

## Biological assessment of the Tang Sorkh River (Iran) using benthic macroinvertebrates

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Received: July 2015

Accepted: June 2016

### Abstract

A biological assessment of the Tang Sorkh River (Iran) was studied from July 2013 to August 2014 using benthic macroinvertebrate communities. Samples were gathered every two months, from five stations using a Surber sampler (30×30cm), fixed in formalin (4%) and then separated and identified in the laboratory. Environmental conditions (current velocity, temperature, depth, width, dissolve oxygen, conductivity, pH, alkalinity, Total Suspended Solids (TSS) and grain size) were measured. In addition, diversity and biotic indices were used to determine the water quality of the river. Results showed that 5 classes, 9 orders and 20 families were identified in this river. The families Hydropsychidae (Trichoptera), Simuliidae (Diptera) and Baetidae (Ephemeroptera) were dominant. Shannon-wiener and Simpson indices showed the highest diversity at station 1 and the lowest diversity in station 4. According to the Hilsenhoff, ASPT and BMWP indices, station 1 had good water quality for aquaculture.

**Keywords:** Macroinvertebrate communities, Diversity index, Biotic index, Tang Sorkh River

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## Introduction

Freshwater communities face numerous stressors such as pollution, habitat and hydrological changes (Allan, 2004; Wenger *et al.*, 2009) and the effects of climate change (Domisch *et al.*, 2011). These factors cause changes in the composition and abundance of the organisms and remove the aquatic organisms from the water body by increasing the levels of stressors (Sundermann *et al.*, 2015). Surface water quality evaluation provides detailed information on pollution of water resources by measuring physical and chemical parameters (USEPA, 2013). But these analyses cannot show the condition of freshwater ecosystems because they do not evaluate the state of biological communities (Mesgaran karimi *et al.*, 2016).

Biological assessments are suitable alternatives particularly in developing countries due to little experience and financial resources (Thorne and Williams, 1997; Resh, 2007). Biological assessment of rivers by macrobenthos compared to other aquatic organisms such as diatoms, fish and aquatic plants have been reported more useful by different researchers (Nemati Varnosfaderany *et al.*, 2010). And Macro-benthos have several benefits including long life cycle as a result of the environmental conditions, easy identification to family level compared to periphytons, abundance and diversity, sensitivity in different chemical and hydromorphological situations, easy sampling and requiring low numbers of people (Balderas *et al.*, 2016) and they are reliable target that can respond to

stress and environmental changes (Dehghan *et al.*, 2012)

Unfortunately, very little information is available about the Macro-benthos in rivers of Iran (Abbaspour *et al.*, 2013; Shirood Mirzaie *et al.*, 2013), and this research is the first study that examines the macroinvertebrates of Tang Sorkh River. Tang Sorkh River is located in southern Iran, in the northwest of the city of Shiraz in the Fars Province. Tang Sorkh River comes from the Qalat, Chahar Makan and Gerou Mountains and much of the catchment is mountainous, and vegetation in the highlands includes scattered trees and shrubs, and short grass in lower altitudes. The average height of the basin is between 1640 to 2940 meters, the weighted average slope of the basin is 33.9%, and rainfall in the basin is between 410 mm to 1070 mm. The region climate is from mild Mediterranean to very humid cold. Tang Sorkh River is one of the main branches of the Shiraz Khoshk River. Khoshk River has two branches namely Nehr-e-A'zam and Tang Sorkh that are joined at the beginning of the city of Shiraz, and after passing through the city, tends towards the southeast basin and goes into Maharloo Lake. Every year, due to rainfall and flood passing through the city, damages are imposed on urban lands and facilities, and major floods are originated from of Tang Sorkh River branch. That is why a dam called Tang Sorkh is through its administrative procedures in the densely populated urban area.

