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The variability influence of physicochemical parameters on macroinvertebrate assemblages in the Rhumel and Endja rivers, Algeria

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Abstract. *Kherief-Nacereddine S, Djeddi H, Nail-Yasmine B, Boukeria S, Benmakhlouf Z, Mehennaoui-Afri FZ. 2023. The variability influence of physicochemical parameters on macroinvertebrate assemblages in the Rhumel and Endja rivers, Algeria. Biodiversitas 24: 539-550.* Water resources are the most essential resource in the development of the various sectors of a country's economy. In Algeria, a country with a semi-arid climate, the supply of drinking and industrial water is mainly provided by surface water. Currently, the water supply for industrial uses is threatened by the problems of anthropogenic pollution (e.g., urban discharges, industrial and agricultural activities, etc.). The objective of this work is to assess the variability influence of water physicochemical parameters on macroinvertebrate communities in the Rhumel and Endja rivers in Algeria which supply the Beni Haroun. In each river, two observation stations were established located upstream and downstream, totaling four stations (Rhumel: (Rh1 and Rh2) and Endja: En 1 and En 2). Physicochemical parameters of water were measured, and biological parameters of benthic macroinvertebrate assemblages were calculated. The physicochemical approach put highlights the monthly changes in water quality along the two rivers in relation to urban, agricultural, and industrial discharges and as a response to seasonal variations in water level. The difference in taxonomic richness corresponded to environmental conditions of stations appearing more or less stable and highlighting a gradient of the stress on organisms. The results showed that there were 2071 individuals of macroinvertebrates recorded, belonging to 19 families and 10 orders. The individual number of this macrofauna consisted of 75.20% insects, 12.50% worms, and 12.30% mollusks, with the most abundant families across all stations being Chironomidae and Baetidae. The spatiotemporal variability of benthic macroinvertebrate assemblages in the two rivers indicated that summer recorded the highest abundance of all samples. The highest number of macroinvertebrate individuals was recorded at Rhumel stations. The elements indicating high pollution were SO_4, PO_4^- and NO_2^- with the highest values recorded during the summer season for the four stations. Higher pollution was observed at the Endja river. The findings of this study imply that the waters of two rivers are unsuitable for use even for irrigation purposes.

Keywords: Biodiversity, environmental variables, pollution, river, water quality

INTRODUCTION

The protection of human health has made it necessary to control pollution of the aquatic environment. The assessment of water quality and pollution of surface water resources is crucial to maintain the integrity of aquatic environments (Guemmaz et al. 2019). According to the United Nations (ONU), 40% of the world's population is now affected by a water shortage. Eighty percent of wastewater is discharged without environmental treatment, and more than 90% of disasters are water-linked. More than 2 billion people do not have access to drinking water, and more than 4.2 billion, or 55% of the world's population, do not have adequate sanitation services (Kherief Nacereddine 2019; Boneit and Gerard 2020; Alabaster et al. 2021). Surface water pollution is possible through both domestic and industrial wastewater discharges as well as from fertilizers and pesticides in agriculture. The pollution risk of an accentuated risk of water shortage imposes the need to protect this resource against alteration and irrational use. Currently, the quality of the river water is subject to heavy pollution exerted by the increase in population, discharges from industrial development, and agricultural and anthropogenic activities, including urban expansion (Belabed et al. 2017; Smatti-Hamza et al. 2019; Keddari et al. 2021). Pollution of aquatic ecosystems is currently one of the most worrying environmental problems of the century that many countries in the world are committed to solving as a challenge (Djeddi et al. 2018; Sahli et al. 2020).

Water quality assessment is an essential measure of environmental monitoring. When water quality is poor, it affects not only aquatic life but also surrounding ecosystems (Davies-Colley 2013; Barbosa-Vasconcelos et al. 2018). The physical, chemical, and biological qualities of water are factors that influence the species composition, diversity, productivity and physiological conditions of populations colonizing rivers. Most researchers recognize the use of macrobenthic invertebrates to assess the impacts of pollutants in aquatic environments (Sharma et al. 2013; O'Callaghan and Kelly-Quinn 2017). The macroinvertebrates are an important biological component of freshwater systems, and their composition in streams is influenced by water quality (Krisanti et al. 2017; Sor et al. 2017). The assemblages of macroinvertebrates link the transfer of matter and energy from producers to consumers and act as excellent bioindicators of stream health (Qazi et al. 2012; Adandedjan et al. 2013; Sanogo et al. 2014; Walag and Canencia 2016; Sanogo et al. 2021).

Macroinvertebrate assemblages also react in predictable ways to pollution. Generally, water bodies in good biological condition support a wide variety and a high number of macroinvertebrate taxa, many of which are intolerant of pollution. However, aquatic macroinvertebrates have the ability to adapt to different habitats. In fact, macroinvertebrates have different tolerance levels depending on the type of pollution, some of which are very sensitive to changes in water quality and can only survive in low-pollution streams with cool temperatures and highly oxygenated waters. Whereas other types of macroinvertebrates can resist even high concentrations of pollution (Linares et al. 2013; Purna et al. 2014; Agouridis et al. 2015; Tenkiano 2017).

Benthic macroinvertebrates have been the subject of a number of studies in Mediterranean regions concerning their diversity as a bioindicator of water quality (Renou et al. 2015; Balderas et al. 2016). In Algeria, different forms of disturbances (natural or anthropogenic) seriously affect benthic macro-invertebrates. The objective of the present study was to investigate the influence of agricultural, industrial, and anthropogenic environmental stresses (mainly caused by the discharge of sewage) on the diversity and abundance of macroinvertebrates in two rivers in the Kebir Rhumel Basin. The assessment is focused on the Rhumel and Endja wadis, which drain urban, industrial, and diffuse discharges and supply the Beni Haroun dam, the most important source of drinking, irrigation, and fishing water in Algeria. We investigated how the variability of physicochemical parameters affects the distribution, diversity, and density of benthic macroinvertebrates in different areas of two rivers. To achieve this objective, we analyzed the results of abiotic and biotic studies carried out upstream and downstream streams.

