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BIO-EVALUATION OF WATER QUALITY OF THE MIDDLE SEBOU BY APPLICATION OF BIOTIC INDEXES

BIO-ÉVALUATION DE LA QUALITÉ DE L'EAU DU MOYEN SEBOU PAR APPLICATION D'INDICES BIOTIQUES

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ABSRACT

Sebou is the most important river flowing into the Atlantic. Its basin knows a very developed industrial activity, as well as an important domestic and agricultural activity; hence the need to assess the quality of its waters. The intensification of these activities generates important pollution causing global habitat degradation and rarefaction and mortality of the biocenosis. An evaluation of water quality of the middle Sebou by biotic indexes founded on the study of macroinvertebrates has been done and the values of the Normalized Global Biological Index, and the Biological Monitoring Working Party ranked the water of the majority of the studied sites into the category of poor to very poor quality water. These indexes are good biological tracers of the water quality and indicators of even insidious pollution.

Keywords: Sebou, water quality, biotic index, pollution.

RESUME

Oued Sebou est le plus important fleuve se jetant dans l'Atlantique. Son bassin connaît une activité industrielle très développée, ainsi qu'une importante activité domestique et agricole; d'où la nécessité d'évaluer la qualité de ses eaux. L'intensification de ces activités génère une pollution importante entrainant la dégradation globale de l'habitat ainsi que la raréfaction et la mortalité de la biocénose.

Une évaluation des eaux du moyen Sebou par des indices biotiques fondés sur l'étude des macroinvertébrés a été réalisée et les résultats basés sur l'application des indices IBGN et BMWP indiquent que les eaux de la majorité des stations prospectées sont qualifiées à la classe médiocre à très mauvaise. Ces indices sont avérés de bons traceurs biologiques de la qualité des eaux et des indicateurs de pollution même insidieuse.

Mots- clés : Sebou, qualité de l'eau, indice biotique, pollution.

INTRODUCTION

The evaluation of water quality and the monitoring of the impacts of the anthropic activities on the water courses uses generally the measure of physico-chemical and ecotoxicological parameters of the water and the sediment. This approach proved their utility but also have their limits (Thomas J.D., 1993). The biological methods, like the indexes based on the invertebrate macrofaune are, according to Verneaux (Lascombe C., 1992), the only valid way for a general appreciation of the systems quality and thus the real effects of pollution. The concept of integrity and ecosystem health requires to take into the account simultaneously the chemical, physical and biological parameters (Genin et *al.*, 1997).

The faunistic studies (benthic invertebrates) and the ecological studies (spatial distribution, community structure) are of paramount importance in understanding the operation and management of natural systems and assessing the ecological health of water systems (Bouzidi, 1989; Dakki, 1979; Dakki, 1992; El Agbani,1984; Fekhaoui, 1990).

Benthic macroinvertebrates are considered very good biological indicators because they are relatively sedentary, abundant and relatively easy to collect. Their communities are able to present a characteristic gradient of responses depending on the intensity and the nature of stress. In addition, their lifetime is sufficiently long and they are taxonomically very heterogeneous and diverse. Moreover, their sensitivity is variable and differentiated depending on the type of pollutant (Moisan et al., 2008) and their reactions are usually quick to provide an integrated recording of environmental quality. Finally, macroinvertebrates as a whole are ubiquitous in hydrographic networks.

This set of characteristics makes that benthic macroinvertebrates are at the origin of numerous diagnostic tools of aquatic ecosystems quality, such as the Normalized Global Biological Index (IBGN) used in this study in its new standard, who is now translated into two AFNOR standards: the XP T 90-333 standard (AFNOR, 2009) for the protocol field and the XP T 90-388 standard (AFNOR, 2010) for the laboratory phase and the BMWP score (Biological Monitoring Working Party) which are the subject of many hydrobiological studies (Bouzidi A. 1989; Chahlaoui, A., 1996; Maqbool et al., 2001; Karrouch, L., 2010; Haouchine, S., 2011). The objective of this work will be to show how benthic invertebrates may indicate biological water quality in the middle Sebou using biotic indexes and to identify the most degraded section.

