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Water Quality Assessment Based on HFBI& BMWP Index in Karoon River, Khuzestan Province, (Northwest of Persian Gulf)

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Abstract: Score-based biotic indices are widely used to evaluate the water quality of streams and rivers. The main objective of this study was the assessment of the water quality of Karoon River through biotic indices based on the Family Biotic Index (HFBI), and the Biological Monitoring Working Party Score System (BMWP). Macroinveratebrate communities are one of the most widely used groups in assessment of water quality, since they respond directively to the level of contamination of aquatic ecosystems. Sampling was performed in 4 stations (Menikh, Zhian Canal, Bahrakani and Dahaneh). Sampling was carried in each station over one year (winter, spring, summer and autumn). Macroinvertebrates were collected by the grab quantitative sampller. Four phylaum (Nematoda, Annelidae, Mollusca and Arthropoda) distributed amoung 11 families were sampled. Station1 (Menikh) had the highest Macroinvertebrate diversity and richness. The highest density of aquatic invertebrates were recorded in winter (Annelidae 46%, Crustacea 28%, Mullusca 21% and Diptera 5%) and spring (Mullusca 58%, Crustacea 27%, Nematoda 10% and Anellidae 5%) respectively. The BMWP index showed that the water quality was in the regular category (for Menikh, Zhian Canal and Bahrakani) and in the poor category (for Dahaneh). HFBI index pointed out the water quality was in the regular category (for Menikh, Zhian Canal and Bahrakani) and poor category (for Dahaneh) . Biotic indices used reflected the changes to the water quality. The changes and stresses in the river, especially the industrial wastewater, have changed macrobentic community, consequently, the percentage of resistant group increased and decreased in sensitive groups. The stations studied were heavily polluted; sources of pollution include oil refinery, industrial and municipal wastewater and these factors have reduced water quality.

Keywords: Benthos, BMWP, HFBI, Karoon River, Water Quality

1. Introduction

Rivers have historically been one of the main resources of water used by humans; current water are considered in terms of biology and fishery. Surface water have a great potential for contamination human societies and industrial centers (Afyoni & Erfanimanesh, 2012). The environmental changes caused by urban and agriculture expansion have generated concern with availability and quality of water resources (Callisto et al., 2001). Maintaining water resources quality, due to the recent droughts and urban, rural and industrial developments is an important task in environment. (Seyyedsharifi et al., 2014). Environmental factors revealed the effect of human activities on river habitats and proved that increasing human activities has caused spatial and temporal changes in river habitats and led to changes in the diversity and abundance of benthic organisms in rivers (Wang et al., 2006). Invertebrates are of major ecologic importance in freshwater environments; they play a decisive role in organic matter fragmentation and decomposition and are important elements in food chains and food webs (Barros etal., 2016). Therefore, assessment of the human pressures on rivers is particularly important to find areas where water resources are threatened and subjected to rapidly increasing anthropogenic effects (Mostafavi and Teimori, 2018). Aquatic biota has been used as an important tool for acquiring information regarding the integrity and environmental quality of fresh water ecosystem (Bieger *et al.*, 2010). Aquatic macroinvertebrates are ubiquitous, and their sensitivity to environmental changes makes them good indicators of water condition. Diversity and biotic indices for benthic macroinvertebrate samples are often applied in an attempt to measure river pollution (Rios-Touma *etal*., 2014). Contamination from organic materials usually limits the diversity of benthic macro-invertebrates, so that their only highly resistant species can survive in low oxygen concentration. On the other hand, the formation of sludge and penetration of toxic chemicals may not only reduce the species population but it may also eliminate the benthic macro-invertebrate population entirely in that contaminated area. Of course, the turbulence of the river and the rolling of water on the stones adds more air and therefore oxygen to the water and accelerates the oxidation of organic materials and reduces toxic substances (self-purification of rivers). Score-based biotic indices are one of the most common biomonitoring methods used by water managers to synthesize large amounts of data from environmental monitoring. In these indices, a score is given to taxa (usually family or genera level) according to tolerance to organic pollution, giving highest or lowest scores (depending on the index) to sensitive taxa. Different species of aquatic invertebrates live in rivers. Insects are the most abundant macro-benthose in aquatic ecosystems. Insects in current waters constitute the main food of predatory; omnivorous and benthic fish. Macro-benthic change their abundance and diversity under environmental impacts (Jalili *et al*., 2012). Identifying macro-benthoses can be utilized as an effective methods to assess the ecological quality and ecosystem health. Investigation of water quality based on physical, chemical and microbiological variables can provide accurate information on contamination rate (Sarafiyan *etal*., 2017).Changes in physical and chemical parameters of water ecosystem can affect macro-benthic life, They are directly involved in energy flow and perform an effective role in biogeochemical cycles. (Buckup *etal.,* 2007). Macroinvertabrates communities may be used for water bio monitoring through the application of the biotic indices, (Duran, 2006). Biotic indices are numeric phrases that combine quantitative quantities of species diversity with qualitative information about the ecological sensitivities of each taxon in relation to a certain level of pollution (Czerniawska-Kusza, 2005). One of the most commonly used index is the BMWP (and its derivations), which was developed in 1978 by the Biological Monitoring Working Party (BMWP) in the United Kingdom (Armitage *et al.,* 1983). This index gives a score to each taxa (mostly families) according to the sensitivity of pollution (mainly organic); being the most sensitive taxa scored with values of 10 and the less sensitive (or more resistant) to pollution a score of 1. In order to classify the severity of pollution, according to the degree of tolerance of indicative species to pollutants, one point is awarded to them. Hilsenhoff Biological Family Index (HBFI) is one of the best and least costly methods currently available in Europe and the United States (Huang *et al.,* 1982). These two indices have been tested and adopted in several countries. Karoon River is one of the main rivers, due to the economic activities carried out in the basin. The water of the basin is used for agriculture, fishery, industrial and population supplies. On the other hand, these aquatic ecosystems are also used as a medium of dilution domestic, industrial and rural waste. Numerous