MATERIALS AND METHODS

Study area and sampling sites

The Kebir Rhumel basin, located in northeastern Algeria characterized by a sub-humid to the semi-arid Mediterranean climate, with two distinct seasons: a cold-wet winter with an average annual temperature of about 16.84°C and a hot and dry summer lasting four months. The average annual precipitation of about 666 mm; produces periodic changes in water chemistry by the effect of dilutions during rainy periods and by the effect of evaporation during dry periods. The study was carried out in the Rhumel and Endja rivers (Figure 1). Rhumel river receives some important tributaries, among others are the Dekri, Athmania, Seguen, Boumerzoug, Smendou and Ktone wadis. It is an important watercourse in eastern Algeria (Sahli et al. 2020) and receives the largest and most harmful industrial discharges located within a radius of 20 km around the Constantine province. These are discharges (partly treated) from the mechanical construction industries Hamimime wadi and Ain Smara as well as those generated by the textile and dairy product units of Constantine cement factory of Hamma Bouziane, the materials units of the building, etc. (Djeddi et al. 2018).

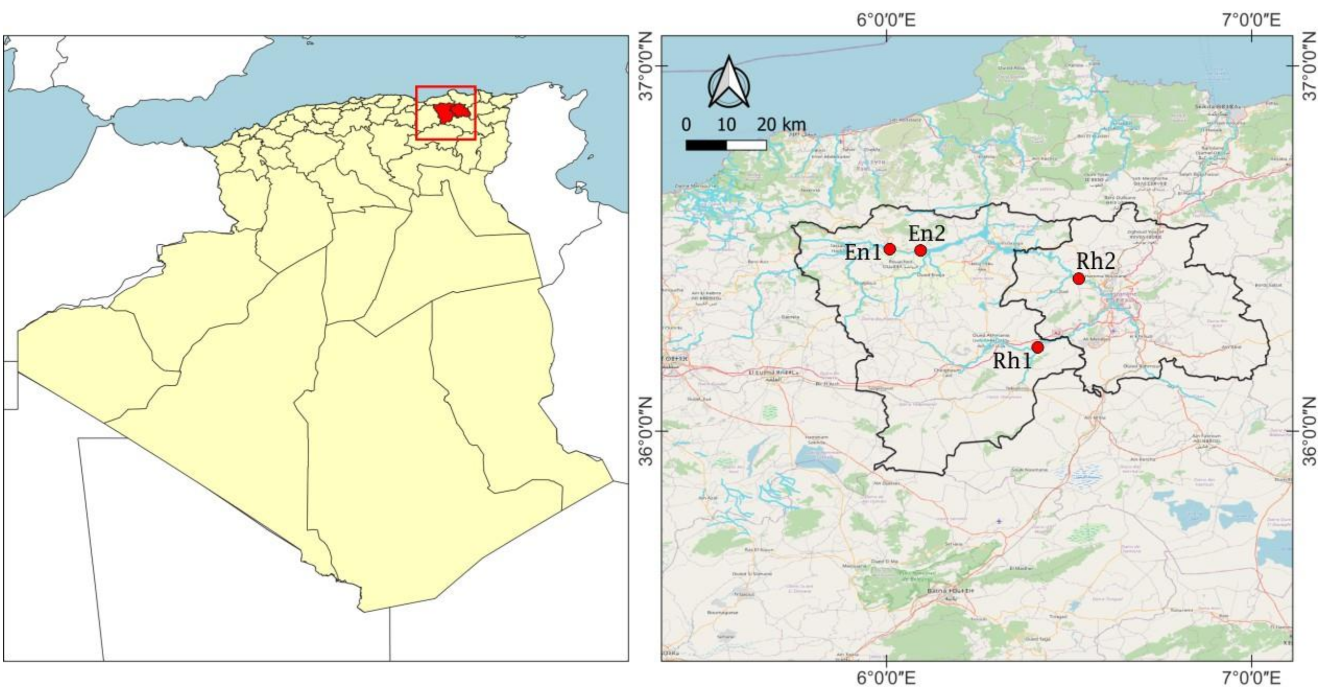

Figure 1. Study area and sampling sites in the Rhumel and Endja rivers, Algeria. Description of each sampling site is provided in Table 1

Table 1. Location and description of the sampling locations

Site code	Site name	Location	Description of the sampling location
Rh 1	Upstream Rhumel river	N : 36°21′20″ E : 6°40′78″ Al : 520 m	On the Rhumel River, upstream from the discharge points. It reflects the quality of the water before it reaches the urban areas of Ain Smara and Constantine.
Rh 2	Downstream Rhumel river	N : 36° 24' 33" E : 06° 33' 29" Al : 547 m	Downstream Rhumel river, located at the exit of the Constantine Province. The choice of this station is based on the effect of pollution caused by the releases of Constantine city.
En 1	Upstream Endja river	N : 36° 29’ 26.8" E : 06° 17’39.16" Al : 530 m	Located upstream the Endja river in the town of Tassala, Machtet Elberja. Upstream of points rejection. It reflects the water quality before it reaches urban areas Ferdjioua and Radjas in Mila Province
En 2	Downstream Endja river	N : 36° 49' 53" E : 06° 09' 11" Al : 532 m	Located in downstream of the Endja river at Taghlissa. This station makes it possible to evaluate the waters quality of Endja river before reaching the Beni Haroun dam.

Endja river is located in eastern of Algeria which occupies the western part of the large Kébir-Rhumel watershed crossing the Mila Province. It collects the waters of the Rarama (or Djemila) wadis as well as those of Bou Selah, Redjas, and El Melah. The industries located around the Ferjioua, Ain El Kebira, and Mila agglomerations also generate significant discharges into the Endja wadi. Moreover, the excessive use of fertilizers in this region accentuates the pollution and increases the risk of water contamination of this river feeding the Beni Haroun dam. In addition, these two wadis (Rhumel and Endja) are the main rivers supplying the largest freshwater reservoir (Beni dam of Haroun) in Algeria, whose water is used as the main source of drinking water supply, irrigation, and industrial activities for six major cities in the northeast of the country (Melghit et al. 2015; Keddari et al. 2021).

