Biological index and pollution assessment of Damghanroud river in the Semnan province

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Abstract

Fresh water rivers are one of the most important aquatic ecosystems in arid and semi-arid regions of Iran in viewpoint of biodiversity and drinking water. Damghanroud river is one of the rivers in the Semnan province that during past years has been threatened by drought and anthropogenic pollutions. This river supplies some parts of drinking water of Damghan city and some vicinity villages. The aim of the present study was biological index assessment of the Damghanroud river. At this study, seven sampling stations were determined based on limnological standard method along the river. Sampling of invertebrates and water were performed respectively to calculate biological index and biochemical oxygen demand (BOD) seasonally during the study period. The results showed that the first station (Cheshmeh-Ali) is free of pollution while the fourth sampling station (Doab) is the most polluted region at the river because the first station has no pollutant resource but the fourth station directly receives wastewater of the agricultural activities and rural wastewaters. According to biomonitoring and water BOD measurement findings, Damghanroud river has relatively polluted situation and is classified in β-mezosaprobe class and benthos biological index has been deteriorated at this river.

Keywords: Damghanroud river; Semnan province; Biological index; Biochemical oxygen demand

1. Introduction

Rivers are considered as the main water suppliers for human uses. Discharging organic and inorganic pollutants as well as nutrients are contributed as major causes of river water quality deterioration (Mehrdadi *et al.,* 2006). Surface waters are most vulnerable to pollution due to easy accessibility for disposal of wastewaters. Both the natural processes, such as precipitation inputs, erosion, weathering of crustal materials, as well as the anthropogenic influences including urban, industrial and agricultural activities, increasing exploitation of water resources, together determine the quality of surface water in a region (Singh *et al.,* 2004). The climate of Iran's central basin is arid and there are a few perennial rivers in these regions (Rezaei Tavabe and Azarnivand, 2013). Also, the precipitation variability is significant in arid and semi-arid regions of the world, such as Iran, (Naserzadeh and Ahmadi, 2012; Shahabfar and Eitzinger, 2013; Zarei *et al.,* 2013; Asefjah *et al.,* 2014; Afzali *et al.,* 2016). Rivers are the most important aquatic ecosystems in these regions of Iran central basin that originate in margins highlands and then are terminated in central plateau. These rivers are worthwhile in point of biodiversity, social, economic and drinking water in arid and semi-arid regions. The rivers and their ecology are often out of sight and out of mind, so it is important to consolidate our knowledge and provide a basic framework for ecological understanding or dry land rivers. Local variations in water quality can be assessed by chemical parameters or by biological effects. Thus, the relationship between aquatic benthos and water quality can

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be studied at several spatial levels (Daniel and Haury, 1995; Maidment, 2016). All environments vary and organisms exploiting them are likely to evolve adaptations for dealing with fluctuations in favorability (Laronne and Reid, 1993).

High concentrations of organic matters in surface waters can result in depletion of dissolved oxygen with subsequent adverse effects upon human life (Kotti *et al.*, 2005). The assessments of water quality contaminations require monitoring of a wide range of physical, chemical and biological parameters. The degree of organic pollution which occurs due to an excessive amount of organic matter has typically been monitored by measuring BOD and COD values in rivers (Hur and Cho, 2012). The usual situation is the measurement of multiple parameters, taken at different monitoring times, and from many monitoring stations (Chapman, 1992; Maidment, 2016). Such species are used for a calculation of biological indices giving information about the state of the natural environment. The structure of biocenosis (in particular taxocenosis) which consists in numbers and abundances of species as well as of their dominance relations can be used for bio-indication. Biocenosis structure is usually described by biodiversity indices and derived indices or by similarity indices allowing the structure of the investigated community to be compared with that of a control community (Chomczyńska *et al.*, 2008).

One of the most important anthropogenic impacts on the environment is the disposal of wastewaters that originate from human activities. Rivers play a major role in assimilation or carrying off the municipal and industrial wastewaters and run-off from agricultural land. Among liquid wastes, wastewaters contaminated by biodegradable pollutants constitute a common by-product of both civil settlements and industrial facilities. Seasonal variations of precipitation, surface runoff, interflow, groundwater flow and pumped in outflows have strong effects on river discharge and subsequently, on the concentration of pollutants in river flow (Vega *et al.*, 1998). Biological monitoring methods are playing an increasingly important role in river quality monitoring, mainly due to the fact that the biota are continuous witnesses of the river's state of health and are collectively sensitive to the whole range of potential pollutants (Grobvi *et al.*, 1997). Degradation of organic matter by heterotrophic bacteria is one of the major processes controlling the oxygen level of aquatic ecosystems and thus their quality. In most aquatic ecosystems, organic matter has a mainly autochthonous origin but, for rivers flowing through urbanized areas, wastewater effluents can be the major source of organic matter (Servais *et al.*, 1995).

