, the S9, S11, S23 and S31 stations are downstream from the agglomerations, which receive a high polluting load from wastewater charged with nitrogen and phosphorated elements that are discharged there without any prior treatment. The result is a high turbidity of the waters and a very important fecal contamination (FC, FT and SF) thus degrading the aesthetic and ecological quality of these aquatic ecosystems. At the end of the winter season in 2019, the S31 station downstream of the basin (estuary) experienced the accumulation of a sand dune due to the low flow of the wadi, which caused a break between the wadi and the Atlantic Ocean. Therefore, multiple changes have taken place: the death of all aquatic fauna due to domestic

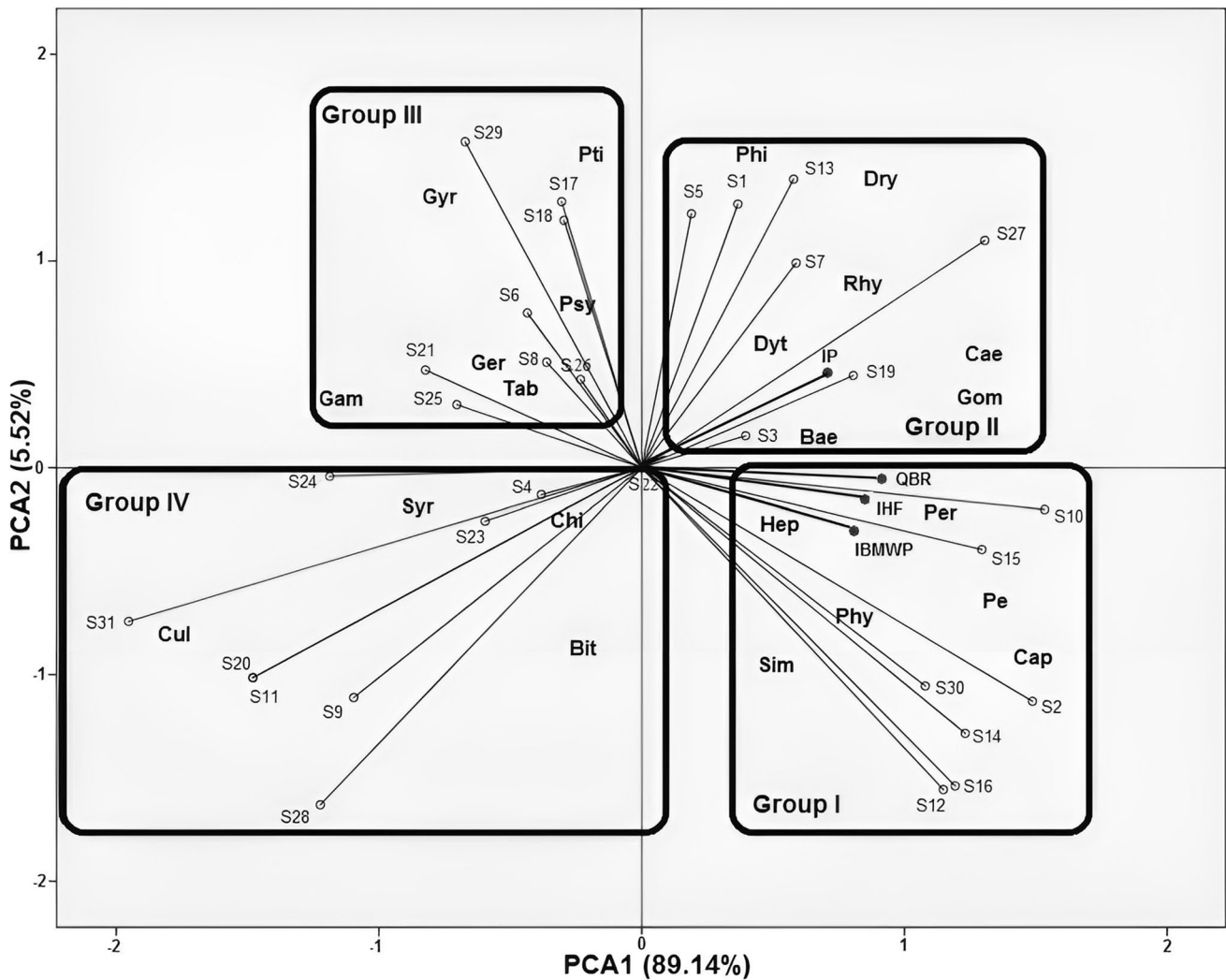


Fig. 5 Projection of distribution of macroinvertebrates: Capniidae (Cap), Perlodidae (Per), Perlidae (Pe), Physiidae (Phy), Simuliidae (Sim), Heptagenidae (Hep), Gomphidae (Gom), Baetidae (Bae), Hydrophilidae (Phi), Dryopidae (Dry), Dytiscidae (Dyt), Caenidae