Data collection procedure

Physicochemical parameters of water

Water samples were collected monthly in four stations located upstream and downstream of two major rivers supplyıng the Beni Haroun dam, Rhumel (Rh1 and Rh2) and Endja (En1 and En2) (Figure 1) between January and December 2015 at a depth of 50 cm. The methodology for physicochemical analyses followed the JORA (2011), which is also applied worldwide. Water samples were taken in sterile polyethylene terephthalate bottles with 1000 mL capacity. Before collection, bottles were washed with dilute hydrochloric acid, rinsed with distilled water in the lab, and washed three times with the water at the site before filling the bottle with the water sample (Rodier et al. 2009). Water temperature, pH, dissolved oxygen (DO) and conductivity (EC) were measured in the field at each sample site using a portable digital meter WTW (Multi 3420 SET G). Magnesium (Mg^{+2}) and Calcium (Ca^{+2}) were analyzed by volumetric titration methods, Sodium (Na^{+}) and Potassium (K^{+}) were measured using the flame photometer, and Sulfate (SO_4^{+2}), Nitrite NO_2^{-}, Nitrate (NO_3^{-}) and Phosphates (PO_4^{-2}) were determined by spectrophotometric technique according to the methods described by (Rodier et al. 2009).

Macroinvertebrates sampling

The collection of macroinvertebrates was done on all the micro-habitats likely to shelter them (micro-biotopes) explored (aquatic plants, pebbles, mud, sunken roots of shrubs). The series of macroinvertebrate samples were carried out in two seasons, the summer and autumn of the year 2015. The sampling technique was carried out according to the standardized protocol XPT90-333 AFNOR (2009) entitled "Sampling of aquatic macroinvertebrates in shallow rivers". It consists of depositing the Surber net (1/20 m^2, 500 μm mesh size) by hand on the bottom of the sampling station with the opening of the net facing the current. The operator puts the sediment in suspension by the movement of the feet. It searches (stones, wood, plants, etc.) the substrate of the bottom and the banks dislodging the organisms which, carried away by the current, were then collected in the net. The purpose of the sampling was to bring together the greatest faunal diversity representative of the environment to be studied. Since net sampling was not always applicable to all habitats, it may have to be done by hand. In the field, coarse organic and mineral elements were then removed from the samples after being carefully washed and examined. Each sample was then fixed in the field with formaldehyde (final concentration of 4%) to be preserved. The actual sorting of organisms was done in the laboratory. The sample was washed with water on a column of sieves of different mesh sizes (2 mm, 1 mm, and 0.25 mm). The debris was discarded, and the organisms from each sieve were transferred to the sorting bins. The various organisms in each sieve were sorted on sight and classified according to taxonomic groups in pillboxes containing a solution of ethanol (40%) and then sorted in the laboratory. The taxonomical determination was carried out with a binocular magnifying glass 30 in normal light and, in certain cases requiring preparations with a microscope using identification keys (Leclercq and Solito de Solis 2010). All benthic macroinvertebrates were identified to the lowest feasible taxonomic level.

Ecological index

The biotic index makes it possible to give a quantitative expression of the community structure studied, as detailed below.

Taxon richness as the total number of taxa (S), it is the number of species or taxa (genus, family, etc.) present in each sample. This parameter provides information on the stability of the ecosystem (Dajoz 2006).

Abundance: Pi = ni / N, ni = individuals number of the species i, and N = total number of individuals

Shannon-Weiner diversity index: The Shannon diversity index (H') measures the degree and level of complexity of a stand. Its formula is as follows:

$$H' = -\sum_{i=1}^{S}(Pi * log2\ (Pi))$$

Where, i: a species from the study environment; Pi: proportion of a species i compared to the total number of species (S) in the study environment (or specific richness of the environment).

Pielou's Evenness index values Equitability index (E), which is the ratio of the real diversity to the maximum diversity, and was calculated by the formula:

$$E = \frac{H'}{(log2)S}$$

Biotic index (BI): the biotic index is based on the standard table of Tuffery and Verneaux (1978).

Statistical analysis

Statistical analyses were conducted using SPSS 19.0 software. Descriptive statistics (minimum and maximum value, mean, and standard deviation (SD)) were described for all water physicochemical parameters. A one-way analysis of variance (ANOVA) was used to test the variation of each physicochemical parameter between study sites and months. Pearson correlation tests were used to express relationships between different parameters of water. The Pearson correlation matrices obtained were plotted using IBM SPSS Statistics 19.0. The diversity of macroinvertebrates in different sites of two rivers was calculated using the Shannon-Weiner index (H'), the richness of taxa in the total number of taxa (S), the index biotic (IB). The relative abundance as a percentage of the total number of individuals belonging to a particular taxon was compared to the total number of individuals at different study sites. In order to find the correlation between macroinvertebrate diversity and different environmental variables, a partial correlation was performed using SPSS 19.0 to find a specific correlation between environmental factors and different diversity indices. The principal component analysis (PCA) was carried out on a data matrix made up of 08 samples (2 campaigns x 4 stations), during which 12 physicochemical water parameters and five biotic variables were measured with SPSS 19.0 software.

