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Hydrobiologie

ASSESSMENT OF THE PHYSICO-CHEMICAL AND BIOLOGICAL QUALITY OF SURFACE WATERS IN ARID AND SEMI-ARID REGIONS OF ALGERIA (NORTH-AFRICA)

par

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An assessment of the physico-chemical and the biological quality of surface waters through the use of macroinvertebrates as bioindicators was conducted in two rivers in Algeria, located in semi-arid and arid regions. These are Wadi M'zi (Laghouat region) and Wadi Djedir (Djelfa region). The sampling strategy developed in this work is based on the analysis of the upstream and downstream waters of each watercourse. Eleven physico-chemical parameters (T°C, pH, CE, OD, Cl^-, SO_4^{2-}, NO_3^-, Salinity, Ca^{2+}, Mg^{2+} and HCO_3^-) were measured to establish a diagnosis of the state of health of these aquatic ecosystems. Macroinvertebrates were studied using kick-net sampling at eight study sites. The faunistic inventory of benthic macroinvertebrates identified 37 families, mostly represented by insect larvae (96%). Among these, Diptera and Ephemeroptera were the most dominant orders, with other groups being relatively poorly represented. The results obtained show that the physico-chemical quality of the water is slightly deteriorated, but the quality is still evaluated as 'good' according to the biotic indices

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IBMWP (Iberian Biological Monitoring Working Party) and IBGN (Standardised global biological index).

Keywords: surface waters, Algeria, macro-invertebrates, physico-chemical quality, IBMWP, IBGN.

Évaluation de la qualité physico-chimique et biologique des eaux de surface dans les régions arides et semi-arides d'Algérie (Afrique du Nord)

L'évaluation de la qualité physico-chimique et biologique des eaux superficielles par l'utilisation des macroinvertébrés comme bio-indicateur est menée dans deux cours d'eau de l'Algérie situés en région semi-aride et aride. Il s'agit de l'oued M'zi (région de Laghouat) et de l'oued Djedir (région de Djelfa). La stratégie d'échantillonnage développée dans ce travail repose sur l'analyse des eaux en amont et en aval de chaque cours d'eau. Onze paramètres physico-chimiques (T°C, pH, CE, OD, Cl^-, SO_4^{2-}, NO_3^-, Salinité, Ca^{2+}, Mg^{2+} and HCO_3^-) ont été mesurés afin d'établir un diagnostique de l'état de santé de ces écosystèmes aquatiques. Les macroinvertébrés ont été étudiés à partir de prélèvements réalisés à l'aide d'un filet troubleau au niveau de huit stations d'étude. L'inventaire faunistique des macroinvertébrés benthiques a permis de recenser 37 familles, représentées essentiellement par les larves d'insectes avec un pourcentage de 96 %. Parmi ces insectes, les Diptères et les Éphéméroptères sont les ordres les plus dominants par rapport aux autres groupes qui sont faiblement représentés. Les résultats obtenus montrent que la qualité physico-chimique des eaux est légèrement détériorée, tandis que la qualité biologique évaluée par les deux indices biotiques IBMWP « Iberian Biological Monitoring Working Party » et IBGN « Indice biologique global normalisé » révèle une bonne qualité de l'eau.

Mots-clés : eaux superficielles, Algérie, macro-invertébrés, qualité physico-chimique, IBMWP, IBGN.

Introduction

Rivers are among the most complex and dynamic ecosystems (DYNESIUS & NILSSON, 1994). They play an essential role in biodiversity conservation, in the functioning of organisms and in the organic matter cycle. Water systems around the world have been more or less modified by human activities (EVERARD & POWELL, 2002). Human influences on aquatic biocoenoses are very diverse. Habitat degradation and fragmentation can cause serious problems for aquatic populations. In Algeria, the impact of pollution in arid and semi-arid rivers can potentially be greater than in wetter regions of the country, due to aridity. In addition, water scarcity in these areas and low local precipitation affect hydrological cycles, which could pose a potential threat to the functioning of aquatic ecosystems (SELLAM *et al.*, 2017).

Studies of the benthic fauna and its ecology are of paramount importance in assessing the ecological health of hydrosystems. In such aquatic environments, the use of biological variables has gradually become established as a means of assessing the quality of water and aquatic systems, since they present a certain number of

advantages and complementarities in relation to physico-chemical variables (BEBBA, 2016).

Macroinvertebrates are responsive to environmental conditions and are commonly used as indicators of environmental disturbance (WARWICK & CLARKE, 1993). These organisms provide useful measures of the condition of aquatic resources (ARCHAIMBAULT, 2003) because they exhibit a wide geographical distribution, high biological diversity, sedentariness within their habitat, their ability to integrate variations in environmental conditions and their sensitivity to disturbances. Therefore, benthic macroinvertebrates are the pragmatic choice for assessing aquatic condition and where there are impairments they may also facilitate eco-diagnosis (CARTER *et al.*, 2007; NORTON *et al.*, 2015; USEPA, 2010).

Traditional water quality assessment methods, based on the determination of chemical and physical variables, have proven less satisfactory, because of the variability of the measurements and because they only provide a partial picture of the problem. Consequently, alternate approaches have been developed on the basis of the presence of particular species, and by grouping different taxonomic bio-indicator units in rivers or, conversely, with varying degrees of water pollution (GENIN *et al.*, 2003).

Many authors have studied the application of biotic indices and their adaptations (ZAMORA MUÑOZ et al., 1995; ALBA TERCEDOR & SANCHEZ ORTEGA, 1988; SOLIMINI *et al.*, 2000; BEISEL *et al.*, 2000; USSEGLIO-POLATERA & BEISEL, 2003). The objective of our study was to evaluate the quality of surface waters in arid and semi-arid zones in Algeria, using physico-chemical methods, and to compare the biological indices IBGN (Standardised global biological index) and IBMWP (Iberian Biological Monitoring Working Party), as well as to test their adaptability to Algerian watercourses.

