Journal of Materials and Environmental Sciences
ISSN : 2028-2508
CODEN : JMESCN

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J. Mater. Environ. Sci., 2017, Volume 8, Issue S, Page 4840-4845

http://www.jmaterenvironsci.com

Pollution evaluation in the Oum ErRbia River (Morocco) using macroinvertebrate-based indices andphysico-chemical parameters.

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Received 01 Aug 2017,
Revised 12 Dec 2017,
Accepted 16 Dec 2017

Keywords

- ✓ Biomonitoring;
- ✓ Biotic indices;
- ✓ Macroinvertebrates;
- ✓ Morocco;

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ABSTRACT
The aim of this study is to try to assess the spatial and temporal water quality variation in the OumErRbia River using water physicochemical parameters and macroinvertebrates data sets obtained over a period of 4 seasons between September 2015 and September 2016 at 10 sampling sites. Biotic indices IBGN (IndiceBiologique Global) and BMWP (Biological Monitoring Working Party) based on macroinvertebrates , River Habitat Index (IHF) and Physico-chemical parameters (pH, temperature, electrical conductivity , dissolved oxygen ,Total suspended solids,chemical oxygen demand , biochemical oxygen demand , ammonium , total phosphorus) were employed to evaluate the water quality. We found extraordinary high values of salinity in the studied streams, reaching conductivities up to 4220 µS/cm. Both the BMWP and IBGN indicate good water quality at the (upstream) reference site (S1), bad water quality at wastewater discharges. According to physicochemical parameters, water quality was classified as low polluted level and it is suitable for drinking purposes aftertreatment. These results show that the increase in electrical conductivity has no impact on the values of the biotic indices used in this study. Our results indicate that biotic indices are efficient indicators in assessing water quality . Finally,The results of this study can be useful not only for assessing the water quality in the OumErRbia River, but also to use them as a data bank for the adaptation of biotic indices based on macroinvertebrates in Morocco.

1. Introduction

Biological parameters are more sensitive indicators of ecosystem integrity than physicochemical parameters [1-2]. Several organisms have been employed in the bioassessment of the water quality and ecological integrity of aquatic ecosystems, including bacteria, protozoans, diatoms, algae, macrophytes, macroinvertebrates and fish [3- 4-5-6], macroinvertebrates are the most widely used group [7]. The role of benthic macroinvertebrates as environmental indicators is based on their ability to react to a change of environmental variables such as sediment quality, water quality, hydrological conditions, shading and biological factors [8]. There are many advantages in using benthic macroinvertebrates in bioassessment [9], they are relatively easy and inexpensive to collect, particularly if qualitative sampling is undertaken, they are largely non-mobile, omnipresent and inhabitants of both lotic and lentic habitats and thus representative of the location being sampled, which enables effective spatial analyses of pollutant or disturbance effects to be undertaken and they have a rapid life cycle and their largely sedentary habits [10]. A lot of biotic indices based on the macroinvertebrate community have been developed and extensively used in recent years [11], such as Global Biological Index (IBGN) was recommended as a standardized method for assessing the biological quality of a watercourse in France [12] and the Biological Monitoring Working Party (BMWP) score system for river pollution [13] was set up in Great Britain in 1976 and have been applied in other countries, like Spain [14] , Argentina [15] ,Canada [16] ,Thailand [17], Brazil [18] and Egypt [19] . The number and type of species in the river are an indication of whether it is impacted by organic or chemical pollution.

The specific objective of our work is to compare the response of two biological indices (BMWP and IBGN ,this comparison was complemented by a physicochemical analysis . River Habitat Index (IHF) was used as a complementary indicator.

2.Materials and methods

2.1.Study area

The study area is located in the Center-Western of Morocco (Figure 1), at 31°19.33′−33°22.21″N lat and 5°8.55′−8°22.53′W Long. The OumErRbia River originates on the Middle Atlas at 1800 m and flows into the Atlantic Ocean at Azemmour city. The Middle Atlas, characterized by a humid cold climate, classified as Mediterranean mountain climate [20]. Rainfall in the OumErRbia basin varies between 1100 mm on the Middle Atlas and 300 mm in the down river region, with an average of 550 mm[21] . Many dams and reservoirs have been constructed on the OumErRbia River to generate hydroelectric power and to provide water for irrigation. The monitoring network is depicted on the map (Figure 1).