RESULTS AND DISCUSSION

Results

Spatio-temporal variation of water physicochemical parameters

Spatio-temporal variations of the physicochemical parameters at the surface level of study sampling locations in the monthly rivers monitored from January to December are summarized in Figure 2. The water temperature measured at the four study sites varied between 10 and 33.4°C, with the highest average (33.4) being recorded at the Endja river on the summer season. In fact, according to the classification of surface water quality by Masson (1999), 66.67% of the samples are below 22°C, which gives the water a normal to good quality for two rivers. The irregular temporal variation of the water pH was rather alkaline and ranged between 7 and 8.7. According to the biological aptitude grid to pH (SEQ-Eau 1999), the water is classified as good quality. Electrical conductivity (EC) varied between 994 and 2897 µS/cm recorded at En 2 (Table 2). The average EC contents varied between 1655 and 1887 µS/cm. According to the assessment grid of Masson (1999), the waters in our stations are of mediocre quality. The irregular spatial concentrations of dissolved oxygen obtained varied between 7.7 and 24.3 mg/L. The highest values are attributed to the downstream station of each river. According to the water quality grid of the ABH (1999), the water quality of two rivers is excellent. Sulfate concentrations varied between 135.5 and 681 mg/L, with the highest values recorded during the summer season marked by the existence of a distinct peak in August at En 2 station. The average values varied between 277 mg/L and 334 mg/L. Indeed, 27% of the samples exceed those of the indicative sulfate content (i.e., 400 mg/L) for surface waters. Calcium concentrations varied between 67 and 111 mg/L recorded at Rh1 (Figure 2). Magnesium ranged between 42 and 84 mg/L recorded at En2 and En1, respectively, implying that magnesium did not present any anomaly for the waters studied, at least during the year of our work. Sodium ranged between 73-142 mg/L. The levels determined are all below 200 mg/L. The standards used for sulfates, Calcium, and Magnesium are those recommended by Executive Decree No. 11-219 (JORA 2011). Therefore, sodium is not a problem. Average potassium levels oscillated between 8 mg/L at En2 station and 14 mg/L at En1, Rh1 and Rh2; in which 43.75% of the samples exceeded those of the indicative potassium content, 12 mg/L (Rodier et al. 2009).

The contents of phosphates and nitrite parameters varied between 9-10 mg/L and 3-4 mg/L, respectively. According to the guide by Algerian Guidelines, the values are well above 2 mg/L and classified in the class "Excess pollution". The nitrate concentrations in the river water ranged from 12 to 22.4 mg/L and were considered fair since they were lower than the threshold value (25 mg/L) indicated by Algerian Guidelines according of surface water.

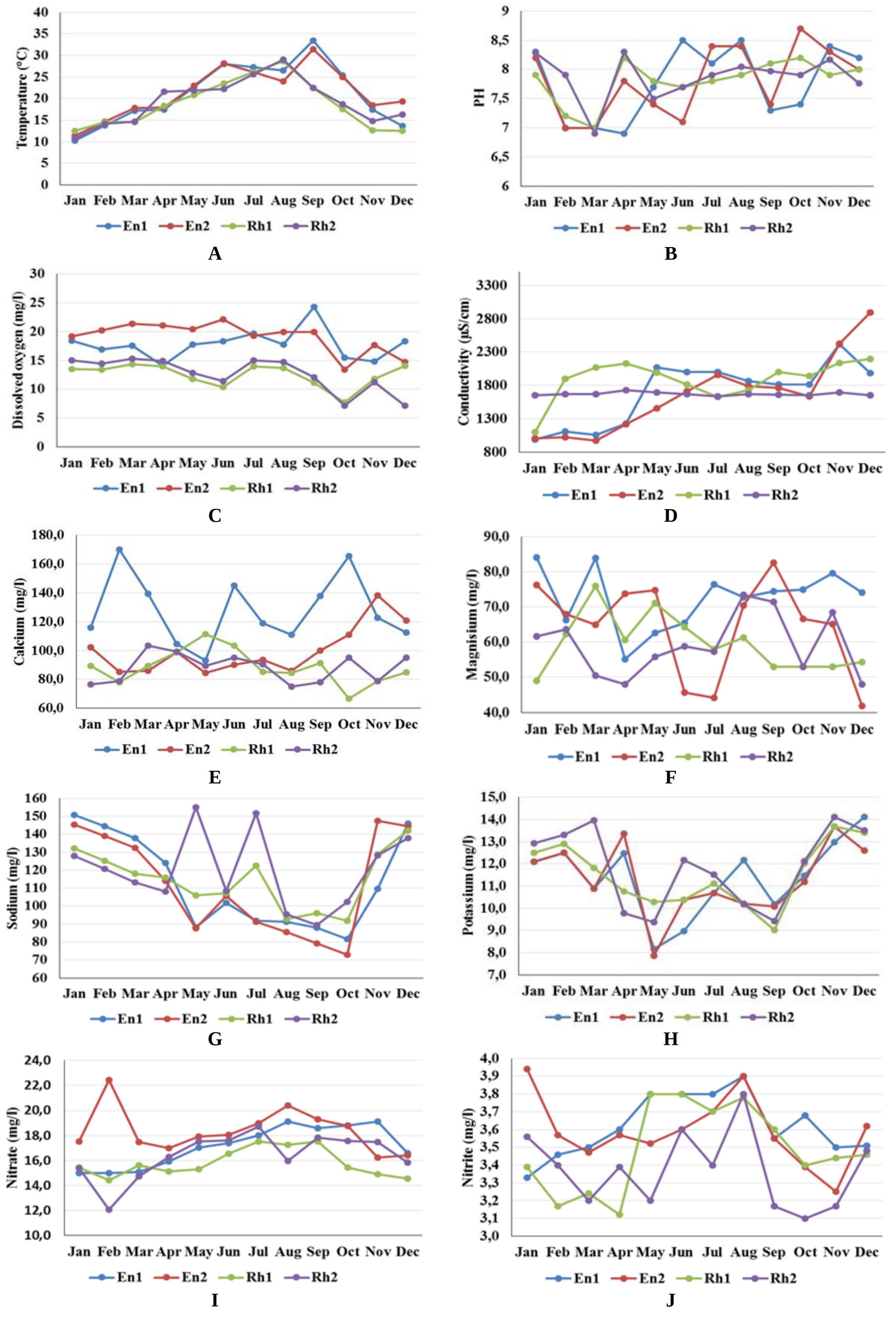

Figure 2. Spatio-temporal variation of water physicochemical parameters for all stations. Notes: En: Endja river; Rh: Rhumel river; 1: upstream; 2: downstream; A: temperature; B: pH; C: dissolved oxygen; D: electric conductivity; E: calcium; F: magnesium; G: sodium; H: potassium; I: nitrate; J: nitrite

Table 2. Physicochemical parameters of water samples in study stations in the Rhumel and Endja rivers, Algeria. Values are expressed as mean ± standard deviation (Mean±SD) and range [minimum maximum]