Material and methods

Study areas

The study was carried out on two Wadis located in the southern region of Algeria :

– *Wadi Djedir (Djelfa)* – Wadi Djedir is a tributary of the left bank of the Mellah Wadi. It is located in the Wilaya of Djelfa, 36 km south-west of Hassi Bahbah, and about 20 km north-west of the town of Djelfa. It runs to the west of the Senelba Forest over a length of 30 km, at an altitude of about 1085 m above sea level. The wadi is located in the cold semi-arid bioclimatic region, with an annual rainfall of 335 mm and an average temperature of 14°C. The watershed of the Djedir Wadi is relatively small, s not exceeding 150 km^2. Its geographical position is 34º 34’ N and 2º 50’ E (ANRH, 2014) (Fig. 1 and 2) ;

– *Wadi M’zi* (Laghouat) – The Wadi M’zi watershed covers an area of 1618 km^2. Its upstream hydrographic network is mainly composed of the wadis M’said and upper

M'zi, which originate in the heart of Djebel Amour of the central Saharan Atlas, at an altitude of 1536 m. The confluence of the M'said and upper M'zi form the lower Wadi M'zi at the outlet of the sector of El Fetha. The wadi is located in the arid bio-climatic region, with an annual rainfall of 178 mm and an average temperature of 21°C. The Wadi M'zi feeds Wadi Djeddi and the latter flows into a terminal saline lake, Chott Melghig. The geographical position is 33° 49' N and 2° 52' E (ANRH, 2014) (Fig. 1 and 3). The general characteristics of the two wadis are summarized in Table 1.

Physical and chemical water quality

Water temperature, electrical conductivity, pH, dissolved oxygen and salinity were measured in situ, whereas other parameters were measured in the laboratory within 24 hours of sampling (Table 2).

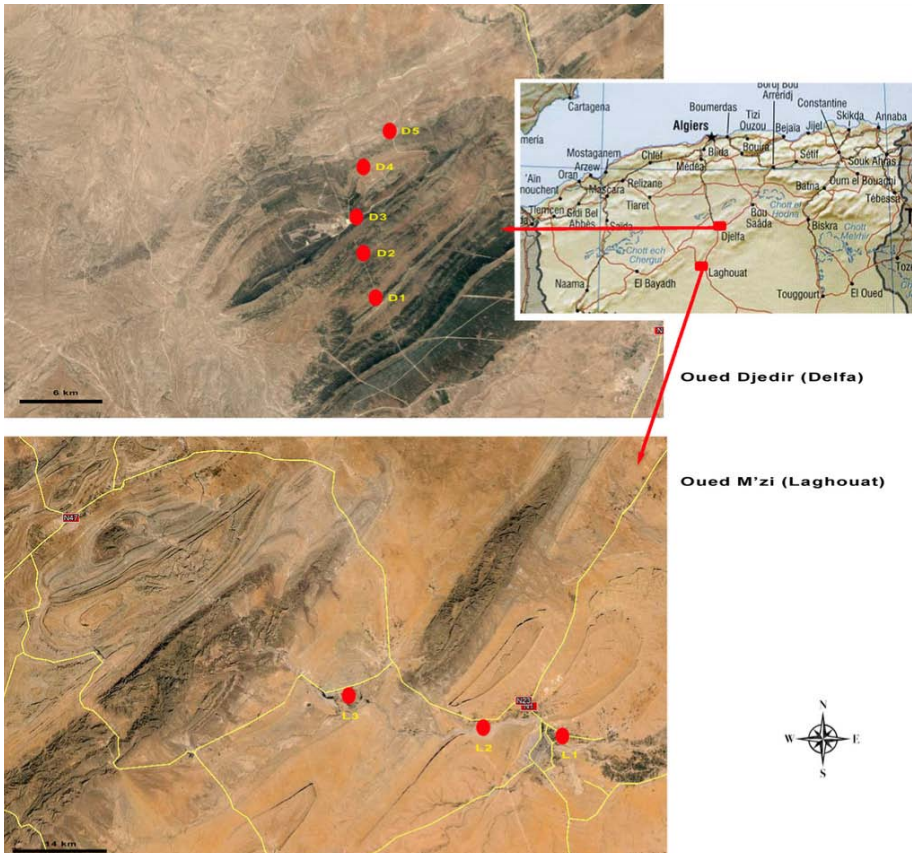

Figure 1

Map of Algeria and location of the two regions studied, showing locations of sampling sites.
Carte de l'Algérie et localisation des deux régions étudiées avec l'indication des sites d'échantillonnage.

Tableau 1

Environmental characteristics of the Wadis studied.
Caractéristiques environnementales des oueds étudiés.

Wadis	**Wadi Djedir (Djelfa)**					**Wadi M'zi (Laghouat)**		
Site	**D1**	**D2**	**D3**	**D4**	**D5**	**L1**	**L2**	**L3**
Altitude (m)	1082	1070	1096	1115	1078	875	1040	1035
Riverbed width (m)	1.5 to 2.5	2.5 to 3	2.5 to 3	1.5 to 2	2 to 3	25 to 30	25 to 30	15 to 20
Catchment Slope (%)	4.30	4.16	3.9	3.29	3.49	1.5	1.90	2.30
Water depth (cm)	60 to 70	20 to 45	45 to 60	100 to 140	50 to 85	10 to 40	15 to 45	12 to 21
Water current (m/s)	0.56	0.23	0.45	0.37	0.60	0.29	0.47	0.38
Sediment substrate	Blocks, limes	Blocks, gravel, sand limes	Sand, limes	Sand, limes blocks	Sand, limes, blocks	Sand clay	Sand stone	Sand stone

Figure 2

Sampling sites at Wadi Djedir (Djelfa).
Sites d'échantillonnages de l'oued Djedir (Djelfa).