Hence according to the literature review, HFBI is a recognized and credible index globally that can be used to monitor the quality of surface water resources based on the macro benthos fauna ;(Mombeini *et al.,* 2012; Abbaspour *et al.,* 2013; Dadgar *et al.,* 2014, Barros *etal*.,2016, Datry *etal*.,2017, Stubbington *etal*.,2019). The specific objectives of the study were: (1) to compare the water quality of Karoon river between different stations (2) to identify the macro benthic fauna between different stations (3) to compare macrobentic fauna abundance and diversity between different seasons and (4) to analyze the relationship of the water quality with the Biotic indices.

2. Materials and methods

Site Description

Khuzestan province enjoying from major rivers Including Karoon, Dez Karkheh,Jarahi and Zohre Rivers fulfills its water needs through

Surface waters (Ebadati, 2017).The Great Karoon Basin is composed of the Dez and Karoon rivers and is located within the Middle Zagros Heights and has an area of 65,000 square kilometers. Karoon River; with a length of 890 km; is the longest and the largest river by discharge in Iran (Seif and Najmi, 2013). The river is bounded at coordinates longitude 48˚ 00˝ E to 53˚ 30˝ E and latitude 30˚ 00˝ N to 34˚ 05˝ N. The main cities of the western part of the basin are Ahvaz, Abadan, and Khoramshahr. Karoon River is divided into 3 branches after reaching Khoramshahr. The first branch passes from Abadan and goes to Arvand Rood. The next branch; known as Dahaneh, pours into the Bahmanshir canal and then poured into the Persian Gulf. The average annual precipitation of this basin is 620 mm. The climate of this basin is warm with dry summers and mild winters (Karimi-Jamshidi & Salari-Dargi, 2015).