MATERIEL AND METHODS

Study area

The Sebou River, having a total length of 614 km from its source, is situated in the northwest of Morocco, between 4-7 degrees west and 33-35 degrees north. It can be divided into three distinct geomorphic catchments: the upper, middle, and lower Sebou. The studied sampling sites are located on the middle Sebou, where the river is subject to a strong anthropogenic pressure.

The study of the macrofauna of the middle Sebou could not be undertaken on the whole of the river system. Therefore, it was necessary to have a sufficiently high number of sampling sites.

Seven field campaigns were performed between March and October 2011. In order to achieve this study, nine sampling sites were selected, taking into account a number of criteria such as accessibility, flow direction, sources of pollution, etc.

The figure 1 and the table 1 show the nine representative sites of all sampled biotopes.

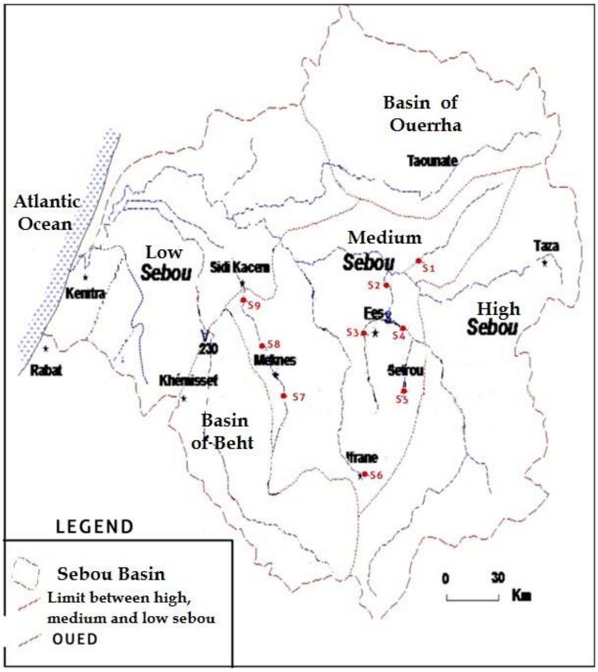

Figure 1: Map of location of sampling sites in the middle Sebou

Table 1: Location, coordinates and characteristics of study sites.

Sampling sites	Code	Province	Commune	Lambert coordinates	Widt (m)	Depth (m)
PT RS 302	S1	Taounate	Tissa	X:558,250 Y: 405,950	-	-
Portuguese bridge	S2	Medina of Fez	Medina of Fez	X:544,05 Y: 385,825	-	-
Downstream of Fez	S3	Medina of Fez	Medina of Fez	X:543,38 Y: 386,540	10	0.2
Dar El Arsa	S4	Fez	Loudayene	X:543,300 Y: 399,700	30	0.25
Downstream Sefrou	S5	Taza	Bab Marzouka	X:554,27 Y: 365,850	-	-
Sidi Mokhfi	S6	Ifrane	Sidi El Mokhfi	X:507,600 Y: 311,800	8	0.7
Downstream of Meknes	S7	Khemisset	Tifelt	X:450,30 Y: 369,150	10	30
Kroumam bridge	S8	Meknes	Oued Roumane	X:466,900 Y: 410,800	4	0.25
Azib Soltane	S9	Sidi Kacem	Selfate	X:492,00 Y: 413,900	Large	Deep

Sampling and analysis

At each station having a length equal to about ten times the width of the stream, the number of samples is twelve. These samples were taken at different locations with different couples “speed- substrate ". Each sample is considered representative of the benthic fauna in an area of 1/20 m^2. Within a station, the main types of facies were surveyed: The lotic areas were sampled using a Surber net and the lentic areas were surveyed using a dip net.