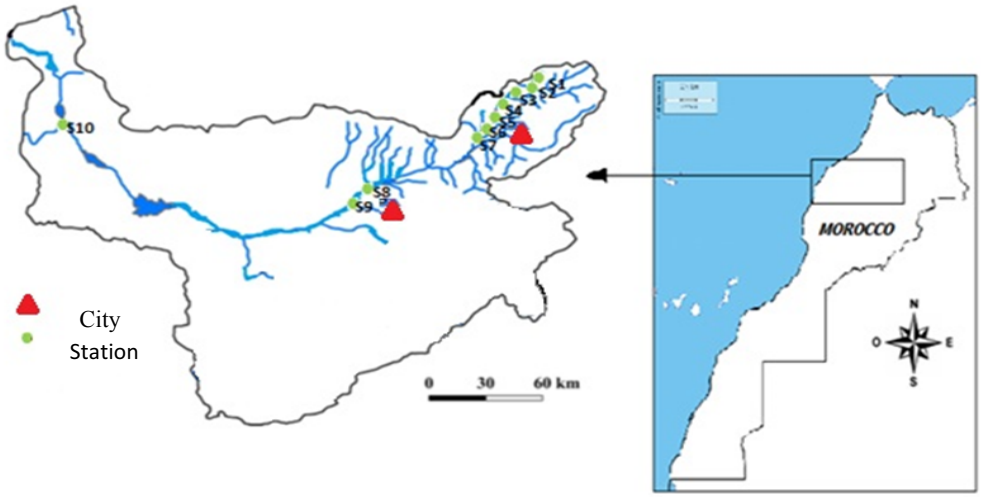

Figure 1: Location of the sampling station S1.S2.S3.S4.S5.S6.S7.S8.S9 and S10.

2.2 *Sampling sites*

The sites (S1. S2. S3.S4. S5. S6. S7. S8. S9. S10) were distributed throughout the OumErRbia Rivers (Figure 1), The samples were taken seasonally from september 2015 until september 2016. In each site we made qualitative samplings of macroinvertebrates, using A Surber sampler (catching area: 0.025 m2) [22] . At each site, eight samples were taken, carried out on different habitats. All captured organisms were placed in plastic bottles and preserved in 10% formaldehyde .The benthic macroinvertebrate identification was done to the lowest possible taxonomic level in the laboratory based on keys presented by Tachet[23 -24]. Physical–chemical data and heavy metals were obtained from the National Office for Electricity and drinking Water (ONEE) of Morocco. For each sampling site, data on pH, temperature, electrical conductivity (EC), dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD5), Total suspended solids (TSS) ,ammonium (NH4+) , total phosphorus (P) , Zinc, Mercury, Cadmium and Chromium were obtained.

2.3 *Data analysis*

Correlations between biological indexes and chemical variables were computed using the Principal Component Factor Analysis of the Correlation Matrix. All statistical analyses were performed using the MINITAB (version 16).The degree of similarity between macroinvertebrate communities and classification of sites was defined on the basis of Ward's method [25] .

3.Resulats and Discussion

3.1.Environmental variables

The results of the spatial variation of the physicochemical parameters are shown onTable 1.The measured temperature values varied between 16.66 and 24.55°C , these measurements indicated that all water samples ranked as good class in terms of water quality [26].

The Conductivity high level is observed at all stations of OumErRbia River and ranged between 4220 and 1210µS/cm. It's due to the high quantity of dissolved salt in the major springs supplying OumErRbia River. The

site S1 which is located very near to Sources of OumErRbia River registered a very high conductivity (3810 µS cm-1) and S10 showed the lowest conductivity value (1230 µS cm-1). These results indicated that the water samples classified as moderate to highly polluted class in terms of water quality [26] . Conductivity showed significant positively correlated with pH but negatively correlated with TSS and NH4 .There were no significant differences between sampling sites for dissolved oxygen and pH. NH4+ ranged between 0 and 0.625 mg/l, indicating that the river water had Excellent to Moderately polluted quality according to Moroccan standards. The higher NH4+ are recorded at stations (S4, S5, S6, S7, S8, S9 and S10) close to wastewater discharge of Khenifra and KasbaTadla .

The BOD5 used to quantify the quantity of oxygen necessary for the degradation of the biodegradable organic matter by the development of micro-organisms[27]. BOD5 in the various stations shows values between 0 and 34.5 mg/l with significant variation between seasons. COD shows contents between 0 and 149 mg/l, with variations between seasons, especially for the station (S6) which is situated downstream the abattoir wastewater in Khenifra.The TSS concentration shows a wide ranging between 23.25 and 1447.75 mg/l, indicating that the river water had excelent to polluted quality according to Moroccan guidelines 2002.