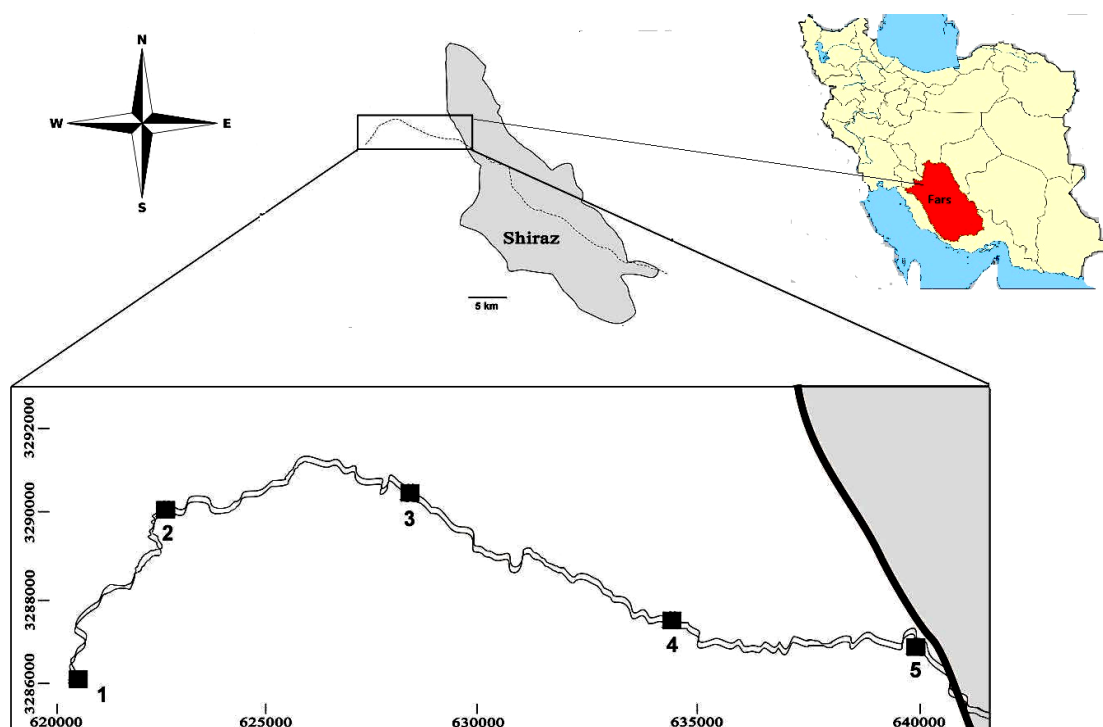


Figure 1: Location of the research area and sampling stations in Tang Sorkh River.

Station selection criteria were determined on the basis of special circumstances in this study, and taking into study sites were chosen along the river, whose profiles have been presented in (Fig. 1).

The aim of this study was to evaluate biological assessment of the Tang Sorkh River using Hilsenhoff, BMWP and ASPT indices base on the diversity of macroinvertebrate communities.

## Materials and methods

### Sampling methods

Sampling was done using Surber (30×30 cm) every two months from July 2014 to May 2015 within the selected stations in three replications. Random sampling was conducted at each station along an imaginary line perpendicular to the water flow. After fixation

with 4% formalin and packing and label installation, samples were taken to the laboratory for subsequent review. In the laboratory, the samples were washed with 70% ethanol again and maintained with ethylic 70%. Samples were identified as much as possible using different authentication keys (Elliott *et al.*, 1988), Hynes (1984), Milligan (1997), and Pescador *et al.*, (2004). In this study, physical and chemical factors were also examined. Temperature and water flow rate were recorded in the sampling site, and water sample was fixed and transferred to the laboratory for other analyses. Dissolved oxygen, pH, EC, TDS and alkalinity were measured using APHA (1992) in the laboratory calculated. ASPT index was calculated by dividing BMWP value to the number of households. (Armitage *et al.*,

1983; Walley and Hawkes, 1996). By the way, Hilsenhoff index was calculated by  $FBI = \frac{\sum n_i a_i}{N}$ , each score, except Euphaeidae household, was calculated by the scores provided by Lenat (1993) and Voelker and Rann (2000).