Water parameter [unit]	Values	Classes of quality or suitability	Study sites				ANOVA results			
			Rh1	Rh 2	En 1	En 2	Spatial variation		Temporal variation	
			Mean ± SD [min - max]	Mean ± SD [min - max]	Mean ± SD [min - max]	Mean ± SD [min - max]	***F***	***P***	***F***	***p***
Temperature T(°C)	≤ 20 20-22 22-25 25-30 ≥ 30	Normal Good Average Mediocre Bad	18.6±5.6 [12.5-28.7]	19.3±5.3 [10.8-29]	21±7 [10-33.4]	21.4±5.8 [11.4-31.4]	0.588	P > 0.05 ns	16.718	P < 0.001 ***
pH	8 8.5 9 9.5 >9	Very Good Good Fair Bad Very Bad	7.8±0.4 [7-8.2]	7.8±0.4 [6.99-8.3]	7.7±0.6 [7.9-8.5]	7.8±0.6 [7-8.7]	0.058	P > 0.05 ns	4.237	P < 0.001 ***
Electric conductivity EC (µS/cm)	< 400 400-750 750 >1500 1500 >3000	Good Good Fair Mediocre	1887±301 [1100-2200]	1670±25 [1635-1726]	1696±474 [988-2420]	1655±586 [974-2897]	0.851	P > 0.05 ns	3.021	P < 0.05 *
Dissolved oxygen DO (mg/L)	>7 5-7 3-5 <3 0	Excellent Good Eligible Mediocre Excess Pollution	12.7±2 [7.7-14.30]	12.6±3 [7.14-15.30]	17.7±2.6 [14-24.3]	19±2.6 [14-22]	21.509	P < 0.001 ***	0.844	P < 0.05 ns
Sulfate SO_4^- (mg/L)	>250	Unsuitable	280.5±97.6 [161-437]	277±113 [162-505]	318±126.8 [158.6-531]	334±17 [135.5-681]	0.553	P > 0.05 ns	23.331	P < 0.001
Phosphate PO_4^-(mg/L)	< 0,2 0.2-0,5 0.5- 1 1-2 >2	Excellent Good Fair Mediocre Excess Pollution	9±0.15 [9-9.5]	9±0.1 [8.9-9.3]	9±0.2 [9-9.5]	9±0.7 [9-10]	5.103	P < 0.01 **	0.880	P > 0.05 ns
Calcium Ca^{+2} (mg/L)	>200	Unsuitable	88.5±12 [67-111]	87.9±10 [75-103]	128±23.7 [93-170]	99.7±16.5 [84.5-138]	15.716	P < 0.001 ***	0.220	P > 0.05 ns
Magnesium Mg^{+2} (mg/L)	>150	Unsuitable	59.6±8 [49-76]	59±8.7 [48-73.4]	72.3±8.7 [55-84]	64.5±13.4 [42-82.6]	4.629	0,007 *	0.822	P > 0.05 ns
Sodium Na^+(mg/L)	>200	Unsuitable	115±16 [92-142]	120±21 [89-155]	113±26 [81.6-151]	112±28.5 [73-147.6]	0.264	P > 0.05 ns	6.509	P < 0.001 ***
Potassium K^+(mg/L)	>12	Unsuitable	11.5±1.4 [9-14]	12±1.7 [9.4-14]	11.4±1.7 [8.2-14]	11±1.6 [8-14]	0.275	P > 0.05 ns	9.679	P < 0.001 ***
Nitrite NO_2^-(mg/L)	< 0,1 0.1-0.3 0.3- 1 1-2 >2	Excellent Good Fair Mediocre Excess Pollution	3.5±0.24 [3.1-3.8]	3.4±0.2 [3-3.80]	3.6±0.2 [3.3-4]	3.6±0.2 [3.3-4]	3.456	P < 0.05 *	2.671	P < 0.05 *
Nitrate NO_3^-(mg/L)	< 5 5-25 25-50 50-80 > 80	Excellent Good Fair Mediocre Excess Pollution	15.8±1.1 [14.4-17.5]	16.4±1.8 [12-18.7]	17±1.6 [15-19]	18.4±1.7 [16-22.4]	5.747	P < 0.01 **	1.371	P > 0.05 ns

Notes: Statistical significance: ***: P < 0.001; **: P < 0.01; *: P < 0.05; ns : P > 0.05

According to Table 2, most parameters varied between upstream and downstream and between Rhumel and Endja rivers. The parameters that increased from upstream to downstream are temperature, DO, NO_3^-, and SO_4^- at Endja river. Those which decreased from upstream to downstream are CE, Mg^{+2}, Na^+, and SO_4^- at Rhumelriver. The rest parameters showed small variations from upstream to downstream, and the other showed a certain similarity in the concentrations (NO_2^-, PO_4^- and pH).

The results of ANOVA indicated that temperature, pH, K^+, and Na^+ varied very significantly between study months ($P<0.001$), and the EC varied significantly between study months ($P<0.05$). On the other hand, the calcium and dissolved oxygen varied very significantly between study sites ($P<0.001$), the NO_3^-, PO_4^- varied significantly between study sites ($P<0.01$), and NO_2- varied significantly between months and studied sites ($p<0.05$). For the rest of the parameters, no significant differences were observed between the month and study sites (Figure 2, Table 2).

Biotic analysis

Spatio-temporal variability of benthic macroinvertebrate assemblages in two rivers

Table 3 shows seasonal variation in the Rhumel River recorded at the Rh1 and Rh2 stations, respectively. The abundance of Diptera in spring was higher (92.31% and 77.25%) compared to summer (53.13% and 23.21%). Conversely, Mollusca was more abundant in summer (13.67% and 28.93%) than in spring (7.69% and 4.88%) in the same stations. Moreover, Rh2 recorded the same variation for Ephemeroptera and Hirudinae. At Endja River, Ephemeroptera was more abundant in summer than in spring in the upstream and downstream stations. For the other taxa, their presence was arbitrary. With the exception of Rh2, summer recorded the highest abundance (Table 3) in all samples. The highest number of macroinvertebrate individuals was recorded in the Rh2>Rh1>En2>En1 station (Table 3).