Sampling Method

Sampling of the river was conducted for 1 year from January 2013 to December 2014. To assess the water quality of Karoon river 4 stations (Menikh, Zhian Canal, Bahrakani and Dahaneh) were selected. In the upper region, the stream was Menikh. In the middle region selected streams were Zhian Canal and Bahrakani and in the lower region the stream was Dahaneh. The geographic location of the sampling locations was determined using a Global Positioning System (GPS). Four samplings were carried out in one year (winter, spring, autumn and winter); totalizing 48 samples. The macroinvertabrates were sampled according to the protocol of the United States Environmental Protection Agency (USEPA). Macroinvertebrates all were collected along the cross profile perpendicular to the riverside, sides and middle of the river and all available stream habitats (muddy, margins) by were collected Ekman Grab ($0.1m^2$) samplers with 3 repetitions (Blomqvist, 1991). All collected samples, after separating unwanted materials by a standard sieve (500 µm) were fixed on 75% alcohol and stored in plastic buckets and transferred to the Fisheries Laboratory of Islamic Azad University Abadan Branch (McCafferty, 1981). Macroinvertebrates were identified to families according to (Pescador *et al.*, 2004, Carter *et al.*, 2011). The position of the sampling stations is shown on Figure 1 and the geographic coordinates of the stations are presented in (Table 1).

Figur 1-Locaton of the sampling stations in Karoon River 2013

Table 1- Geographical coordinates of sampling stations in Karoon River 2013.

Latitude	Longitude	Name station	Number station
″E 48□ 12	N 30□ 25	Menikh	1
E 48□ 36	N 30□ 05	Jian Canal	2
E 48□ 22	N 30□ 01	Bahrekani	3
E 48□ 10	N 30□ 26	Dahaneh	4

Biotic Indices

BMWP Index

All collected benthoses were identified at the family level. Based on the scores given for each family according to modified BMWP, each family has a numerical score (Wally and Hawkes, 1997) (Table2). Finally, the scores of the families in the samples are added up to gain the BMWP of that station (Table3).

Table 2- Family Privilege in BMWP System (Wally and Hawkes, 1997)

BMWP Modified Score	Family	Order
3	Lymnea	Lymnaeidae
3.5	Lumbriculidae	Oligocheata
3.5	Libelluidae	Coengrioidae
3.8	Chironomidae	Diptera
3.9	Pisciculidae	Erpobdella
4.5	Gammaridae	Amphipoda
5.3	Baeitidae	Ephemeroptera
6.4	Elmidae	Coleoptera
7.8	Capniidae	Plecoptera
8.6	Uenoidae	Trichoptera

Table 3-Water quality classification based on the BMWP index (Wally and Hawkes, 1997)

BMWP	Water Quality
0-10	Very poor
11-40	Poor
41-70	Regular
71-100	Good

Hilsenhoff Biological Index

The Hilsenhoff method, by identifying aquatic macro invertebrates (macro benthoses) in the family level and determining their tolerance to river pollution (in terms of organic pollution level) gives a score of 0 to 10 per family. The range of tolerance is from non-tolerant (0) to tolerant (10). High values of the biochemical index indicate water pollution, while its low values of the index indicate a clean water; (Table 4).

Hilsenhoff index (FBI) was calculated from:
HFBI= $\sum n \times a/N$

a = Tolerance value of taxa

n= number of specimens in taxa
N=total number of specimens in sample

Table 4: Water Quality Based On Biotic Indices (HFBI and BMWP) (Hilsenhoff, 1988)

HFBI	Water quality	BMWP	Water quality	Degree of Organic Pollution
0 -3.75	Class I Excellent	≥90	Class I Excellent	**Organic Pollution Unlikely**
3.76-4.25	Class II Very good	75-89	Class II Very good	**Possible slight organic pollution**
4.26-5	Class III Good	60-74	Class III Good	**Some organic pollution probable**
5.01-5.75	Class IV Fair	45-59	Class IV Fair	**Fairly substantial pollution likely**
5.76-6.50	Class V Regular	30-44	Class V Regular	**Substantial pollution likely**
6.51-7.25	Class VI Poor	15-29	Class VI Poor	**Very substantial pollution likely**
7.26-10	Class VII Very Poor	14 ≥	Class VII Very Poor	**Severe organic pollution likely**

Analysis of Statistics

Statistical analysis was performed using SPSS 21 software. First, Normality of the data and uniformity of variances were investigated respectively by using Kolmogorov-Smirnov test and Levene test. One-way analysis of variance (ANOVA) was used to study the differences between stations and different sampling stages. Subsequently, the Duncan's Mean Comparison Test was used at 95% confidence level.