Tableau 2

Analytical methods for physico-chemical parameters.
Méthodes d'analyse des paramètres physico-chimiques.

Temperature	**°C**	Measured *in situ* with a Consort C5020 multi-parameter analyzer
Hydrogen potential		
Dissolved oxygen	mg/L	
Conductivity	µS/cm	
Salinity	‰	
Nitrates	mg/L	Spectrophotometric determination with Sodium Salicylate, Sulfuric Acid and Sodium Hydroxide, and Sodium Potassium Tartrate Double Reagent Solution
Calcium	mg/L	Determination by molar titration method with Sodium Hydroxide, EDTA and Murexide reagent
Magnesium	mg/L	Determination by molar titration method with Ammonium Hydroxide, EDTA and Eriochrome black reagent
Chlorides	mg/L	Determination by volumetric method with Silver Nitrate and K_2CrO_4 reagents
Bicarbonates	mg/L	Determination by hydrochloric acid reagent titration method
Sulfates	mg/L	Gravimetric determination with concentrated acetic acid and barium chloride reagent

Tableau 3

Sampling dates.
Plan d'échantillonnage.

Wadis	**D1**	**D2**	**D3**	**D4**	**D5**	**L1**	**L2**	**L3**
Wadi Djedir (Djelfa)	10/03/2013	10/03/2013	12/03/2013	12/03/2013	12/03/2013			
	18/04/2013	18/04/2013	21/04/2013	21/04/2013	21/04/2013			
	22/05/2013	22/05/2013	25/05/2013	25/05/2013	25/05/2013			
Wadi M'zi (Laghouat)						18/03/2013	19/03/2013	19/03/2013
						23/04/2013	24/04/2013	24/04/2013
						27/05/2013	28/05/2013	28/05/2013

Choice of sampling period and intensity

Sampling was carried out three times during the spring season (March-April-May) in 2013, with six samples taken for each station. This period was selected because it is more favourable for collecting macro-invertebrates, according to the hydrological regime of the Wadis. Table 3 shows the sampling frequency and dates for each station.

Sampling and identification of macroinvertebrates

Macroinvertebrate sampling survey was carrying out at eight sites evenly distributed in the Wadi Djedir (5 sites: D1-D5), and M'zi (3 sites: L1-L3). The samples

were taken using a kick-net sampler (net area of 0.05 m^2, 275-µm mesh size). The procedure consisted of wading back and forth over the selected area and disturbing the substrate while passing the net over the disturbed area for one meter. The collected samples were immediately put in plastic bags and fixed in 10% formaldehyde. In the laboratory, the specimens were rinsed and then preserved in 70% alcohol. All specimens were identified under a Zeiss Discovery V8 stereomicroscope. Taxonomic identifications of specimens were based on TACHET *et al.* (2003) and other documents such as ARCHAIMBAULT (2007), MERRITT *et al.* (2008) and MOISAN & PELLETIER (2008, 2011). In order to include all sampled families and identify as many specimens as possible to genus or species, additional sources were used (NILSSON, 2003; MAZZOLDI, 2003; VONDEL, 2010; EL ALAMI, 2002).

Biological water quality

Among the indices available to assess water quality, we compared two, the IBMWP index and the IBGN index, which were developed for rivers with a Mediterranean climate :

• *IBMWP index* (Iberian Biological Monitoring Working Party) – For the evaluation of specimens as bio-indicators of water quality in the wadis studied, we used a methodology based on the tolerance or intolerance of macroinvertebrates to pollution (PRAT *et al.*, 2009). The Iberian Biological Monitoring Working Party (IBMWP) index is mainly used in Spain. It consists of a modification of the original method (BMWP), with changes that include the addition of new families (ALBA-TERCEDOR & SÁNCHEZ-ORTEGA, 1988; ALBA-TERCEDOR *et al.*, 2002). It is a qualitative method that assigns scores between 1 and 10 to families of macroinvertebrates, grouped according to tolerance to pollution, such that the most tolerant organisms have the lowest score. The total score of a site is obtained by adding the scores assigned to different indicator taxa. Table 4 gives the water quality categories of the IBMWP index.

• *IBGN (Standardized Overall Biological Index)* – The IBGN is based on benthic macroinvertebrate communities analysis (AFNOR, 2004). The record used contains 138 taxa (usually families, sometimes order or class). Among these, 38 constitute indicator groups numbered from 1 to 9, in order of sensitivity to increasing

Figure 3

Sampling sites at Wadi M'zi (Laghouat).
Sites d'échantillonnages de l'oued M'zi (Laghouat).

pollution. The index is based on taxonomic richness and indicator faunal groups (reflecting sensitivity to organic pollution) (Table 5).

Tableau 4

Water quality according to the IBMWP index (Iberian Biological Monitoring Working Party).
Qualité de l'eau en fonction de l'indice IBMWP.

Class	Water quality	Score
I	Very good	>81
II	Good	50-80
III	Moderate	29-49
IV	Deficient	12-28
V	Bad	<12

Tableau 5

Evaluation of water quality according to IBGN (Standardized Overall Biological Index) (AFNOR 1992).
Évaluation de la qualité de l'eau selon l'IBGN (Indice biologique global normalisé) (AFNOR, 1992).