Macroinvertebrate diversity and abundance

According to Figure 3, in Rhumel river (Rh1 and Rh2), the identified benthic macroinvertebrates accumulated the highest number of 1543 individuals (7 taxa); of which (70.07%) were Diptera, 11.09% mollusks, 7.32% Annelida, 5.98% Hemiptera and 5.54% Hirudinae, in the upstream station Rh1. While in the downstream station (Rh2), the same order was presented with Diptera as the highest (49.54%), followed by Mollusca (17.22%), Ephemeroptera (10.81%), Annelida (10.80%), Hirudinae (7.69%) and finally Trichoptera (3.94%). In Endja river (En1 and En2), 7 taxa have been identified for a total number of 528 individuals. For the upstream station (En1), the most abundant group was Ephemeroptera with 53.13% (163 individuals), followed by Trichoptera (16.80%), Diptera (15.23%) and Plecoptera (14.88%). While the downstream station (En2) showed the Ephemeroptera (40.07%) as the very frequent group, followed by Hemiptera (18.01%), Diptera (16.91%), Trichoptera (9.93%), Odonata (8.46%) and Mollusca (6.62%).

According to Table 4, the downstream stations of Endja and Rhumel rivers had the highest value of invertebrate richness (10 family and 9 family) with a maximum abundance of 28.57% and 25.71%, respectively. Followed by the downstream stations with the same values of richness and abundance. The Shannon-Weiner Diversity Index (H') and Evenness Index (E) were calculated for each sample to determine macroinvertebrate structure in the four sites. The highest values of the Shannon-Weiner Diversity Index (3.0) and Evenness Index (0.91) were obtained at En2. As for the lowest values (2.7 for the Shannon-Weiner Diversity Index and 0.89 for Evenness Index), they were recorded at upstream stations for the two rivers. According to the classification proposed by Tuffery and Verneaux (1978), the waters with low pollution of the Rhumel river belong to class II, while those of Endja with average pollution belong to class III.

Relationships between physicochemical and biotic water parameters

Out of 105 correlation tests between physicochemical and biotic parameters of water, 18 were statistically very significant ($P<0.01$), and 11 were statistically significant ($P<0.05$). Twenty positive correlations were indicated between T, SO_4^-, NO_2^-, NO_3^-, pH, EC, DO, Ca^{+2}, Mg^{+2}, PO_4^-, and between richness (S) and Shannon diversity index (H'). Other parameters indicated negative correlations, namely water temperature, SO_4^-, Na^+, K^+, NO_2^-, and NO_3^-. Besides, the Biotic index (BI) was negatively related to pH (Table 5).

The PCA analyzing relationships between water physicochemical variables and biotic parameters revealed that the explained constrained values for the axes were 30.938% and 56.661% for the first and the second axes, respectively. According to the first component axis, eight water parameters were positively correlated with richness (S), Shannon diversity index (H'), insects, worms, and mollusks that were plotted on the positive side. BI was positioned on the negative side of the same axis, which revealed that it was positively correlated with other water parameters (Na^+, $K^{+,}$ Mg^{+2}, and DO) (Figure 4). On the second axis of PCA, biotic characteristics were positively associated with T, NO_3^-, NO_2^-, SO_4^-, Na^+, and K^+ concentrations in the water but negatively with water pH, EC, PO_4^- , DO, Ca^{+2}, and Mg^{+2}.

Discussion

Water resources are major concerns of countries in arid or semi-arid regions because they are absolutely essential to the development of all humans, economic and social activities elements. In this study, the assessment of water quality from all stations indicates that temperature, pH, Na^+, and K^+ varied only between study months and dissolved oxygen and calcium varied only between study sites (f: 21.509 and f: 15.716, $p<0.001$), respectively. For the rest of the water physicochemical parameters, there is a dominance of cations with order $Na^+ > Ca^{+2} > Mg^{+2} > K^+$, and anions $SO_4^- > NO_3^- > PO_4^- > NO_2^-$.

Table 3. Seasonal abundance of benthic macroinvertebrate assemblages in the Rhumel and Endja rivers, Algeria

Taxons	Rh1				Rh2				En1				En2			
	Spring		Summer		Spring		Summer		Spring		Summer		Spring		Summer	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Diptera	180	92.31	136	53.13	411	77.25	130	23.21			39	27.46			46	24.21
Trichoptera					43	8.1			43	37.72			27	32.93		
Ephemeroptera					20	3.76	98	17.5	33	28.95	103	72.54	45	54.88	64	33.68
Plecoptera									38	33.33						
Hemiptera			27	10.55									10	12.19	39	20.53
Odonata															23	12.11
Mollusca	15	7.69	35	13.67	26	4.88	162	28.93							18	9.47
Hirudinae			25	9.76	32	6.01	52	9.29								
Annelida			33	12.89			118	21.07								
Total/ season	195		256		532		560		114		142		82		190	
Total / station	451				1092				256				272			
Total/river	1543								528							

Table 4. Biotic indicators of macroinvertebrate assemblages in the Rhumel and Endja rivers, Algeria

Diversity ındices			Streams			
	Values	Quality class	Rh1	Rh2	En1	En2
S			8	9	8	10
A (%)			22.86	25.71	22.86	28.57
H'			2.7	2.8	2.7	3.0
E			0.89	0.90	0.89	0.91
BI (Tuffery and Verneaux)	9<Ib<10	I-Low or zero pollution				
	7<Ib<8	II-Low pollution				
	5<Ib<6	III-Average pollution	5	5	7	7
	3<Ib<4	IV-Heigh pollution				
	0<Ib<2	V-Very heigh pollution				
Pollution class			III	III	II	II

Notes: S: richness; A: abundance; H': Shannon-Wienner diversity index; E: Evennes index; and BI: Biotic index