In a station, the samples were fixed on the field by adding a solution of formaldehyde at 10% (Foto Menbohan, 2010). Before fixing the samples, a pre-sorting allowed to remove the mineral elements (rocks, gravels and sands) because these may damage the fauna during the transport (Karrouch, 2010; Haouchine, 2011). Sorting and determination of invertebrates were performed in the laboratory using a binocular microscope (maximum magnification is 40). All the individuals were counted. The treatment of samples required numerous working months (7 in total). The identification of specimens was made at the most precise taxonomic level possible (genus or species). All individuals were counted. Sample processing required many months of work (7 in total). The identification of specimens was performed as specific as possible taxonomic level (genus or species). The determination of harvested specimens is performed using books, collections and macroinvertebrate identification keys (Clergue, 1991; Dommanget, 1994; Tachet et al., 2010; Poisson, 1957).

The methods of bioassessment of water quality that have been adopted in this investigation are the stand diversity indexes and the diversity indexes and the biotic indexes (IBGN (AFNOR, 2009) and BMWP index (Walley et Hawkes,1997)).

These indexes were compared to each other by the Spearman’s rank correlation coefficient. This non-parametric method allows to measure the intensity of the relation between the two indexes. The Spearman correlation coefficient varies between -1 and 1, these extreme values indicating perfect correlation between the two considered indexes (Legendre et Legendre, 1984).

RESULTS

The table 3 presents the average values of the nine indexes calculated from faunal data from the 9 surveyed stations. The figures (2, 3 and 4) represent the diversity and the biotic indexes according to stations.

The average values EPT (Ephemeroptera, Plecoptera and Trichoptera) show significant variations between stations: the highest values (33.33% to 56.25%) at S1, S4 and S9 where species richness is the most important, intermediate values (16.66% to 23.07%) in S2, S6 and S7. However, there is a disappearance of these taxa polluo-sensitive on disturbed sites (S3, S5 and S8). The graphs of EPT and species richness showed a significant linear relationship between the two indexes and the stations (Figure 3).

On the other hand, the percentages of chironomidae dramatically increased in S3, S5 and S8 (42.58% to 100%). Other stations show lower values not exceeding 32%.

The stations (S3, S5 and S8) present the lowest values of diversity and biotic indexes. The average values range between 0 (S3) and 1.63 (S5) for the Shannon index, 0.2 (S5) and 1 (S8) for the Simpson index, 0 (S3) and 2.75 (S5) for Margalef index, 1 (S3 and S8) and 3 (S5) for IBGN, 0 (S8) and 27 (S5) for BMWP.

Table 2: Average values of indexes calculated on the 9 studied stations

Sampling sites	Species richness	EPT	% EPT	% Oligochaetes	% Chironomid	Simpson Index	Shannon Index	Margalef Index	IBGN	BMWP
S1	14	6	42,85	0	83	0.25	2.54	5.72	5	55
S2	26	6	23,07	6.82	24.58	0.12	3.6	8.86	8	92
S3	1	0	0	0	100	1	0	0	1	2
S4	16	9	56.25	0	17.39	0.16	2.94	5.73	9	71
S5	65	0	0	0	0	0.2	1.63	2.75	3	27
S6	18	3	16.66	0.31	16.47	0.33	2.03	5.46	10	68
S7	10	2	20	20.29	1.008	0.53	1.32	3.05	8	46
S8	3	0	0	0	0	0.5	1.02	0.82	1	0
S9	15	5	33.33	3.22	3.23	0.24	2.69	7.11	6	59

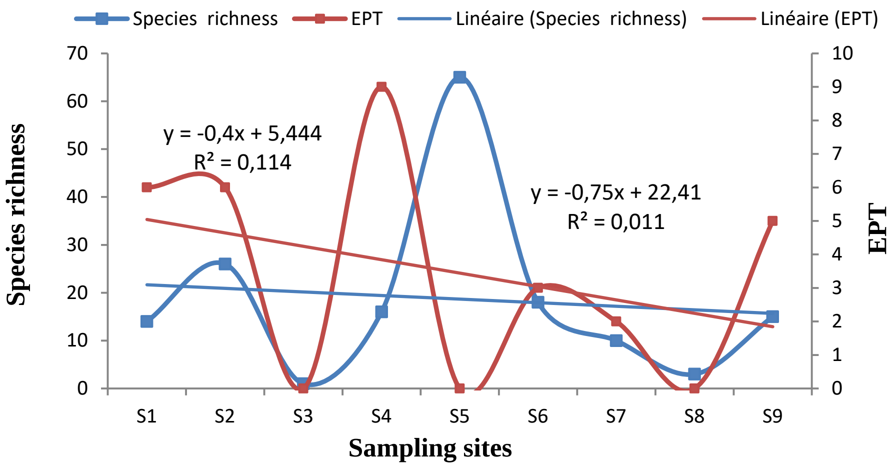

Figure 2 : Representation of average values of species richness and EPT of the studied stations