The concentrations of heavy metals variables, including Zinc, Mercury, Cadmium and Chromium Table 2, were not higher than permissive maximum values for each element in the OumErRbia River based on guideline of the World Health Organization [28].

Table 1: Spatial variations of mean values of heavy metal concentration (mg/ L),in the OumEr Bia River.

Sites	Chromium mg/L($\times 10^{-3}$)	Zinc mg/L ($\times 10^{-2}$)	Mercury mg/L($\times 10^{-5}$)	Cadmium mg/L ($\times 10^{-4}$)
S1	8.5	2.25	0	5.25
S2	4.85	0	0	0
S3	0	0	0	0
S4	3	0	2.5	0
S5	2	0	5	0
S6	3.233	11.75	10	3
S7	1.175	0	5	0
S8	0	0	0	0
S9	0	2.6667	0	0
S10	0	0	5	0

The River Habitat Index (IHF , named originally Indice de Hábitat Fluvial in Spanish) evaluates the ability of the physical habitat to host a particular fauna according to 7 criteria : substrate, current velocity , depth, shadow, the presence of elements of heterogeneity and aquatic vegetation [29] .According to the IHF hydromorphological index Table 3 ,the S6 site showed the most deteriorated habitat (value of 37). The rest of stations shown IHF values between 42 and 62.7. These results showed that the major stations ofOumErRbia River have good to moderate habitat quality . On the other hand, S1 shows a decrease in habitat quality in Autumn, it's due to the absence of vegetation in this site and the low diversity of speed regimes in the channel in autumn, that means the habitat is impoverished and can limit the presence of some species in Autumn [30].

3.2.Biotic indices and Environmental variables

Examination of all samples resulted in a total number of 36 families representing the orders Ephemeroptera, Trichoptera, Odonata, Coleoptera, Heteroptera ,Diptera ,Oligochaeta, Crustacea, Gastropoda and Bivalvia. The total number of identified families varied between eight and 32 among particular sites. Insect constituted the highest number of families (25 out of 36 families), The most frequently found taxa in the study river were Simuliidae (25.37%).

The water quality for all 10 sampling sites based on the BMWP ranged from 31.75 to 113.25 (Table 3), and from 5.5 to 14 for the IBGN (Table. 3). Both indices had high values at sites with IHF values between 62.7 and 58, COD lower than 9.75 mg/L and TSS lower than 106.25 mg/L. Values of BMWP index were higher at the reference site (S1) than at downstream sampling sites (S5,S7 and S9), with S6 exhibiting the lowest values .

Table 2: Distribution of water-quality classes, based on mean values of physicochemical variables measured in the OumEr Bia River in comparison with Moroccan surface water guidelines (2002).

Sites	(COD)	Q C	T°	Q C	pH	Q C	(NH_4^+)mg N/L	Q C	(EC) (µs/cm)	Q C	TSSmg/L	Q C	BOD5	Q C	(DO) mg O2/L	Q C
S1	9.25±18.5	E	18.9±4.6	E	8.5±0.10	E	0.04±0.07	E	3450±685.3	V.P	99.8± 119.3	G	6.75 ± 5.9	A	6.4±0.6	G
S2	9.75±19.5	E	20.65±3.8	G	8.4±0.03	E	0.30±0.47	E	2340±105.5	A	98.6± 107.9	G	6.25 ± 4.9	A	6.9±0.5	G
S3	9.5±19.0	E	20.25±3.6	G	8.4±0.05	E	0.27±0.42	E	2390±150.1	A	106.3± 110.6	G	6 ± 5.0	A	6.9±0.4	G
S4	0±0.0	E	20.6±3.7	G	8.4±0.10	E	0.03±0.06	E	2405±147.3	A	1295.3±2470.2	P	4.5 ± 5.3	G	6.4±0.5	G
S5	4.75±9.5	E	20.55±3.0	G	8.4±0.11	E	0.26±0.16	G	2347.5±111.5	A	1394.8±2670.6	P	5.75 ± 7.6	A	6.5±1.1	E
S6	98.5±181.4	V.P	20.1±3.6	G	8.4±0.15	E	0.39±0.21	G	2310±202.2	A	1447.8±2768.6	P	34.5 ± 50.4	V.P	6.2±1.5	E
S7	0±0.0	E	17.67±2.0	E	8.4±0.15	E	0.30±0.13	G	2220±249.1	A	34.9±30.2	E	3.75 ± 4.8	G	6.2±0.7	G
S8	0± 0.0	E	16. 7±2.3	E	8.2±0.10	E	0.38±0.28	A	1987.5±130.0	A	34.3±28.2	E	0 ± 0.0	E	6.1±0.5	G
S9	0±0.0	E	20.8±4.8	G	8.3±0.13	E	0.45±0.29	A	2017.5±88.1	A	23.3±29.9	E	14.25 ± 7.8	P	6.0±0.3	G
S10	0± 0.0	E	24.55±1.8	G	8.3±0.09	E	0.02±0.04	G	1235±20.8	G	24.5±30.4	E	0 ± 0.0	E	7.3±0.3	E