Table 5. Pearson correlation matrix between water parameters

	T	pH	EC	DO	SO_4^-	Na^+	K^+	Ca^{+2}	Mg^{+2}	PO_4^-	NO_2^-	NO_3^-	S	H'	BI
T	1	.071	.222	.258	**.762****	**-.676****	**-.668****	.137	.066	.214	**.426****	**.532****	.285	.549	-.153
pH		1	**.377****	-.176	**.301***	-.166	.010	-.079	-.018	.255	.170	.089	-.320	.046	**-.974****
EC			1	-.224	**.296***	-.198	.011	.045	-.246	.051	.000	-.046	-.134	.398	-.698
DO				1	.233	-.063	-.210	**.303***	**.412****	**.443****	**.344***	**.373****	-.220	-.288	.092
SO_4^-					1	**-.508****	**-.403****	-.014	.073	**.291***	**.585****	**.515****	.368	.563	.030
Na^+						1	**.541****	.037	-.142	-.112	**-.319***	**-.365***	-.337	-.633	.529
K^+							1	.012	-.109	-.133	**-.326***	**-.334***	-.040	-.460	.519
Ca^{+2}								1	**.321***	.172	.160	.070	-.574	-.330	-.345
Mg^{+2}									1	.260	.173	.192	-.515	-.547	-.262
PO_4										1	**.599****	**.459****	-.578	-.225	-.598
NO_2^-											1	**.342***	.232	.116	.296
NO_3^-												1	.420	.382	.144
S													1	**.852****	.192
H'														1	-.192
BI															1

Notes: ** the correlation is very significant at the 0.01 level (two-sided); * the correlation is significant at the 0.05 level (two-sided)

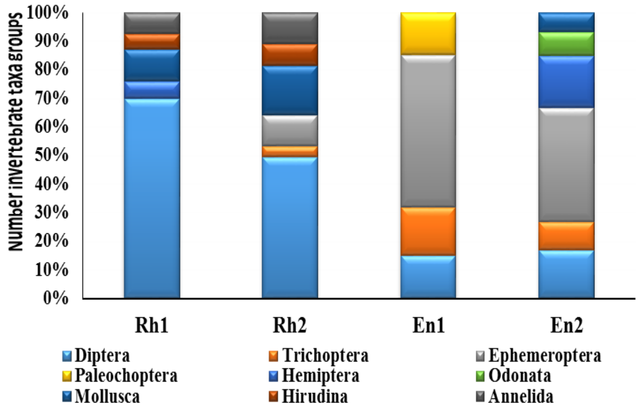

Figure 3. Percentage of total number for each invertebrate taxa group recorded during the study period at each study site

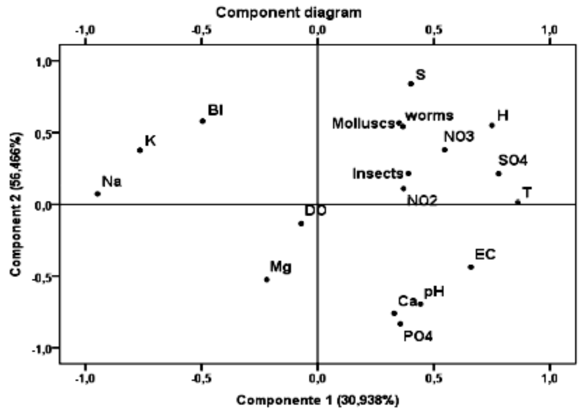

Figure 4. Principal Component Analysis (PCA) diagram showing the relationships between the physicochemical parameters and the biotic parameters in the different study stations in northeastern Algeria

Temperature can induce significant effects on the physical, chemical, and biological characteristics of water as well as on dissolved oxygen and biological requirement. In particular, temperature influences the solubility of salts and gases, the dissociation of dissolved salts, chemical and biochemical reactions, and the development, growth, and behavior of living aquatic organisms (Guemmaz et al. 2019). Temperature variation in running waters at the study stations generally had seasonal and daily time scales due to climate, the extent of streamside vegetation, and the relative importance of water inflows (Rohasliney and Jackson 2008). Temperature is a critical environmental variable determining the metabolic rates of organisms, their distribution along a river's length and over geographic regions, and quite possibly their success in interacting with other species and behavior of aquatic and amphibiotic living organisms, and particularly the activity of aquatic microorganisms (Kumar et al. 2010). In addition, the orientation of the watercourse is affected by shading. Watercourse oriented east/west receives, over the course of a day, more lights than an oriented stream north/south (Environment Agency 2012). Finally, to understand river temperature, it is necessary to combine spatial and temporal approaches.

High dissolved oxygen concentrations and low nutrient levels are therefore supposed to considerably involve in the water quality from the downstream stations. Indeed, aquatic species choose their habitats, taking into account combinations of factors. Among them, the primary factor is the physiological availability of oxygen, which directly depends on the temperature and the movement of water. Benthic macroinvertebrate, mostly dominated by the aquatic insect, prefers a cold and clean river with high dissolved oxygen concentration (Anzani et al. 2016).

The water in the study sites had a normal pH. This result is in accordance with that reported by Heramza et al. (2021) at Ain Dalia dam, Algeria. The pH of all stations was moderately alkaline. This alkalinity can be attributed to photosynthetic activity and promotes the productivity of phytoplankton (Bouzid-Lagha and Djelita 2012; Draredja et al. 2019) which will, in turn, serve as food for benthic macroinvertebrates (Kazancı et al. 2013). These results confirm the presence of formations of limestone in the Kébir-Rhume watershed. Similar results were also obtained by (Melghit et al. 2015), working on the same study site. According to Brémond and Vuichard (1973), alkaline waters generally present richer and more diversified fauna than acidic waters. EC, which indicates the mineralization degree of the water, showed high salinity with EC values higher than 1100 µS/cm. The waters in the upstream and downstream stations for the two rivers were highly saline. The same results were found on the Beni Haroun dam by Bouraoudj et al. (2019) and Benayache et al. (2022). Indeed, the use of these salty waters, even in the field of agriculture, can lead to a rapid increase in agricultural soil salinity. This has been well demonstrated by several authors in arid regions (Belksier et al. 2016).