3. Results

A total of 2,400 macroinvertebrates distributed among11 families were sampled in Karoon River. The families of macroinvertebrates belonged to four phylum (Arthropoda, Mollusca, Annelida and Nematoda), five sub-subphylum (Insecta, Crustacea, Gastropoda, Diplopoda and Bivalvia), eleven orders and eleven families (Table5). The amount of dissolved oxygen in water changes with increasing pollution, and macroinvertebrates are diffrent in terms of resistance to contamination and reduced oxygen. Oxygen fluctuation eliminate sensitive and semi-sensitive groups.

Table 5: List of macro invertebrates identified in Kroon River 2013

Phylum	Sub Phylum	Order	Family
Arthropoda	Insecta	Diptera	**Chironomidae**
Arthropoda	**Crustacea**	Maxillopoda	**Cirripedea**
Arthropoda	**Crustacea**	Decapoda	**Portunodae**
Arthropoda	**Crustacea**	Mysida	**Mysidae**
Mollusca	Gastropoda	Plumonata	**Physidae**
Mollusca	Gastropoda	Basommatophora	**Lymnaeidae**

Mollusca	Diplopoda	Amphipoda	**Gamaridae**
Mollusca	Bivalvia	Veneirdae	**Veneridae**
Mollusca	Bivalvia	Mytida	**Mytilidae**
Annelidae	-	Oligocheata	**Naididae**
Nematoda	-	Rhabditida	**Rhabditina**

Mollusca phylum with five orders and five families presented the highest diversity and abundance, also; Annelidae and Nematoda have the least diversity among the benthic fauna of Karoon River (Table 5). Table 6 showed that the families (Mytillidae, Naididae, Lymnaeidae, and Cirripedea) were observed in all seasons and in all stations. Four families (Mytillidae, Naididae, Lymnaeidae and Cirripedea) presented in autumn and this season had the lowest macro benthoses density compared to other seasons. Winter has the highest density compared to other seasons, and the only Rhabditina family has not been present in the winter. Chironomidae family has also been seen among macro benthoses only in winter. Chironomidae also are essential components of quantitive (rapid assessment) community approaches to bio monitoring (Rosenberg, 1992).

Table 6: The presence of macro invertebrates Family in 4 seasons in Karoon River 2013

Familly	**Spring**	**Summer**	**Fall**	**Winter**
Physidae	*	*	-	*
Rhabditina	*	—	—	—
Gammaridae	*	—	—	*
Mytillidae	*	*	*	*
Veneridae	—	*	-	*
Cirripedea	*	*	*	*
Naididae	*	*	*	*
Lymnaeidae	*	*	*	*
Chironomidae	—	—	—	*
Mysidae	*	*	—	*
Portunodae	*	*	—	*

According to Table 7, Mysidae and Portunodae families were not found at Dahaneh station. Five families (Physidae, Gammaridae, Rhabditina, Veneridae, and Cirripedea) were not reported at Station Bahrekani. The Rhabditina family was only reported at Station Dahaneh. The Gammaridae family was found only at stations Zhian Canal and Dahaneh only two families Lymnaeidae and Mytillidae families were reported at all stations.