#### *Data analysis*

Data were tested for normality and homogeneity of variance before application of parametric tests. Subsequent significance between diversity and biological parameters in different months and stations was defined by Duncan's multiple range tests using the statistical software SPSS version 18. Pearson correlation coefficient was calculated for physiochemical variables, biological and diversity indices. Data are presented as means  $\pm$  standard of deviation (SD). Differences were considered significant when *p* value was less than 0.05.

#### **Results**

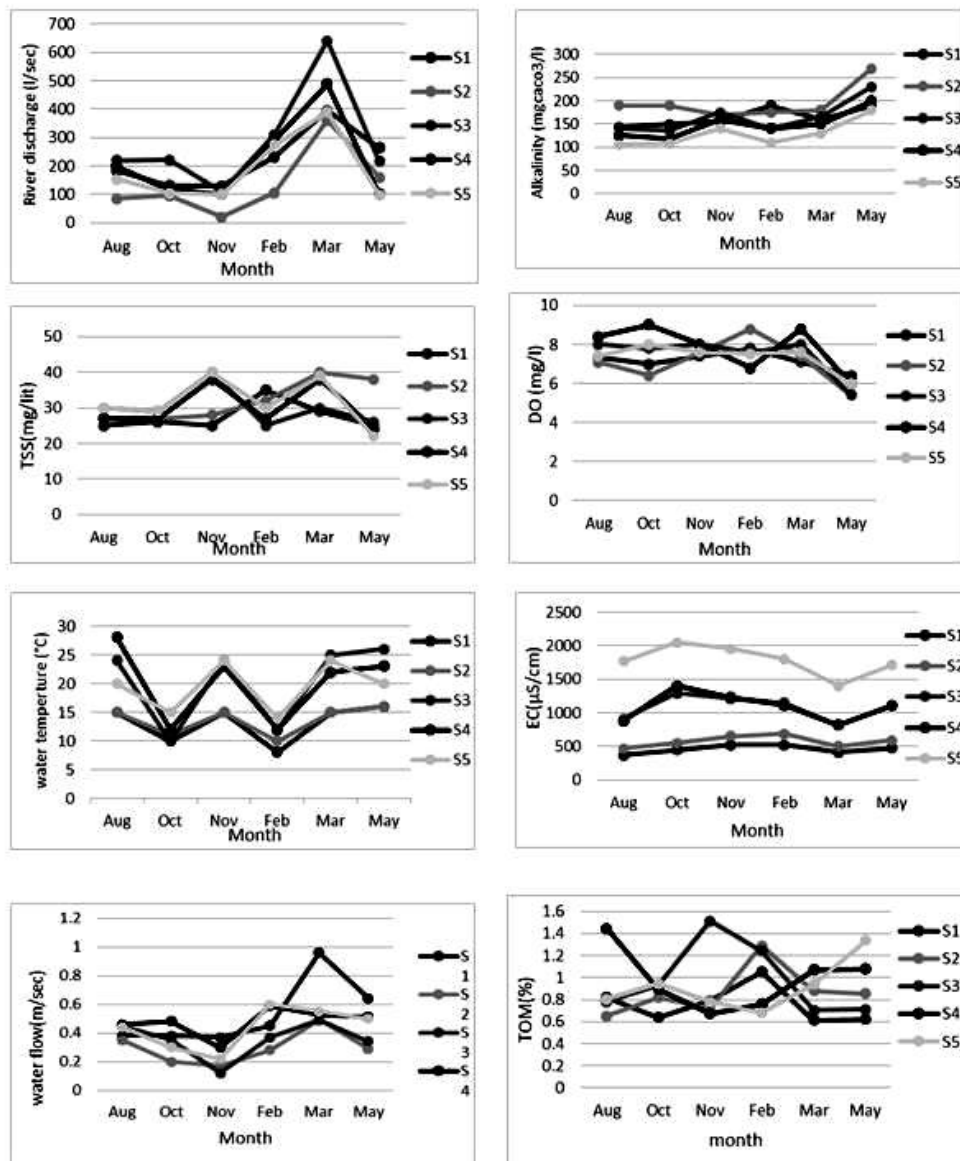
Hydrological factors of Tang Sorkh River have fluctuated in different months and stations. Water flow in different periods and stations showed a lot of changes, so that the minimum average water flow rate in November was  $0.24 \pm 0.02$  m/sec and maximum water flow rate in March was  $0.6 \pm 0.09$  m/sec. Consequently, the lowest and highest average rates were observed in November and March equal to 92.5 and 455.6 L/sec, respectively.