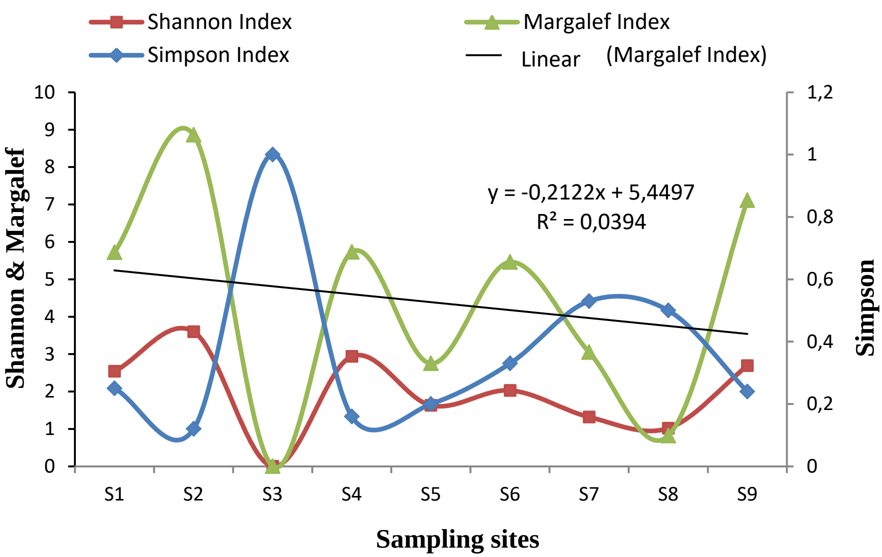

Figure 3 : Representation of diversity indexes of studied stations

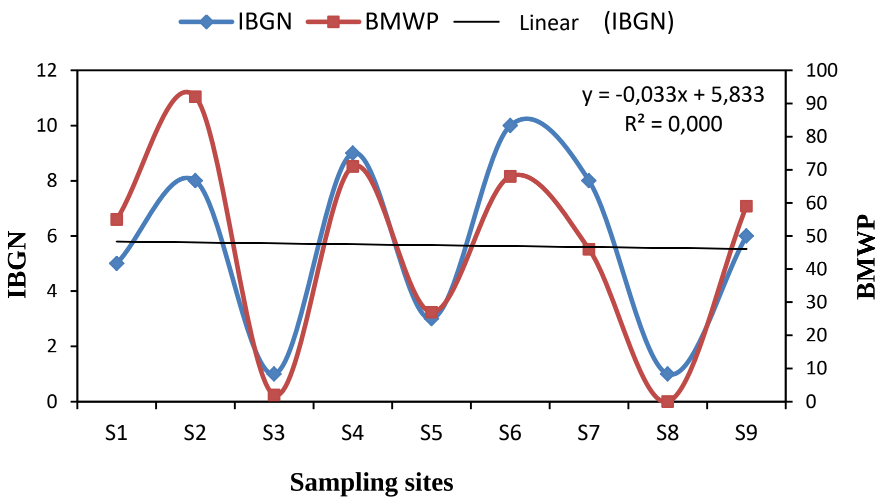

Figure 4: Representation of biotic indexes of the studied stations

Table 3: The Spearman's rank correlation coefficients between the 9 studied indexes