Table 7: The presence of macro invertebrates Family in 4 stations in Karoon River 2013

Familly	Menikh	Zhian Canal	Bahrekani	Dahaneh
Physidae	*	*	—	*
Rhabditina	—	—	—	*
Gammaridae	—	*	—	*
Mytillidae	*	*	*	*
Veneridae	*	*	—	*
Cirripedea	*	*	—	*

Naididae	*	*	*	*
Lymnaeidae	*	*	*	*
Chironomidae	—	—	*	*
Mysidae	*	*	*	—
Portunodae	*	*	*	—

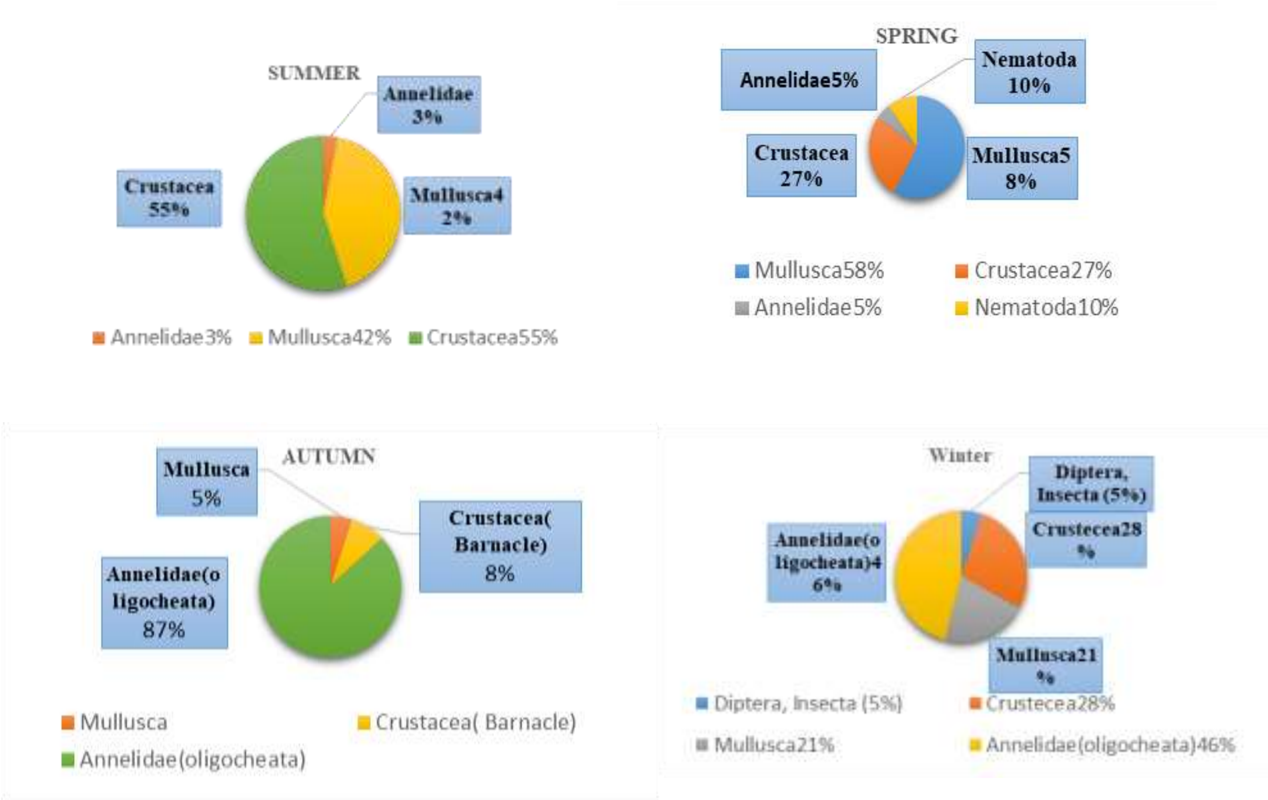

Figure 2: The percentage of abundance of macro invertebrates Phylum in different seasons

Mollusca was the most abundant macroinvertabrates phylum, corresponding to 58% and 48% of total sampled in spring and summer and Annelidae was the lowest density with 5% and 3% in the spring and summer, respectively. Crustacea was the second frequent with 55% and 28% in the summer and winter, respectively. In the autumn and winter, Annelidae has the highest density with 87% and 46%. Diptera was present only in winter with 5% total samples. Results of one-way analysis of variance showed a significant difference in the frequency of macro benthoses in different seasons (P≤0.05). Also, the diversity index was significant in different seasons (P≤0.05). Station Dahaneh showed a significant difference in terms of abundance and species richness compared to other stations (P≤0.05) (Table7).