Excellent: E Good: G Average: A Poor :P Very Poor : V.P Quality classification : Q C

Table 3 : Macroinvertebrate indices values (mean), water quality levels (WQL) and habitat quality levels (HQL) in the OumEr Bia River.Abbreviations: Biological Monitoring Working Party (BMWP), IndiceBiologique Global (IBGN) and index of habitat heterogeneity (IHF).

Sites	BMWP	BMWP-WQL	IBGN	IBGN-WQL	IHF	IHF- HQL
S1	113.25	Very Good	14	Good	61	Good
S2	117	Very Good	13.25	Good	57	Moderate
S3	101.5	Very Good	13.5	Good	58	Moderate
S4	79	Good	10.75	Moderate	54	Moderate
S5	36.25	Poor	6.5	Poor	50	Moderate
S6	36 .25	Poor	5.5	Very Poor	37	Bad
S7	31.75	Poor	6	Poor	54	Moderate
S8	72	Good	10.5	Moderate	58	Moderate
S9	47.5	Moderate	7.5	Poor	42	Moderate
S10	86	Good	11.5	Moderate	62.7	Moderate

The dendrogram separates all sampling sites. According to the results of the analysis, the most similarity was observed between the stations 2 ,3 and 4.The stations S1 and S10 showed the most difference in the content of benthic macroinvertebrates, in terms of the numbers and taxa (Figure 2).
The IBGN performed similarly to IHF, since neither of the sites reached the very good status and their values progressively decreased as water TSS increased. The BMWP clearly differed from the IBGN, BMWP indice showing higher values at all sites. For example, according to this index, S1, S2, and S3 had a very good ecological status**.**All biotic indices were significantly correlated. The IBGN were more tightly correlated with habitat indices (IHF) than BMWP (Table 4).

Table 4: Correlation among biotic indices (IBGN, BMWP) and River Habitat Index (IHF) using Spearman's correlation. ($P < 0.001$)

	IBGN	IHF
IBGN		0.6153
BMWP	0 .96255	0 .58056

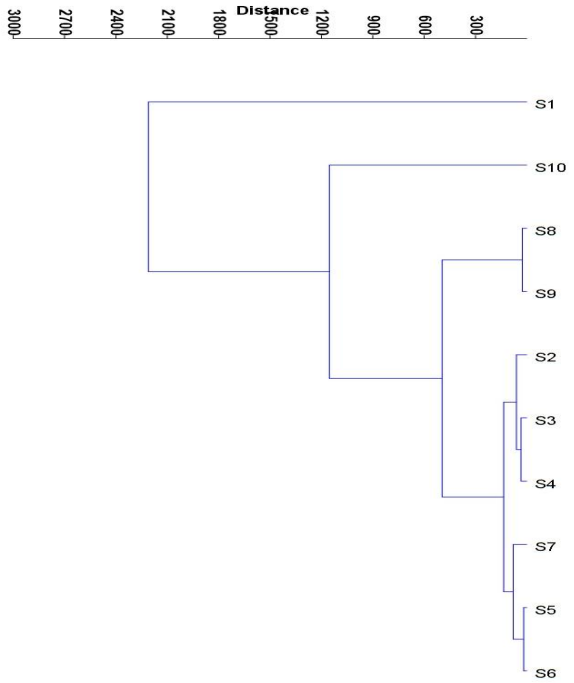

Figure 2: Classification of sites based on similarities of macroinvertebrate communities Ward's clustering method