Biotic indexes	EPT	% Oligo	% Chiro	Simpson	Shannon	Margalef	IBGN	BMWP
Specific richness	0,341	0,164	-0,192	**-0,817**	0,650	0,533	0,504	0,617
ETP	**1**	0,196	0,453	-0,647	**0,894**	**0,877**	0,665	**0,868**
% Oligo		**1**	-0,110	-0,055	0,292	0,475	0,525	0,438
% Chiro			**1**	0,000	0,234	0,226	0,089	0,351
Simpson				**1**	**-0,883**	**-0,767**	-0,395	**-0,717**
Shannon					**1**	**0,967**	0,630	**0,917**
Margalef						**1**	0,639	**0,900**
IBGN							**1**	**0,840**
BMWP								**1**

The relative percentages of Oligochaeta show a maximum peak of about 20.29% at S7, lower values are stored in S2 (6.82%) and S6 (0.31%).

The other stations have relatively higher values for these indexes. The average values vary between 1.32 (S7) and 3.6 (S2) for the Shannon index, 0.12 (S2) and 0.53 (S8) for the Simpson index, 3.05 (S7) and 8.86 (S5) for Margalef index, 5 (S1) and 10 (S6) for IBGN, 46 (S7) and 92 (S2) for BMWP.

The table 4 shows the Spearman’s rank correlation coefficients between different studied indexes. Species richness and EPT are moderately correlated with Shannon index (0.65 and 0.894, respectively), Margalef (respectively 0.533 and 877), the IBGN (respectively 0.504 and 0.665) and BMWP (0.617 and 0.868 respectively). Moreover, Simpson index and percentages of Chironomidae have negative correlations with EPT and species richness, and are weakly correlated with the percentages of Oligochaeta.

The values of Shannon, Simpson and Margalef indexes have highly significant correlations between them and with the biotic indexes. The highest are situated between Margalef and Shannon indexes (r = -0.967) and between BMWP and Shannon index (0.917) and between the BMWP and Margalef index (0.9). As signal Mary (1999), the values of Simpson index increased in the presence of disturbances and have negative correlations with the values of other indexes. For the biotic indexes, IBGN and BMWP are highly correlated (r = 0.84). The percentages of Oligochaeta and Chironomidae are moderately correlated with diversity indexes (% Oligochaeta / Simpson: -0.055, % Oligochaeta / Shannon: 0.292, % Oligochaeta / Margalef: 0.475, % Chironomidae / Simpson: 0, % Chironomidae / Shannon: -0.234, and % Chironomidae / Margalef 0223).

DISCUSSION AND CONCLUSION

The Simpson index is unsatisfactory, it can assign similar values to unpolluted and polluted stations. As indicate Pelletier (2002) and Berryman et al (2002), this index doesn't seem to be able to differentiate the agricultural organic pollutions of those more intense caused by the domestic wastes. The Margalef and Shannon indexes, heavily dependent on species richness seem more efficient than the Simpson index. They discriminate well between disturbed sites and those which are less disturbed. These three indexes, sensitive to the conditions of sampling and sample size (Norris and Georges, 1993), are not always effective when it comes to estimating the water quality of the middle Sebou.

An overabundance of Oligochaeta can indicate an organic pollution. Oligochaeta , known for their resistance to this type of pollution, can proliferate in large numbers. (Gross, 1976; Giani, 1984; Williams, 1980; St-Onge et Richard, 1994; Giani et *al*., 1995). The use of this group in the assessment of water quality of the middle Sebou allowed, according to Goodnight and Whitley (1961), to classify the waters of the majority of the stations in the category poor to very poor. This could be explained by the significant and worrying discharges of olive oil mills (Foutlane et al., 2002) and the discharge of wastewater. Indeed, the Fez city, for example, is responsible for 40% of the total impact of water quality on the Sebou River (ABHS 2006). All wastewater from Fez city (estimated at 200 000 m^3 per day in 2004 by (Koukal et al., 2004)) are discharged directly into the Sebou River leading to severe pollution of its waters. This includes industrial effluents generated by many industries, including tanneries, brass works, episodicolive oil mill activity, the canning and yeast factories, and textile industries are also considered as polluting activities due to their wastewater, including various pollutants (e.g. degradable organics, surfactants, metals and dyes) (Giorgetti et al., 2011).