pH in the river had low fluctuations over a period of one year with an average of  $7.6 \pm 0.09$ . In this study, the max-

imum amount of alkalinity was observed in May in station 2 ( $270 \pm 37$  mg CaCO<sub>3</sub> L<sup>-1</sup>) and its minimum was measured in August in station 5 ( $106 \pm 31$  mg CaCO<sub>3</sub> L<sup>-1</sup>). Water temperature changes showed a decreasing trend from August to February, but in October, the arrival of cold weather in the region caused a sudden drop in air temperature and thus reduced water temperature and then the water temperature showed a rising trend until May. Reviewing analyses of dissolved oxygen in Tang Sorkh River, the minimum and maximum values of the parameter was observed in May and October, respectively. It is noteworthy that the average amount of dissolved oxygen in the river during a year of sampling was recorded as  $7.45 \pm 0.34$  mgL<sup>-1</sup>.

Electrical conductivity (EC) was significantly increased in the river from upstream to downstream, and for the entire period of sampling, the lowest and highest EC were observed in the stations of 1 and 5, respectively. The average percentage of organic matter in the survey was measured at about  $0.9 \pm 0.06$ , and total organic materials in all seasons, was less than or close to one. Soil texture in Tang Sorkh River was as follows: station 1 and 3: Sand; station 2: Sandy Loam; station 4: Loamy Sand; and station 5: Silty Loam.

During one year of sampling in Tang Sorkh River of Shiraz, a total of 5 classes, 9 orders and 20 families of Macro-benthos were identified (Table 1).



**Figure 2: Variations in physicochemical parameters Tang Sorkh River of Shiraz during one year of sampling: River discharge (L/sec), Alkalinity (mgCaCO<sub>3</sub> L<sup>-1</sup>), TSS (mg/L), DO(mgL<sup>-1</sup>), Water temperature (°C), EC (µS/cm), Water flow (m/sec), TOM (%).**

These Macroenthos included Odonata, Ephemeroptera, Plecoptera Diptera, Coleoptera, Trichoptera, Amphipoda, Haplatoxida, Basommatophora.

The highest frequencies were in Trichoptera (40%), Ephemeroptera (21.2%) and Diptera (16.4%), respectively. The lowest frequencies recorded

in Amphipoda, Haplatoxida, Plecoptera and Rhynchobdellida, respectively. In terms of number and diversity, insect larvae constituted the major composition of the population in all stations, among which larvae of Odonata and Diptera order had the largest number of identified families (four families).

**Table 1: Macroinvertebrates collected during one year of sampling in Tang Sorkh River of Shiraz along with scores of BMWP and revised BMWP (Walley and Hawkes, 1996) and Hilsenhoff indices.**