IBGN	**>out = to 17**	**13-16**	**9-12**	**5-8**	**4**
Class quality	1A	1B	2	3	HC*
Matching colour	Blue	Green	Yellow	Orange	Red
Hydrobiological quality	Very good	Good	Medium	Poor	Bad

Tableau 6

Average values of physico-chemical measures in the different sampling sites.
Valeurs moyennes des paramètres physico-chimiques mesurés dans les différentes stations d'études.

	Wadi Djefir (Djelfa)					**Wadi M'zi (Laghouat)**		
Parameters	**D1**	**D2**	**D3**	**D4**	**D5**	**L1**	**L2**	**L3**
T (°C)	20.93	21.1	21.4	21.5	21.83	19.5	20.33	21.5
pH	7.1	7.53	6.93	7.43	7.6	7.6	7	7.4
CE (mS/cm)	3884	3880	3721	3796	3934	2268	2134	1811
OD (mg/L)	6.83	8.56	7.93	9.83	8.73	4.51	4	5.32
Salinity (‰)	1.98	1.96	1.87	1.95	2.05	1.13	1.08	0.91
Ca^{2+} (mg/L)	503.66	552	610.75	473	595.61	245	187.7	174.67
Mg^{2+} (mg/L)	71.63	54.5	52.5	43	45.66	23.10	126.09	49.73
Cl^{-} (mg/L)	562	575	519	583.23	627.23	307.23	283.6	185.11
NO_3^{-} (mg/L)	66.83	55	51.23	62	52.4	3.46	8.45	12
SO_4^{-} (mg/L)	114.8	127.5	152.5	93.5	93.11	148.67	273	243.77
HCO_3^{-} (mg/L)	311.66	368	388.66	297.43	273	378.14	304.77	212.73

Results

Physico-chemical analysis

The variations in the physico-chemical parameters studied are shown in Table 6.

• Temperature and pH

The average temperature values of each wadi did not vary greatly from one site to another. The average water temperature of the sites surveyed varied between 19.5°C (Station L1 at Wadi M'zi) and 21.83°C (station D5 at Wadi Djedir). In each wadi surveyed, the temperature values revealed a slightly increasing gradient from upstream to downstream. Fluctuations in this parameter are related to local climatic conditions and in particular to air temperature.

The mean pH values of Wadi M'zi and Wadi Djedir waters range from neutral to slightly alkaline (6.93-7.6), probably owing to the geological nature (marly limestone) of the river beds of the wadis (DUSSART, 1966) (Table 6).

• Conductivity and salinity

The waters of the Djedir Wadi are highly mineralized, with values exceeding 3000 µS/cm at all sites. Wadi M'zi waters at Laghouat show a mineralization ratio that varies between 1811 and 2268 µS/cm (Table 6).

• Dissolved oxygen

Dissolved oxygen values ranged between 6.83 and 9.83 mg/L in the Djedir Wadi, which indicates good oxygenation during the sampling period. However, near the town of Wadi M'zi, dissolved oxygen minima are > 5 mg/L (Table 6).

• Calcium and Magnesium

The calcium content of Djedir Wadi water was very high, ranging between 473 and 610.75 mg/L, while that of M'zi Wadi varied between 174.67 and 245 mg/L. The magnesium concentrations of the waters of the Djedir Wadi varied from one station to another. However, they were below 72 mg/L and above 43 mg/L, indicating that water flows through sedimentary magnesian rocks (Table 5). In Wadi M'zi, station L2 had higher magnesium levels, perhaps associated with reduced flow (BOUZIDI, 1983).

• Chlorides

Wadi Djedir had chloride concentrations that exceed the established standard (200 mg/L) (RODIER, 2009), with average values above 500 mg/L. These levels increased from upstream (562 mg/L) to downstream (627.23 mg/L). At Wadi M'zi, high values were observed at L1 (307.23 mg/L) and L2 (283.6 mg/L), whereas station L3 (185 mg/L) did not exceed the standard (RODIER, 2009) (Table 6).

Tableau 7

Taxonomic richness of benthic macroinvertebrates in the two wadis studied.
Richesse taxonomique des macro-invertébrés benthiques dans les deux Oueds étudiés.

Phylum	Class	Order	Family	Genus/species (Djelfa)	Wadi Djedir (Laghouat)	Wadi M'zi
Annelida	Oligochaeta	Clitellata	Tubificidae			*
	Hirudinea	Arhynchobdellida	Hirudinidae	*Hirudo*	*	*
		Rhynchobdellida	Glossosomatidae	*Glossosoma*	*	
Nemathelminths	Nematoda		Nematode			*
Mollusca	Gastropoda	Basomatophora	Planorbidae	*Planorbis*	*	*
			Physidae	*Physa*	*	
			Lymnaeidae	*Radix*	*	
Arthropoda	Crustacea	Harpacticoida				*
		Copipoda	Cyclopidae	*Cyclops*	*	*
		Ostracoda			*	*
	Arachnida	Hydracarina			*	
		Araneae			*	*
	Insecta	Ephemeroptera	Baetidae	*Baetis rhodani*	*	
				Baetis cf. nigrescens	*	
				Baetis nigrescens		*
			Caenidae	*Caenis luctuosa*	*	*
				Caenis sp.		*
		Odonata	Coenagrionidae	*Ischnura*	*	
			Libellulidae	*Trithemis*	*	
			Platycnemididae	*Platycnemis*	*	
		Heteroptera	Corixidae	*Corixa*		*
			Notonectidae	*Notonecta maculata*	*	*
			Nepidae	*Nepa*	*	
			Hydrometridae	*Hydrometra*	*	
		Coleoptera	Dryopidae	*Dryops*	*	