The percentage of Oligochaeta is strongly influenced by the organic load of waters, indeed favorable to the development of Oligochaeta. This index seems well suited to assess organic pollution in the waters of the middle Sebou.

The EPT is an index used by the Anglo-Saxons in bio-indication. It estimates water quality by the relative abundance of taxa belonging to the orders of Ephemeroptera, Plecoptera and Trichoptera. These taxa are considered as the most sensitive to pollution (Lenat, 1988; Hilsenhoff, 1988; Klemm *et al.*, 1990; Bode *et al.*, 1991; Lenat & Crawford, 1994; Resh *et al*., 1996; Cayrou et *al*., 2000 ; Lamri 2009).

The EPT index and species richness allow a global differentiation of the stations: 4 and 6 stations are qualified to the class good (S1,2,7 and 9) to the class poor and (S3, S5 and S8) to the class very poor. These results are related the simultaneous loss of families of Ephemeroptera, Plecoptera and Trichoptera. These results are similar to those obtained by Gup (1994) and Pelletier (2002) in the basin of Saint-Maurice River (Canada) and Compin and Cereghino (2003) in the basin of Adour-Garonne (France), these authors mention that the EPT index is influenced by industrial and urban activities.

The biotic indexes IBGN and BMWP discriminate between stations in the same way. They depend on the species richness which itself is linked to the diversity of habitats. The decline of these biotic indexes is caused by the disappearance of large number of faunal indicator groups. These results are comparable to those found by Czerniawska-Kusza (2005) in the Nysa Klodzka River (Poland) and those found at Boufekrane River (Morocco) by Karrouch and Chahlaoui (2009).

The IBGN and the BMWP discriminate correctly between disturbed stations and those who are less (Czerniawska-Kusza, 2005). It has been proved that these indexes are good biological tracers of water quality and indicators of even insidious pollution. It is therefore highly recommended to generalize their use to complete the physicochemical analysis.

REFERENCES

ABHS. (2006). Débat National sur l'eau: l'avenir de l'eau, affaire de tous. Agence du Bassin Hydraulique du Sebou (ABHS), 48p.

AFNOR. (2010). Qualité écologique des milieux aquatiques. Qualité de l'eau. Traitement au laboratoire d'échantillons contenant des macro-invertébrés de cours d'eau, Association française de normalisation, Prénorme expérimentale XP T 90-388.

AFNOR. (2009). Qualité écologique des milieux aquatiques. Qualité de l'eau. Prélèvement des macroinvertébrés aquatiques en rivières peu profondes, Association française de normalisation, Norme expérimentale T 90-333.

AGENCES DE L'EAU. (1993). Etude bibliographique des méthodes biologiques d'évaluation de la qualité des eaux de surface continentales. Etude inter-Agences 35, 259 p+ annexes.

BERRYMAN, D., NADEAU, A., DEBLOIS, C. (2002). Le Bassin Saint-Maurice: Evaluation de la qualité de l'eau a l'aide de mousses aquatiques et de cellules à dialyse, Québec, ministère de l'environnement, Direction du suivi de l'état de l'environnement, envirodoq ENV/2002/0292, rapport EA/2002, 3,60p

BODE, R.W., NOVAK, M.A., ABELE, L.E. (1991). Quality assurance work plan for biological stream monitoring in New York State, Albany, New York, NYS Department of Environmental Conservation, Division of water, 80 p.

BOUZIDI, A. (1989). Recherches hydrobiologiques sur les cours d'eau des massifs du Haut-Atlas (Maroc). Bio-écologie des macroinvertébrés et distribution spatiale des peuplements. Thèse d'état, Fac.Sc. Tech. St. Jerome, Université d'Aix- Marseille III, 190pp.

CAYROU, J., COMPIN, A., GIANI, N., CEREGHINO, R. (2000). Associations spécifiques chez les macroinvertébrés benthiques et leur utilisation pour la classification des cours d'eau. Cas du réseau hydrographique Adour–Garonne (France). Annls de Limnologie, (36): 189–202.