Table 8: HFBI &BMWP results in different stations and seasons in Karoon River 2013

Stations	Spring HFBI	Spring BMWP	Summer HFBI	Summer BMWP	Autumn HFBI	Autumn BMWP	Winter HFBI	Winter BMWP
1	6.5	44	6.27	40	6	37	6	37
2	6	37	6	37	6	37	6	37
3	6	37	6	37	6	37	6	37
4	7.05	20	6	37	6	37	6	37

According to Table 8, in Menikh station, the water quality varied between 6-6.5 Class V (Regular) for the HFBI, and regular (Class V) for the BMWP (Table 8). In the middle region (Zhian Canal and Bahrekani) of Karoon river, the water quality were 6 class V (Regular) for the HFBI and regular (Class V) for the BMWP (Table 8). In the lower region (Dahaneh) the water quality varied between 6-7.05 Class V and VI (from regular to poor) for the HFBI and between 20-37 Class V and VI (from regular to poor) for the BMWP (Table 8). Results showed that there was not significant differences in HFBI and BMWP indices between station (2, 3) ($P \geq 0.05$), but station 1and 4 (Menikh and Dahaneh) showed that it was significant in HFBI and BMWP indices with other station ($P \leq 0.05$). The water quality did not change HFBI and BMWP indices between 4 stations in the fall and winter. In the summer water quality was similar in 3 regions (stations: 2, 3 and 4). In the spring

water quality declined. Results showed that there was not significant differences in HFBI and BMWP indices between three (winter, summer, autumn) seasons ($P \geq 0.05$) but spring season showed that it was significant in HFBI and BMWP indices with other seasons ($P \leq 0.05$.

4. Discussion

Increased contamination reduced the diversity and abundance of aquatic macroinvertebrates; as a result, in these polluted area, the BMWP index decreased and opportunistic species increased; (Sounders *etal.*,2007). The values of the physical variables of aquatic ecosystems mainly reflect the ecological conditions in different seasons and agricultural, urban, and industrial activities along the river (Ehlinger *et al.*, 2003). Changes in the diversity and abundance of benthic organisms in different seasons are due to fluctuations in the quantitative and qualitative parameters of water, nutrition and competition that affect the life cycle of these organisms. In Karoon River during the research period, the most abundance and diversity of benthic invertebrates was observed in spring. The water quality decreased in lower region (Dahaneh), this can reflect a variety of environment impact. Studies by Vosoughi *et al.* (2014) and Ebrahimi *et al.* (2017) are consistent with the results of this research. Increased contamination due to soluble nutrients and suspends solids (household wastewater, agriculture wastewater and industrial wastewater) caused increased contamination resistant macrobentic. According to studies, the structure of macro benthic communities of (Bivalvia, Gastropoda, Crustacea, and Annelidae) have been recorded. Results showed that in winter and spring, the water temperature is very suitable for growing aquatic plants and algae. In the winter, the highest density is for Annelidae with 46% and the lowest density for Diptera with 5%, and in the spring, the highest density is for Mollusca (58%) and the lowest for Annelidae with 5% (Figure 1). In these seasons (winter and spring), 9 families were identified (Table 7). Diversity of benthoses decreased and only three orders of Annelidae (87%), Mollusca (5%) and Crustacea (8%) from 4 families were present in autumn. In the summer, Crustacea with 55% and Annelidae with 3% from two orders and 8 families were present. Environmental factors such as the size of sediment constituents, the amount of dissolved oxygen in sediments, and the amount of organic materials in the sediment and biological agents, including how nutrition of the benthoses and the effects of their nutrition from other smaller species and the effects of biological disturbance in the environment are involved in the density and dispersion of benthic organisms in an ecosystem (Gholami *&* Nabavi ., 2016). Benthoses consumed organic materials in sediment; in addition to environmental parameters, hunger and changes in food in different seasons are factors that affect benthic communities. Hunters also affect the seasonal pattern of the macro benthic communities. But any external factor that can overcome periodicity, as a stressor will force the ecosystem to respond (Reiss & Koroncke, 2005). The results of HFBI indexes evaluated the water quality of Karoon River in regular and poor quality classes. In general, the values of this index have not been very fluctuating and have not been influenced by seasonal changes.