| Order           | Family            | Genera               | Species                | BMWP score | Revised BMWP score | Hilsenhoff score |
|-----------------|-------------------|----------------------|------------------------|------------|--------------------|------------------|
| Odonata         | Aeshnidae         | <i>Anax</i>          | Sp.                    | 8          | 6.1                | 3                |
|                 | Curdolegasteridae | <i>Curdolegaster</i> | <i>Insignis</i>        | 8          | 6.4                | 3                |
|                 | Gomphidae         | <i>Onychogomphus</i> | Sp.                    | 8          | 8                  | 1                |
| Ephemeroptera   | Euphaeidae        | <i>Epallage</i>      | <i>Epallage fatime</i> | 9          | 9                  | 6                |
|                 | Baetidae          | <i>Baetis</i>        | Sp.                    | 4          | 3.5                | 4                |
|                 | Oligoneuriidae    |                      |                        | 8          | 8                  | 2                |
| Plecoptera      | Leuctridae        | <i>Leuctra</i>       | Sp.                    | 10         | 10                 | 0                |
|                 | Simuliidae        | <i>simulium</i>      | Sp.                    | 5          | 5.8                | 6                |
| Diptera         | Tipulidae         | <i>Tabanus</i>       | Sp.                    | 5          | 5.5                | 1                |
|                 | Tabanidae         |                      |                        | 5          | 5                  | 1                |
|                 | Chironomidae      |                      |                        | 2          | 3.8                | 6                |
| Coleoptera      | Dytiscidae        | <i>Lacobius</i>      | <i>Lacobius</i> sp.    | 5          | 4.8                | 5                |
|                 | Hydrophilidae     |                      |                        | 5          | 5.1                | 5                |
|                 | Dryopidae         |                      |                        | 5          | 6.5                | 5                |
| Trichoptera     | Hydropsychidae    |                      |                        | 5          | 6.6                | 4                |
|                 | Hydroptilidae     |                      |                        | 6          | 6.6                | 4                |
| Amphipoda       | Gammaridae        | <i>Gammarus</i>      | <i>Crinicanthus</i>    | 6          | 4.5                | 6                |
| Haplatoxida     | Haplotoxidae      |                      |                        | 1          | 3.5                | 5                |
| Rhynchobdellida | Glossiphoniidae   |                      |                        | 3          | 3                  | 10               |
| Basommatophora  | Lymnaeidae        | <i>Lymnaea</i>       |                        | 3          | 3                  | 6                |

Unlike other insects, only one family of Leuctridae was seen in Plecoptera order in the station 1. Samples of Baetidae, Simuliidae and Hydropsychidae families were present at all stations. However, members of Oligoneuriidae family was present at stations 3, 4 and 5. Gomphidae family was seen only in the station 3. Chironomidae and Glossiphoniidae families were seen only in station 5.

According to Shannon-Wiener diversity index, Simpson diversity index and Margalef index, stations 1 and 4 showed the maximum and minimum variation, respectively. And the biological indices used except Hilsenhoff showed no significant differences in the months of sampling, but these indices were different among stations.

Pearson correlation coefficients between physicochemical variables, biotic and diversity indices are shown in Table 3. EC and water temperature significantly correlated with diversity indices but others did not significantly correlate. Also biotic indices (Re-BMWP and HFBI) have negative correlation ( $p \leq 0.01$ ) with EC and Re-BMWP index has positive correlation ( $p \leq 0.05$ ) with depth.

## Discussion

### Macroinvertebrates

In this research, during a year of sampling, most of the aquatic insects in the Tang Sorkh River were comprised of types of Trichoptera (*Hydropsychidae*), Ephemeroptera (*Baetidae*) and Diptera (*Simuliidae*). It seems that these three

families exist in most rivers of Iran (Nemati Varnosfaderany *et al.*, 2010; Abbaspour *et al.*, 2013; Shokri *et al.*, 2014). A wide range of macrobenthos in the river was larvae from *Trichoptera* that they can be useful in detection of unknown pollution and because of their easy identification toward other macrobenthoses, they have potential ability in designation of water quality (Balint *et al.*, 2006). Another group observed abundantly in rivers was *Baetis* (*Baetidae*) which is mostly found in rocky substrates where soil texture of this river is often rocky.

*Simuliidae* is one of the families found in abundance in Tang-Sorkh River. This family has allotted a considerable part of macrobenthos communities to itself which is discussed as a food for other invertebrates (Werner and Pont, 2003) and they feed from organic materials floating in the water column. The principal environmental factors affecting simuliid distribution are water temperature, current velocity, pH, stream width and depth, etc (Tangjura *et al.*, 2015). Because they are heat-loving (Butler and Hogsette 2007) rising temperature in downstream stations in this study, increased the number of family members. Presence of this family is as an indicator which is representative of rivers health and that it has not been affected by human activities (Resh *et al.*, 1995).