CHAHLAOUI, A. (1996). Etude Hydrobiologique de l'Oued Boufekrane - Impact sur l'environnement et la santé, Thèse d'état en Biologie. Univ. Moulay Ismail Fac. Sci. Meknès, 256pp.

COMPIN, A., CEREGHINO, R. (2003). Sensitivity of aquqtic insect species richness to distrubance in the Adour-Garonne stream (France), Ecological indicators,(3): 135-142.

CZERNIAWSKA-KUSZA, I. (2005). Comparing modified biological monitoring working party score system and several biological indices based on macroinvertebrates for water-quality assessment Limnologica, (35): 169–176.

DAKKI, M. (1979). Recherches hydrobiologiques sur un cours d'eau du Moyen- Atlas (Maroc). Thèse de 3ème cycle, Aix- Marseille III, 126pp.

DAKKI, M. (1992). Etude National sur la biodiversité Faune aquatique continentale (Invertébrés et Poissons). Projet PNUE/ GEF/6105-92, 121pp.

EL AGBANI, M. (1984). Le réseau hydrographique du bassin versant de l'oued Bou Regreg (plateau central marocain). Essai de biotypologie. Thèse Doctorat 3éme cycle, Université Claude Bernard LyonA, 147 pp.

FEKHAOUI, M. (1990). Recherches hydrobiologiques sur le Moyen Sebou soumis aux rejets de la ville de Fès: suivi d'une macro-pollution et évaluation de ses incidences sur les composantes de l'écosystème. Thèse d'Etat, Fac. Sci. Rabat, 173 pp.

FOTO MENBOHAN, S., ZEBAZE TOGOUET, S. H., NYAMSI TCHATCHO, N.L., NJINÉ T. (2010). Eur. J. Sci. Res. 43, 96.

FOUTLANE, A., SAADALLAH, M., ECHIHABI, L., BOURCHICH, L. (2002). Pollution par les margines et production d'eau potable. Cas de l'Oued Sebou au Maroc. Eastern Mediterranean Health Journal, 8(1): 10.

GENIN, B., CHAUVIN, C., MENARD, F. (1997). Cours d'eau et indices biologiques: pollution et méthodes IBGN, Dijon, ENESA-CNERTA, 202pp.

GIANI, N. (1984). Le Rio mort, affluent du lot pollué par les métaux lourds. IV. Etude des Oligochétes. Annls. Limnol, 20 (3): 167-181.

GIANI, M., MECCOZZI, M., GESUMUNDO, G. (1995). Physico-chemical features and nutrients distribution in the Marsala Lagoon (Italy). Papp. Comm. Int. Mer Medit., 34- 81.

GIORGETTI, L., TALOUIZTE, H., MERZOUKI, M., CALTAVUTURO, L., GERI, C., FRASSINETTI, S. (2011). Ecotoxicology and environmental safety genotoxicity evaluation of effluents from textile industries of the region Fez Boulmane, Morocco: a case study. Ecotoxicol Environ Saf., 74:2275–83.

GOODNIGHT, C.J., WHITLEY, L.S. (1961). Oligochaetes as indicators of pollution. Proc.15 th Indust. Waste Conf., Purdue Univ. Eng. Ext. Ser., (106): 139-142.

GROSS, F. (1976). Les communautés Oligochètes d'un ruisseau de plaine. Leur utilisation comme indicateurs de la pollution organique .Annls Limnol., 12 (1): 756-87.

GUP, T. (1994). Dammed from here to eternity: dams and biological integrity, Trout, winter., p14-20.

HAOUCHINE, S. (2011). Recherche sur la faunistique et l'écologie des macroinvertébrés des cours d'eau de Kabylie. Mémoire de Master, Faculté des Sciences Biologiques et Sciences Agronomiques, Université Mouloud Mammeri de Tizi ouzou, Algérie, 157 pp.

HILSENHOFF, W.L. (1988). Rapid field assessment of organic pollution with family-level biotic index. J.N. Am .Benthol.Soc., (7): 65-68.