Sulfate is a natural compound that corresponds to the presence of sulfur in the water. The higher level of sulfate in our samples is generally linked to the presence of gypsum in the drained soils and reflects the intensification of agriculture exceptionally at Endja downstream (En2), which is surrounded by crop fields. Besides, the SO_4^- contents are higher than those recorded in Kebir west river in Algeria and lower than those recorded by Belksier et al. (2016) in Righ wadi in southeast Algeria and by Kherief Nacereddine et al. (2018) in Beni Haroun Dam.

The NO_3^- concentrations in water found in two rivers were higher than those reported from the Medjerda river in Tunisia (Etteieb et al. 2015). The intensive use of azote fertilizers to improve the yield of agricultural as well as runoff waters, which transport mineral salts, are the causes of the high NO_3^- concentrations in surface waters (Aera et al. 2019; Bouraoudj et al. 2019). In fact, the upward trend in PO_4^- and NO_2^- concentrations is quite alarming. The high PO_4^- concentrations recorded in the stations indicate the enrichment of domestic and agricultural wastes as well as the existence of direct contributions from agricultural and livestock activities well observed during our investigation (Chakravorty et al. 2014).

The physicochemical elements can serve as explanatory factors of biological conditions. Aquatic macroinvertebrate populations are influenced by physical and chemical parameters. The increasing number and diversity of aquatic macroinvertebrates in streams mean an improvement in both the physical and chemical components of streams (Agouridis et al. 2015).

A total 2071 individuals of aquatic macroinvertebrates (7 taxa) belonging to 19 families and 10 orders were harvested. The abundance of macroinvertebrate assemblages in the Rhumel river was higher (1543 individuals) than that obtained in the Endja river (528 individuals). Usually, the river's biological composition is seasonally variable. The spatiotemporal variability of benthic macroinvertebrate assemblages in the two rivers in this study indicates that summer recorded the highest abundance in all samples.

The macroinvertebrate community in the Rhumel river macroinvertebrate community was composed mainly of 70.07% Diptera. While Endja wadi was dominated by Ephemeroptera (53.13%). This macrofauna consists of 75.20% insects, 12.50% worms and 12.30% mollusks. This dominance of insects was also reported by Benzina and Si Bachir (2018) in Belezma park (Northern-East, Algeria), Adouony et al. (2018) in Faé Dam Lake (Southwest, Côte d'Ivoire), Agblonon Houelome et al. (2017) in Benin cotton basin (West Africa) and Gouissi et al. (2019) in Affon river, Benin. The families of Chironomidae and Baetidae are the most frequent and the most abundant across all stations, which could be regarded as early warning signals of pollution loads that can degrade water quality and overall ecological health (Arimoro et al. 2011; Keddari et al. 2019).

The richness (S) of macroinvertebrates increased from upstream to downstream in the two rivers. The distribution and abundance of aquatic macroinvertebrate communities could be related to the component of the substrates and the hydrological characteristics of the streams (Kownacki and Szarek-Gwiazda 2022). Indeed, several studies have shown that water quality parameters, as well as the availability of food in the water (e.g., algae) (Chorus et al. 2021; Benayache et al. 2022), also influence the distribution and diversity of aquatic macroinvertebrates (Wahizatul and Hoon 2016).

Diversity indices explain species richness and uniformity of diversity. These indices facilitate the interpretation of changes in benthic communities and can be used as ecological indicators of water quality status and complement other approaches to water quality assessment, such as physical and chemical assessments (Ekoko et al. 2022). The Shannon-Weiner index (H') and Pielou's Evenness index (E) were almost similar across all sites except in En2 where higher values (H': 3.0 and E: 0.91) were recorded. This site showed the highest diversity. However, this diversity is linked to mayflies, which have surely found suitable habitats for the development of mayfly communities. Therefore, our results are superior to those found by Kamb et al. (2015) in Mangengenge (Gombe and Kinkusa rivers, Congo) and Kobenan Kra et al. (2018) in Kodjoboué lake (southeast of Côte d'Ivoire).

Based on Biotic Index and according to the classification proposed by Tuffery and Verneaux (1978), the waters of the Rhumel river had low pollution (level 5), and Endja river with average pollution (level 7). Therefore, the deterioration of the water quality was reflected in the family biotic index calculated according to the tolerance of the organisms (Kripa et al. 2013). Some aquatic macroinvertebrates are highly sensitive to changes in water quality and can only survive in rivers with minimal pollution (Gültekin et al. 2019). Other types of aquatic macroinvertebrates can tolerate polluted waters, such as Chironomidae larvae, which were the most abundant in our study stations (Sellam et al. 2017). This result may be related to the natural and/or anthropogenic factors influencing the watercourse. Abiotic factors can influence the distribution of benthic macroinvertebrates (Li et al. 2015; Arifi et al. 2018; Hou et al. 2020), including altitude, current velocity, water transparency, type and heterogeneity of substrate, macrophyte abundance, and wide river.

In conclusion, the quality of a watercourse is the result of all the alterations it undergoes. It is, therefore, the combined expression of its physicochemical characteristics and biological capacity. The water quality of two rivers in this study is deteriorating due to urban and industrial activities, although it can still be considered moderately good with respect to physicochemical parameters. The elements which presented anomaly were SO_4^-, PO_4^-, and NO_2^-; which showed the highest values recorded during the summer season at four stations. According to the concentrations of nutrients, the Endja river is more polluted than the Rhumel river. We found that macroinvertebrates in the Rhumel and Endja rivers have been influenced by the physical and chemical conditions of the river environments. The low diversity presents a faunal impoverishment from upstream to downstream. However, a greater diversity of mayflies was recorded in the less disturbed study sites, which probably provided better habitats for the mayfly community. This diversity is a response to the anomaly physicochemical parameters of the streams. In general, less degraded watercourses contain more diverse macroinvertebrate communities. With increasing anthropogenic actions, the abundance of the most sensitive taxa decreases while the abundance of pollution-tolerant taxa increases. Therefore, the waters of two rivers are unsuitable for use, even for irrigation purposes.

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