Arthropoda (suite)	Insecta (suite)	Coleoptera (suite)	Hydrophilidae	*Coelostoma*	*	
				Helochares	*	
				Helophorus	*	
				Laccobius	*	*
				Hydrochus	*	
			Dytiscidae	*Deronectes*	*	*
				Hydaticus	*	
				Hydroglyphus		*
				Hydrovatus		*
				Laccophilus	*	*
				Nebrioporus	*	*
				Yola		*
			Elmidae	*Oulimnius*	*	*
			Heteroceridae	*Augyles*		*
				Heterocerus		*
			Gyrinidae	*Gyrinus*	*	*
			Haliplidae	*Haliplus*	*	
			Hydraenidae	*Ochthebius*	*	*
			Chrysomelidae	*Chaetocnema*	*	
		Diptera	Chironomidae		*	*
			Limoniidae		*	*
			Tabanidae	*Tabanis sp.*	*	*
			Cératopogonidae		*	*
			Simuliidae	*Simulium*	*	*
			Dixidae			*
			Thaumaliedae			*
			Tipulidae			*
			Empididae			*
			Ephydridae			*
		Trichoptera	Hydroptilidae	*Hydroptila*	*	
4	**7**	**16**	**37**			

• ***Nitrates***

The average nitrate concentrations measured at Wadi M'zi (Laghouat) varied between 3.46 and 12 mg/L, within the limits (1-15 mg/L) suggested by NISBET & VERNEAUX (1970). Those of Wadi Djedir (Djelfa) oscillated between 51.23 and 67 mg/L. The nitrate concentrations of the Wadi M'zi and Wadi Djedir were lower than the level suggested by international standards (50 mg/L) (Table 6).

• ***Sulfates***

Average sulfate ion concentrations in the waters of Wadi Djedir increased from D1 (114 mg/L) to D3 (152.5 mg/L) and then decreased from D3 to D5 (93.11 mg/L). The concentrations of sulfate ions in the waters of Wadi M'zi showed values between 148.67 and 273 mg/L. According to the recommended standard of NISBET & VERNEAUX (1970), the waters downstream of station L2 at Wadi M'zi have sulfate contents that include the last class (class 7: SO_4^{2-} > 250 mg/L), corresponding to very seleniteous or highly polluted waters (Table 6).

• ***Bicarbonates***

In natural environments, the alkalinity expressed as HCO_3 varies from 10 to 35 mg/L (RODIER, 2009). All average bicarbonate concentrations in our study sites were above 200 mg/L. The highest values were observed at sites D2 and D3 of Wadi Djedir, respectively with 368 and 388.66 mg/L, and at L1 of Wadi M'zi, with 378.14 mg/L. The waters of Wadi Djedir acquire this alkalinity in crossing the marly limestone substrate and, moreover, the heavy winter rains induce ground leaching that could be responsible for the increase in the bicarbonate content (Table 6).

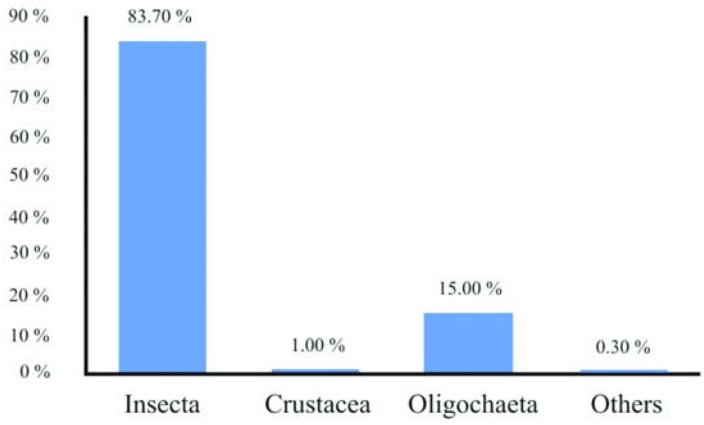

Figure 4

Benthic invertebrate classes in Wadi M'zi (Laghouat).
Classes d'invertébrés benthiques dans l'oued M'zi (Laghouat).

Biological analysis results (macroinvertebrate communities)

• ***Faunistic list of the collected taxa***

The faunistic list consists of seven classes of invertebrates, represented by 16 orders and 37 families. The analysis of the collected samples showed that the insects are the most numerous and present the highest percentile at Wadi Djedir with 96% and Wadi M'zi with 84% (Figures 4-5). The taxonomic composition of the benthic macroinvertebrates is presented in Table 7.

• ***Quantitative abundance of macroinvertebrate groups in Wadi Djedir (Djelfa)***

The eleven orders found in the Djedir Wadi in the Djelfa region are represented by 32 families. The macroinvertebrate community in this region is dominated by the Caenidae (Ephemeroptera) with 43.99%, followed by Chironomidae (Diptera) with 20.21%, Notonectidae (Heteroptera) with 14.37% and Coenagrionidae (Odonata) with 5.59% (Figure 6).

Concerning diversity, among the 32 families surveyed, 96% represent insects and 4% other taxa. Of the 24 insect families, 5 are dipteran, 10 are coleopteran, two of them ephemeropteran, one trichopteran and finally three to odonates and heteropterans.

Thirty-two families of benthic macroinvertebrates and 38 genera have been identified from 5984 individuals collected from 5 sites in Djedir Wadi, of which more than 32% of the fauna is recorded in the first station in Djedir Wadi (D1), followed by the second station (D2) with 23.22%. Indeed, the sites downstream of this Oued (D3, D4, D5) are moderately represented, with 15.89%, 15.26% and 13.61%, respectively (Figure 8).