Principal Component Analysis PCA summarizes these results (Figure 3). COD , BOD5 and total phosphorus have been grouped together as they are closely correlated from a statistical point of view. IBGN , BMWP and IHF these three variables are strongly correlated with each other and uncorrelated to the Conductivity . NH4+ , TSS, these variables were also strongly correlated and then completely uncorrelated to the previous variables According to our results, the water quality based on macroinvertebrate indices (BMWP and IBGN) was related to the anthropic activities, a clear deterioration of the water quality was observed from upstream to downstream sites. The water quality changed from very good (S1) to poor (S6) quality. Also, important anthropogenic sources can be detected in this river, the downstream section of the KasbaTadla has received urban wastewater effluents discharged directly into the OumEr Bia River (S7, S8), the downstream section of the Khenifra receives Wastewater from the slaughterhouse (S5, S6). Both the BMWP and IBGN indicate good water quality at the (upstream) reference site (S1) and bad water quality at wastewater discharges. Factors such as the natural geology and anthropogenic activities (for example : discharge of domestic untreated wastewater in KasbaTadla and Khenifra) were found as the major determinants for point pollution events in the Basin [31- 32].The results of this study indicate that indices based on macroinvertebrates are not influenced by the increase in electrical conductivity. Meanwhile, the two macroinvertebrate indices (BMWP, IBGN) to assess the state of water quality in the OumEr Bia River have shown the different responses to other Environmental variables (TSS, DBO5 and DCO). In agreement with several studies, the macroinvertebrate based indices showed significant responses to water quality degradation [33 - 34].

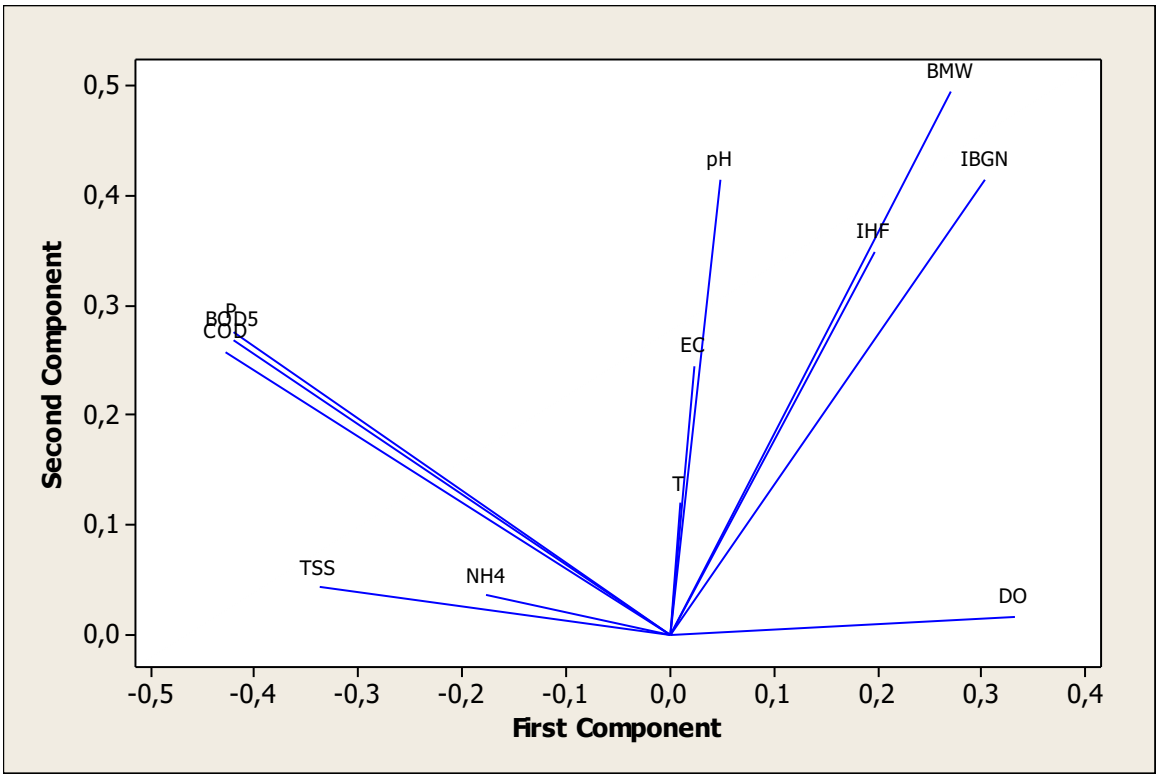

Figure 3: Correspondence analysis of biotic indices (IBGN, BMWP) and environmental variables.

Conclusions

Macroinvertebrate composition was more influenced by physical habitat and chemical quality than the electrical conductivity of water and macroinvertebrates were less in the most heavily polluted sites with a high COD, TSS and BOD5 content .Also, we noticed a small difference between the two indices. This difference being related to calculation methods and the table of the selected families for each index.

We suggest future studies should include several river ecosystems, more sampling sites, more sampling time, also development of appropriate taxonomic identification keys for Morocco fauna. We recommended that the use of biotic indices could be employed as a tool for biomonitoring of pollution riverine ecosystems in Morocco. Although it is still necessary to adapt a biotic index specific to Morocco based on macroinvertebrates.

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