#### *Diversity index*

According to information presented in Table 2, Shannon-Wiener diversity index decreases from upstream to down-

stream of Tang Sorkh River. Station 4 (S<sub>4</sub>) shows the minimum diversity recorded during all sampling courses which seems that gradual increment of velocity and re-mountainous nature of this region has invoked the omission of sensitive species and a decrease in diversity (Allan, 2004). In the following, this index shows little growth in station 5 which is probably due to outbreak of species which are resistant to pollution such as *Glossiphoniidae*. The macrobenthic community structure is sensitive to the hydrological changes. Results have shown that the abundance of some species belonging to *Trichoptera* and *Diptera* orders vary by a change of water flow and habitat. Some studies have reported increment of these orders in low-water seasons and other similarities of macrobenthic community structure in different seasons (Melo and Froehlich, 2001; Tomanova and Usseglio-Polatera, 2007; Rios-pul Grain *et al.*, 2016). Mathuriua *et al.* (2008) associated the differences in these results to difficulty of fauna change detection of each region.

Besides, according to Table 3, EC and temperature have negative effects on diversity index of this river ( $p \leq 0.01$ ) and by increment of these two factors in downstream of Tang-Sorkh River, the value of Shannon-Wiener and Simpson diversity index decreased

**Table 2: Biological and diversity indices calculated during one year of sampling in Tang Sorkh River of Shiraz (mean + SD).**

| <i>Indices</i> \ <i>Site</i>   | <i>S<sub>1</sub></i>   | <i>S<sub>2</sub></i>   | <i>S<sub>3</sub></i>   | <i>S<sub>4</sub></i>   | <i>S<sub>5</sub></i>   |
|--------------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
| BMWP                           | 38±10.2 <sup>a</sup>   | 20.6±7.1 <sup>bc</sup> | 28.8±6 <sup>ab</sup>   | 11.6±5.8 <sup>c</sup>  | 14.5±6.4 <sup>c</sup>  |
| ASPT                           | 6.1±1.5                | 4.6±0.7                | 5.4±1                  | 4.9±1.1                | 4.8±1.5                |
| Re-BMWP                        | 42.4±11.8 <sup>a</sup> | 25.4±6.9 <sup>bc</sup> | 30.2±4.6 <sup>b</sup>  | 16±7.5 <sup>c</sup>    | 17.5±3.8 <sup>c</sup>  |
| Re-BMWP                        | 6.8±1.7                | 5.7±0.86               | 5.6±0.64               | 6.7±1.1                | 5.8±0.67               |
| HFBI                           | 4.9±0.47 <sup>ab</sup> | 5.2±0.27 <sup>a</sup>  | 4.9±0.68 <sup>ab</sup> | 4.4±0.43 <sup>bc</sup> | 4.1±0.4 <sup>c</sup>   |
| Shannon-wiener diversity index | 1.51± 0.4 <sup>a</sup> | 1.32±0.2 <sup>ab</sup> | 0.69±0.4 <sup>bc</sup> | 0.51±0.4 <sup>c</sup>  | 0.7± 0.4 <sup>c</sup>  |
| Margalef's index               | 1.59± 0.6 <sup>a</sup> | 1.1±0.3 <sup>bc</sup>  | 1.23±0.2 <sup>ab</sup> | 0.46±0.3 <sup>d</sup>  | 0.69±0.3 <sup>cd</sup> |
| Simpson's diversity index      | 0.7±0.1 <sup>a</sup>   | 0.7±0.07 <sup>a</sup>  | 0.46±0.2 <sup>b</sup>  | 0.23±0.3 <sup>c</sup>  | 0.39±0.6 <sup>bc</sup> |

Different letters within the same row show significant differences ( $p < 0.05$ ).