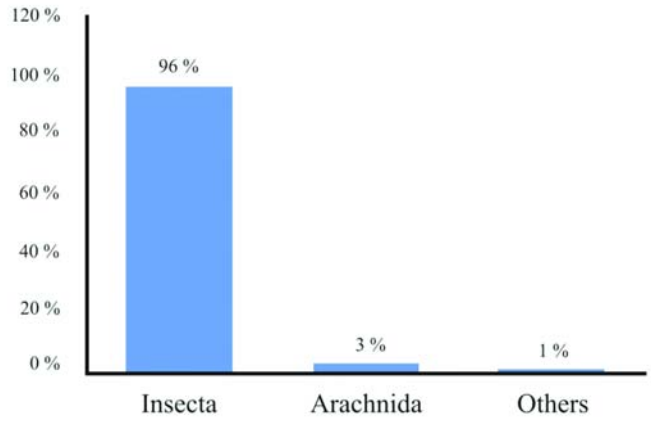

Figure 5

Benthic invertebrate classes in Wadi Djedir (Djelfa).
Classes d'invertébrés benthiques dans l'oued Djedir (Djelfa).

• ***Quantitative abundance of macroinvertebrate groups in wadi M'zi (Laghouat)***

The ten orders listed for the M'zi Wadi are represented by 28 families. The Chironomidae (Diptera) dominate the macroinvertebrate community with 49.84%, followed by Limoniidae (Diptera) with 26.21% and finally Tubificidae (Oligochaetes) with 15.39%. In terms of richness, of the 28 families surveyed, 83.7% are insects and 16.3% the other taxa. Of the 20 families of insects, ten families belong to Diptera, two to Ephemeroptera, two to Heteroptera and six to Coleoptera (Figure 7).

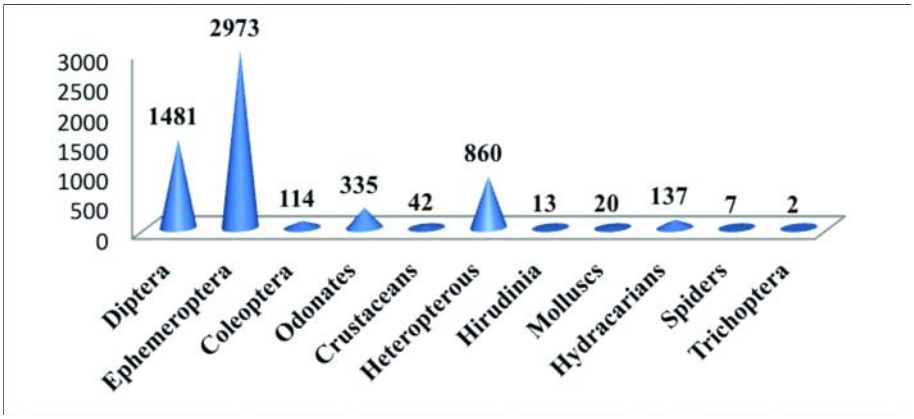

Figure 6

Abundance of benthic fauna in the Djedir Wadi.
Abondance de la faune benthique dans l'oued Djedir.

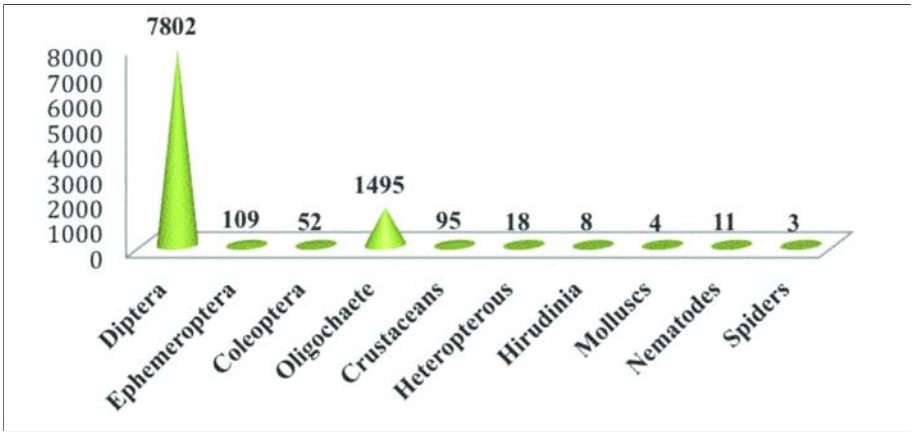

Figure 7

Abundance of benthic fauna in the M'zi Wadi.
Abondance de la faune benthique dans l'oued M'zi.

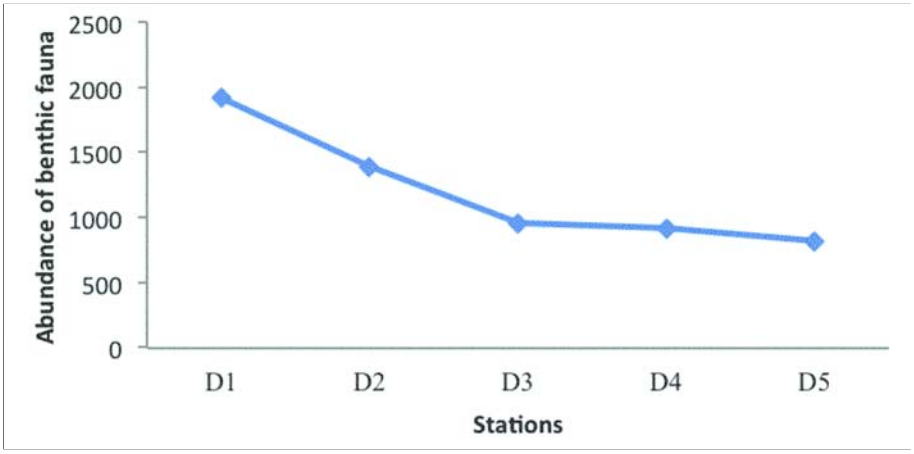

Figure 8

Abundance of macroinvertebrates in the waters of the Djedir Wadi.
Abondance des macroinvertébrés dans les eaux de l'oued Djedir.