Higher levels of HFBI are due to the higher prevalence of highly polluted infections such as Chironomidae, Oligocheata, leeches, and vice versa. Low levels of this indicator are dominant contamination of benthic faunas such as Ephemeroptera and Trichoptera families (Ehlinger, 2003). The use of the BMWP index to assess wastewater contamination has been widely reported (Camargo and Gonzalo, 2007). During the study of the Helleh River, water quality was reported to be poor, BMWP index was undesirable and middle quality in hot and cold month respectively (Tabatabaei *etal*., 2009). The results of the BMWP index in Karoon River showed that the index is in poor and weak condition. In similar studies, from 2012 to 2014, the qualitative study of Karoon River using the NSF qualitative index and the AHP method reflects the fact that water quality index decreases when we approach the lower region of Karoon River (Madady Nia et al., 2014; Salari *et al.,* 2014). In 2015 to 2017, the results of independent studies on the quality indicators of Karoon River showed that Karoon River was affected by agricultural drainage, urban and industrial wastewater and placed on the middle class indexes, which means the use of water. The river is advanced after treatment, it is also heavy in terms of Hg and PAH levels above the limit. Khorramshahr Soap Factory and Abadan Oil Refinery have been the cause of the high levels of these pollutants in the region (Keshavarzi *et al.*, 2015; Moravej *et al.*, 2017). Overall, the findings from this study showed that all stations were in weak and poor and quality classes. These findings indicate that Karoon River has been increasingly affected by human activities, water utilization in agricultural seasons, receiving agricultural waste, evacuating domestic and industrial wastewater, and reducing the water quality of this river has risen, and if the proper management does not take place to organize and maintain its quality, the river will face a very high pollution risk in the near future and the life of its organisms will be at the risk of extinction.

5. Conclusion

Macro-bentic family are differentially sensitive to biotic and abiotic factors in their environment. Macroinvertabrates community has been used as an indicator of condition of an aquatic ecosystem. A total of 2,400 samples were collected. A total of 11 families were identified for Karoon River (Menikh, Canal Zhian, Bahrekani, Dahaneh). Our results showed that seasonal variation caused bio-diversity; consequently, we observed the greatest diversity of macrobentic in winter and spring due to increased nutrient and appropriate water temperatures. In Khuzestan region, winter and spring have the best temperature for the growth of macrobentic. Also, the upstream station (Menikh) of Karoon river had a better water quality of Biotic indices (HFBI, BMWP) than other stations. Urban and industrial wastewater treatment, preventation of household waste, river dredging, control of heavy metals and petroleum materials in the river to preserve the aquatic life, long term planning of water quality monitoring can improve the environmental status of Karoon River ecosystem.

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7. Additional information and declarations

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Competing Interests

The authors declare there is no competing interests, regarding the publication of this manuscript

Author Contributions

Sahar jalili: proposed the plan, conceived the experiments, analyzed the data, prepared figures, and tables, authored or revised drafts of the paper, and approved the final draft.

Data Availability

All the data are shown in the tables and graphs of this article.

Ethics Statement

The study was conducted by national and international guidelines (Directive

2007/526/EC of the European Commission) for the protection of animal welfare. Also approved by Scientific Association of Environmental Education and Sustainable Development (EESD)
http://www.ac.ir/environment

Supplemental Information
There is no supplementary information on this paper. Any questions and request for more information should be addressed on correspondence author.

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