KARROUCH, L. (2010). Bio-évaluation de la qualité des eaux courantes de la région Meknès (Centre- Sud, Maroc) –Impact sur l'environnement et la sante. Thèse doctorat es sciences en biologie. Faculté des sciences. Meknès, 216pp.

KARROUCH L., CHAHLAOUI A. (2009). Bio-évaluation des eaux de l'oued Boufekrane (Meknès) Maroc.Biomatec Echo.vol 3 n°6, pp.6-17.

KLEMM, D.J., LEWIS, P.A., FULK F., LAZORCHAK J.M. (1990). Macroinvertebrate field and laboratory methods for evaluating the biological integrity of surface waters, Cincinnati, Ohio, U.S. Environmental Protection Agency, Office of Research and Development, Environmental monitoring systems laboratory, EPA/600/4-90/030, 256 p.

KOUKAL, B., DOMINIK, J., VIGNATI, D., ARPAGAUS, P., SANTIAGO, S., OUDDANE, B., BENAABIDATE, L. (2004). Assessment of water quality and toxicity of polluted Rivers Fez and Sebou in the region of Fez (Morocco). Environ. Pollut., 131, 163–172.

LAMRI, D. (2009). Caractérisations physico-chimique et biologique de cours d'eaux de la Moulouya. Evaluation de la qualité des eaux par des indices biotiques fondés sur l'étude des macro-invertèbrés. Thèse de doctorat, Université Ibn Tafail faculté des sciences Kénitra, 149p.

LASCOMBE, C. (1992). Les méthodes d'évaluations de la qualité des milieux aquatiques superficiels, Tribune de l'eau, (555) : 18-29.

LEGENDRE, P., LEGENDRE, L. (1984). Ecologie numérique. Tome 2 La structure des données écologiques. Collection d'Ecologie13, Masson Paris et Presses de l'Université du Québec, 335p.

LENAT, D.R., CRAWFORD, J.K. (1994). Effects of lands use on water quality and aquatic biota of three North Carolina piedmont streams, Hydrobiol., (294): 185-199.

LENAT, D.R. (1988). Water quality assessment of streams using a qualitative collection method for benthic macroinvertebrates. J. N. Am. Benthol. Soc., (7): 222-233.

MAQBOUL, A., AOUJDAD, R., FEKHAOUI, M., FADLI, A., TOUHAMI, A. (2001). Riv. Idrobiol., 40,2-3:129-152.

MOISAN, J., PELLETIER, L. (2008). Guide de surveillance biologique basée sur les macroinvertébrés benthiques d'eau douce du Québec – Cours d'eau peu profonds à substrat grossier. Direction du suivi de l'état de l'environnement, ministère du Développement durable, de l'Environnement et des Parcs, 86 p.

NORRIS R.H., GEORGES, A. (1993). Analysis and interpretation of benthic macroinvertebrate surveys. In: Rosenberg D.M. & Resh V.H (Eds) Freshwater Biomonitoring and benthic macroinvertebrates. Chapman & Hall NY., 234-286.

PELLETIER, L. (2002). Le bassin de la rivière Saint-Maurcie: Les communautés benthiques et l'intégrité biotique du milieu. Ministère de l'environnement du Québec. Canada. Envirodoq : ENV/0291, 83p.

RESH, V.H., MYERS, M.J., HANNAFORD, M.J. (1996). Macroinvertebrates as biotic indicators of environmental quality. In : Methods in Stream Ecology, Academic Press., 647-667.

ST-ONGE, J., RICHARD, Y. (1994). Les communautés benthiques du basin de la riviére L'Assomption et l'intégrité des écosystèmes fluviaux, ministère de l'environnement et de la faune, Direction des écosystèmes aquatiques, envirodoq EN940241, rapport QE-88; 105p.

THOMAS, J.D. (1993). Journal of Natural History, 27, 795-806.

WALLEY, W.J., HAWKES, H.A. (1997). A computer based development of the biological monitoring working party score system incorporating abundance rating, site type and indicator value. Water research., 31(2): 201- 210.

WILLIAMS, W.D. (1980). Australian Freshwater Life. The invertebrates of Australian inland waters. Macmillan, Melbourne, 321 p.