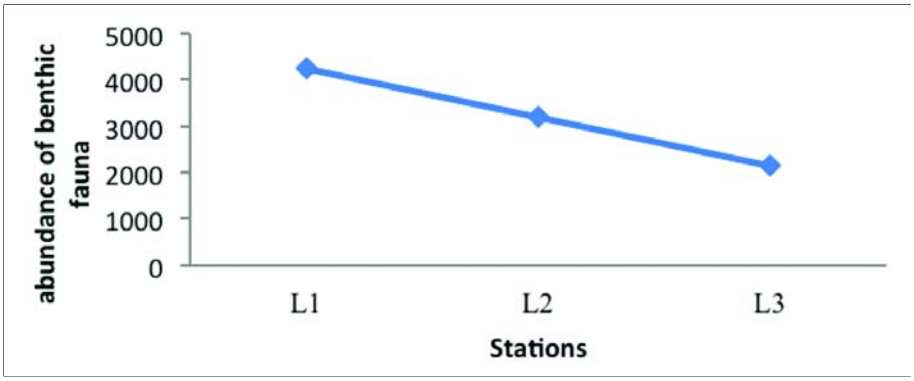

Figure 9

Abundance of macroinvertebrates in the waters of the Wadi M'zi.
Abondance des macroinvertébrés dans les eaux de l'oued M'zi.

A total of 9597 individuals were inventoried in Wadi M'zi, these mainly belong to 28 families and 32 genera. Site L1, downstream of the city of Laghouat, represented more than 44.35% of the abundance of the benthic fauna in this Wadi, followed by sites L2 and then L3, with 33.31% and 22.32% respectively (Figure 9).

Water quality indexes

• *IBMWP index*

Based to the values obtained, we found that the quality of the water is very good in Wadi Djedir, falling into category 1 (IBMWP = 115), whereas in Wadi M'zi

Tableau 8

Évaluation of the quality of the water of the two wadis studied with IBMWP index.
Valorisation de la qualité de l'eau des deux oueds étudiés avec l'indice IBMWP.

Families	Wadi Djedir	Wadi M'zi
Libellulidae	8	/
Platycnemididae	6	/
Hydroptilidae	6	/
Dryopidae	6	/
Elmidae	5	5
Hydraenidae	5	5
Hydrochidae	5	/
Haliplidae	4	4
Chrysomelidae	4	/
Hydrophilidae	3	3
Dytiscidae	3	3
Gyrinidae	3	3
Tipulidae	5	
Simuliidae	5	5
Tabanidae	4	4
Limoniidae	4	4
Dixidae	/	4
Empididae	/	4
Ceratopogonidae	4	
Chironomidae	2	2
Ephydridae	/	2
Thaumaleidae	/	2
Baetidae	4	4
Caenidae	4	4
Hydracarina	4	/
Notonectidae	3	3
Nepidae	3	/
Corixidae	/	3
Hydrometridae	3	/
Physidae	3	/
Planorbidae	3	3
Lymnaeidae	3	/
Hirudinidae	3	3
Ostracoda	3	3
Oligochaeta	/	1
IBMWP index value	**115**	**79**
Category	**I**	**II**
Grade	**Very good**	**Good**

Tableau 9

Évaluation of the quality of the water of the two wadis with IBGN index.
Valorisation de la qualité de l'eau de deux oueds étudiés avec l'indice IBGN.

IBGN	Wadi Djedir (Djelfa)	Wadi M'zi (Laghouat)
Diversity	32	28
Indicator group	5	2
IBGN Value	13	9
Class quality	1B	2
Hydrobiological quality	Good	Medium

the hydrobiological quality is good (IBMWP = 79), it is worth mentioning that the evaluation of our rivers was carried out using the IBMWP index for the temporary water flows (see Table 8).

• IGBN index (standard global biological index)

Based on taxonomic diversity and the presence or absence of indicator taxa, we assigned to each wadi a score for the hydrobiological quality ranging from 1 to 20. For Wadi Djedir we obtained a good hydrobiological quality (IBGN = 13, class 1B), with an important faunistic diversity (32 taxa) and a group index of 5 (pollution sensitive taxon: Hydroptilidae), whereas for Wadi M'zi we obtained a medium hydrobiological quality (28 taxa and group index of 2) (see Table 9).

Discussion

Physico-chemical analysis

Water conductivity gives a good indication of the concentrations of dissolved ionised minerals present in water (DERWICH *et al.*, 2010). The high values of this parameter in our wadis can be explained by the high salinity levels at Wadi Djedir (between 1.87 and 2.05‰) and Wadi M'zi (0.91 to 1.13‰). According to RODIER *et al.* (2005), high conductivity reflects either uncommon pH or high salinity. The soils through which our rivers flow are mostly humiferous and calcareous limestone at the ends of the wadis. Soil leaching, which results in the dissolution of mineral salts from calcium- and magnesium-rich soils, appears to be the cause of the increased conductivity.

The sampling period coincided with the spring winds that characterize the region of Djelfa. The high wind speeds at this time generate a continuous mixing of the water mass and consequently an enrichment of the dissolved oxygen phase during the spring season (MAKHOUKH *et al.*, 2011; BEN MOUSSA *et al.*, 2012). At Wadi M'zi, the low values of oxygen could be explained by the beginning of warming of the water and the low flow of the wadi, which causes a decrease in dissolved oxygen, aggravated by an increase in oxygen consumption by living organisms.