(Cae), Rhyacophilidae (Rhy), Gyrinidae (Gyr), Gerridae (Ger), Gammaridae (Gam), Psychodidae (Psy), Hydroptilidae (Pti), Tabanidae (Tab), Chironomidae (Chi), Syrphidae (Syr), Culicidae (Cul), Bithyniidae (Bit) in thirty-one stations on the PCA1-PCA2 factorial plane

and industrial discharges, changes in watercolor, an intense development of aquatic vegetation all accompanied by the release of bad odors, which threatens the health of the population of the city of Azemmour.

Our results are consistent with those of previous work on other Moroccan watersheds, including those of Oued Laou and Tahadart (Errochdi 2015), Martil (Guellaf and Kettani 2020), (Slimani 2018), Oum Er-rabie (Bitar et al. 2013; Souilmi et al. 2017). There is a concordance at the level of the different types of pollutants mentioned which showed variations according to the characteristics of each locality under both natural and anthropogenic impact.

We obtained the same results as those found by Souilmi et al. (2017) at three upstream stations of Oum Er-Rabie: Oyon Oum Errabie (S2), El Borj (S7) and Aassa (S11)

in their study on the assessment of pollution in the Oum Er-rabie River using indices based on macroinvertebrates and physico-chemical parameters. However, by comparing the stations of the middle course: Zraib (S22) and Imfoute (S26), which coincide in our respective studies, we noted a significant degradation caused by the decrease in the flow and by the discharges of the surrounding Slaughterhouses.

The Iberian Biological Monitoring Working Party (Albatercedor et al. 2002), updated by macroinvertebrate families present in Morocco and those absent from Morocco (Bennas unpublished data) attests to the presence of 120 families of macroinvertebrates in the Moroccan mainland waters.

Oum Er-rabie River basin, with the total number of macroinvertebrates (86 families) registered in this study, has 71.6% of the Moroccan macroinvertebrate fauna; results

close to those of the largest basin in northern Morocco (Oued Laou), with 90 families and 75% of the fauna. While the Tahaddart basin hosts 72 families (Errochdi 2015) and represents 58% of the fauna, the Oued Martil (Guellaf and Kettani 2020) and Lökkouss (Slimani 2018) basins have only 68 (56.6%) and 42 (35%) families, respectively. So, the Oum Er-rabie is, by virtue of the diversity of its habitats, a very diverse river basin in Morocco promoting the installation of benthic fauna.

The organization of aquatic fauna in the surveyed stations indicates that macroinvertebrate communities are negatively correlated with the increase in concentrations of certain physico-chemical and bacteriological indicators. This confirms, as is known (Tamiru et al. 2017), that mineral, nutrient, organic pollution and physical habitat are among the main factors controlling the health of aquatic assemblages and the ecological integrity of ecosystems.

Conclusions

For years, the Oum Er-rabie River has hosted increasingly growing populations near rivers with multiple and diverse water needs. This increase in settlement is the main factor responsible for the alteration of this river through a multitude of impacts.

The distribution of macroinvertebrates at the Oum Er-rabie River basin revealed spatial variations and temporal variations between seasons. A significant richness has been recorded in the sections that are located at high altitudes, on the other hand, the lower the altitude, the greater the richness and abundance.

An increase in pollution due to domestic, agricultural, industrial or sewage discharges directly into the river have all contributed to the depreciation of the water. This affects and influences the physical habitat, ripisylve and chemical composition of the waters of the basin and therefore the ecological state and health of the ecosystem. The assessment of the results of the weighted index reveals an average water quality due to all the disturbances experienced by most streams in this basin.

The microbiological results, on their part, generally show a water quality ranging between good and medium, evidence that the waters of the prospected stations are not highly contaminated with bacteria.

Although the three indices of biological analyses show converging results, the IBMWP index is the most reliable in that it yields accurate results. Therefore, it shows that the overall quality of the stations varies between good and acceptable because of human activities.

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Data availability All relevant data are within the paper and its Supporting Information files.

Declarations

Material collected All specimens were sampled according to the Scientific permit delivered by the Department of Desertification Control and Nature Protection, Rabat, Morocco, under the number: 12/2018.

Conflict of interest We, the authors, declare that no competing interests exist.

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