**Table 3: Pearson's correlation coefficients between biological indices and water physico-chemical variables.**

|                   | BMWP      | ASPT      | Re-BMWP    | Re-ASPT | HFBI       | H'         | D          | R         |
|-------------------|-----------|-----------|------------|---------|------------|------------|------------|-----------|
| Water temperature | -0.257    | 0.055     | -0.36      | -0.024  | -0.357     | -0.597(**) | -0.626(**) | -0.423(*) |
| EC                | -0.474(*) | -0.159    | -0.535(**) | -0.053  | -0.509(**) | -0.510(**) | -0.467(*)  | -0.439(*) |
| TSS               | -0.24     | -0.420(*) | -0.21      | -0.334  | 0.032      | -0.031     | -0.046     | -0.002    |
| Alkalinity        | 0.071     | -0.118    | 0.051      | -0.323  | 0.342      | 0.197      | 0.198      | 0.222     |
| Water flow        | -0.061    | -0.033    | -0.023     | -0.173  | -0.05      | -0.084     | -0.08      | -0.079    |
| Width             | -0.033    | -0.147    | -0.078     | -0.266  | 0.23       | -0.131     | -0.218     | 0.015     |
| Depth             | 0.369     | 0.214     | 0.425(*)   | 0.236   | 0.045      | 0.247      | 0.223      | 0.265     |
| River Discharge   | 0.084     | -0.028    | 0.067      | -0.031  | -0.029     | -0.049     | -0.098     | 0.061     |

The variable include Biological working Party score (BMWP), average score per taxon (ASPT), revised BMWP score (RE-BMWP), revised ASPT (Re-ASPT), Hilsenhoff (HFBI), Shannon-wiener diversity index (H'), Simpson's diversity index (D) and Margalef's index(R).

EC depends on a region primarily where a river flows through it. Soil texture of Tang-Sorkh River changed from station 1 to station 5, from sandy to loamy-silty causing increment of portable materials in river (Sponseller *et al.*, 2001). On the other hand, various gardens around river (Stations 2 and 3) as well as town and dam construction around station 5 have increased sediment input to the river. In similar examinations, EC has also been introduced as one of the effective factors on mac-

robenthic community structure (Misrendino *et al.*, 2008).

A major part of the rainfall in the case study is accomplished during November to April (Montazeri *et al.*, 2014). The results of flow rate are in conformity with annual precipitation results and maximum and minimum flow rates and velocity were recorded in April and November, respectively and the abundance of macrobenthoses decreased in April as following. By decrement in flow rate in the coming months, the abundance of macroben-



thoses also increased. According to the report from Alimohammadi *et al.* (2013), this river is flooded in winter and spring. Erosion and sedimentation will occur only within a flooded month and significantly change morphology of the river (Zhang, 2010) and creatures depending on their species take one or several months to be replaced (Xu *et al.*, 2012).

#### *Biological index*

In this research, BMWP and revised BMWP indices were calculated at the family level because they did not have access to detection key of macrobenthos in Iranian waters at species level. In fact, calculated score at the family level shows tolerance range of species (Armitage *et al.*, 1983) and besides, using these indices at the family level, due to easy calculation and less necessity to taxonomic science, is beneficial (Nemai Varnosfaerany *et al.*, 2010). To calculate BMWP index presented score in revised list, because of absence of family score of Tabanidae, and to calculate revised BMWP, family score of Gomphidae in primary list was used. Similarly, family score of Euphaeidae was used in other articles since it did not exist in none of calculated score lists (Blakely *et al.*, 2014). In this study range of changes of revised BMWP index calculated was 17.5 to 42.4 that according to water quality standard, based on this water quality index, this river is recorded in the middle class in station 1 and in other stations it was established in the bad class. Also, according to Table 3 these indices show a negative cor-

relation with EC which was in agreement with results reported by Nemai Varnosfaderany *et al.* (2010) and Shokri *et al.* (2014). In this study, minimum average value of Hilsenhoff index was obtained in station 4 and the maximum value was obtained in station 2. All indices presented station 1 as the cleanest station from the viewpoint of contamination and other stations are placed in various quality classes according to different indices. Besides, Hilsenhoff index recorded study stations, except station 2, in water quality class with high quality while revised ASPT index, except for station 1, showed station 4 in clean water class and BMWP index put station 1 in an intermediate water quality class and the others were placed in bad class. In other studies it has been explained that some biological indexes cannot specify water quality accurately because response of different species to chemical conditions in geographical regions is varied (Sharifinia *et al.*, 2015). According to the results, it seems that these indexes shall be examined in accordance with Iranian river conditions and tolerance of each family to various pollution shall be reviewed so that these indexes can explain better water quality of Iranian rivers. To evaluate this river more precisely, more and more regular sampling and further investigations upon species will be useful.

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