Calcium and magnesium are elements responsible for the hardness of water and their levels essentially vary according to the nature of the terrain crossed (NISBET & VERNAUX, 1970). The high values of these elements in the present study are mainly due to the geological nature of the terrain crossed by the two wadis (Djedir and M'zi).

Chlorides are widespread in nature as NaCl, KCl or $CaCl_2$. Water almost always contains chlorides, but in very variable proportions (REJSEK, 2002). They are often used as a pollution index. They have an influence on the aquatic fauna and flora, including plant growth. The elevated values recorded in our wadis are due to organic waste from pasture animals (mainly sheep); the sites of Wadi Djedir show a high concentration of chloride ions, caused by the geological nature of the ground crossed, as well to construction work on a dam in this area that started during the year of study. Sites L1 and L2, located respectively downstream of Laghouat and Tadjmout, showed high chloride levels, indicating a possible anthropogenic input of urban origin (wastewater discharges, organic waste from livestock, etc.).

Nitrate pollution can be estimated by the levels of nitrate and ammonium ions. Nitrate ions (NO_3-) represent the most soluble form of nitrogen; its presence in surface waters is linked to the intensive use of fertilizer products (REGGAM *et al.*, 2015). The Djedir Wadi sites are liable to be polluted by nitrates from the agricultural land bordering the Senalba Forest (runoff of phosphate fertilizers and agricultural effluents).

The concentration of sulfate ions in unpolluted waters is highly variable, reaching up to 300 mg/L in gypsum containing zones, especially when the contact time with the rock is high (RODIER, 2009). In addition to the geological nature of Laghouat, the results obtained for sulfate could be related to the discharge of domestic wastewater from the village of Tadjmout, which the wadi bed directly receives without any treatment.

Biological analysis

The differences in the taxonomic richness of the two wadis are manifested by the total of 28 families for Oued M'zi, as opposed to 32 for Oued Djedir. This reflects the homogeneity of the M'zi Wadi environments; the biotope of the M'zi Wadi does not provide macroinvertebrates as much refuge from predators: the more uniform the habitat, the fewer are the number of ecological niches, resulting in a lower number of taxa. Only a few taxa adapted to this type of standardized environment can proliferate (worms, chironomid Diptera) (HAOUCHINE, 2011). In terms of global abundance, analysis of spatial distribution shows a wide variation in the numbers and relative abundances of harvested taxa. A total of 9597 individuals were collected in the Oued M'zi, against 5984 individuals in the Oued Djedir level. Thus the fine substrate type of Oued M'zi could have a significant influence on the abundance of macroinvertebrates.

The faunistic richness of the water courses of the semi-arid and arid regions is relatively lower compared to those observed in other water flows in the Kabylia

regions. For instance, whereas a total of 88 families were listed by LOUNACI in 2005, only 55 families were inventoried by ZOUGGAGHE (2010) in Soummam region.

The low diversity of the studied water flows can be explained by the semi-arid and arid climate, the low amount of precipitation and the high temperatures (maxima between 34°C and 44°C), which lead to longer drought periods, which have a negative impact on the biological diversity, which therefore tends to be poor.

Temporary water course often host fewer species than the permanent one (BONADA, 2003; DEL ROSARIO & RESH, 2000). Long drought periods are an important factor in the biological diversity of these water flows, as has been observed for the temporary water flows of all the regions around the world with a Mediterranean climate, such as California, the Mediterranean basin, Chile, South Africa and Australia (BONADA, 2003).

The IBMWP allows the evaluation of the general quality of a water flow based upon a system of scoring the macroinvertebrates. It does not require counting the number of the collected individuals or identification of the species, requiring only a list of the collected families. This index therefore seems to be more suitable for the wadis in our arid and semi-arid regions, which does not harbour the most pollution sensitive taxa, such as Plecoptera. However, the IBGN index can change depending on different habitat samples. In our case, the study sites in Wadi M'zi show a homogeneity that provides a standardised substrate (sand and some stones).

According to the variability of the taxonomic richness, we can consider the integration of the value of the taxonomic richness as an advantage, so we relate the efficiency of the IBGN score to the different habitat samples and to the variability of the taxonomic richness (BEISEL *et al.*, 1998). Hence, the more uniform the habitat is, the lower will be the index of ecological richness, with a decrease in the number of taxa. Only a few taxa are adapted to this uniform environment, in which rapidly reproducing species manage to proliferate (e.g. worms and dipteran Chironomidae).

Conclusion

The results of the physico-chemical analysis show that the rate of water flows during this study was slow to average, with high concentrations of dissolved minerals, such as salt content, reflected by and high electrical conductivity. To this are added high rates of magnesium, calcium, chloride, and selenite, is the latter being indicated by the high concentrations of sulfate.

The physico-chemical quality of the water flows studied seems generally normal. Although most of the concentrations of ions are higher than normal, this can be attributed to natural factors of the geological nature of the terrains crossed and the climatic conditions (aridity). Nevertheless the surface water of these small rivers present some signs of degradation, such as the high level of nitrates, which are a by product of the grazing activities typical of the regions of Djelfa and Laghouat in Algeria.

We also highlight a convergence between the results of the two biological indexes employed, although the IBMWP is the most convenient and convincing of them.

It should also be necessary to have a database of the fauna of our water flows with their requirements and ecological values in order to establish a list of the pollution sensible and pollution resistant taxa. This can help us in applying the biotic indexes specific to the conditions of the water courses in Algeria even more in North Africa.

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