Damghanroud river is one of the most important rivers in the Semnan province that originates from northwestern of the Damghan city and then terminates in the Hajaligholi desert in the southern of Damghan city. The most importance of this river is related to a new established dam (Damghan dam) with multi-purpose usages along the river. The river has been threatened by different pollutions during past years. In the present study, Damghanroud river saprobe condition, self-purification rate and biological index evaluate based on limnological and hydrobiological standard methods.

2. Material and Methods

2.1. Sampling stations

The Damghanroud river has been located in 32 Km northwestern from the Damghan city in the Semnan province on way the Damghan-Kiasar-Sari road. The main branch of the river is Cheshmehali that originates from a permanent spring near to the Roudbar village. Other branches that connect to the Damghanroud river are Doab, Shourtangeh and Chardeh rivers. At the present study, totally 7 sampling stations, namely Cheshmehali (station 1), downstream of Cheshmehali (station 2), downstream of Shourtangeh river mixed point (station 3), downstream of Doab river mixed point (station 4), location of the teleferic bridge (station 5), between the teleferic bridge and Damghan dam (station 6) and Damghan dam drainage (station 7) were selected on the river under the river quality-monitoring network. The sampling network was designed to cover a wide range of determinants at key sites, which reasonably represent the water quality of the river system accounting for nranch and inputs from wastewater drains that have impact on downstream water quality.

2.2. Invertebrate and water sampling

Invertebrate and water (BOD factor) samples were collected each season at three points (1/4, 1/2 and 3/4) across the river width at all the 7 stations with a view to monitor changes caused by the seasonal limnological. Invertebrate sampling was accomplished by surber or foot square-foot sampler and BOD of the water

samples were determined by winkler azide   method (Chapman, 1992).

Table 1. Location and geographic point of sampling stations

Station number	station	position
1	Cheshmehali	N 36° 16′ 42″ E 54° 05′ 04″
2	downstream of Cheshmehali river	N 36° 16′ 02″ E 54° 05′ 53″
3	downstream of Shourtangeh river	N 36° 16′ 16″ E 54° 06′ 37″
4	downstream of Doab river	N 36° 15′ 08″ E 54° 09′ 06″
5	location of the teleferic bridge	N 36° 13′ 33″ E 54° 12′ 57″
6	between the teleferic bridge and Damghan dam	N 36° 13′ 35″ E 54° 03′ 27″
7	Damghan dam drainage	N 36° 13′ 39″ E 54° 15′ 10″

3.2. Biologic index (Z) estimating

To determine river water quality, estimating the biological index is requirement. Biological index is calculated by Baur formula (Baur, 1980) and wegl invertebrate benthos table (Wegl, 1983). As below:

$$Z = \frac{\sum o + 2\sum \beta + 3\sum \alpha + 4\sum p}{\sum h}$$

Z= Biological Index
$\sum o$= Number of invertebrates related to oligosaprobe region
$\sum \beta$= Number of invertebrates related to β-mezosaprobe region
$\sum \alpha$= Number of invertebrates related to α-mezosaprobe region
$\sum p$= Number of invertebrates related to polysaprobe region
$\sum h$= Total number of invertebrate samples

Table 2. Biological index and river saprobic condition (Ahmadi and Nafisi, 2001)

Biological index (Z)	Water quality	Water region	Saprobic condition
1-1.5	Good	I	Oligosaprobe
1.5-2.5	Moderate	II	β-mezosaprobe
2.5-3.5	Relatively weak	III	α-mezosaprobe
3.5-4	Weak	IV	polysaprobe

4.2. Statistical Analysis

The data were normalized by Shapiro-Wilk test and then were analyzed statistically. Data were subjected to one-way ANOVA; significant differences between the means were compared with the Duncan's test, and statistical significance was tested at a 0.05 probability level using SPSS version 18.0.

3. Results

1.3. Biological index

The results of biological index assessment are given in table 3. In the current study, 18 genius and species of aquatic insects including larvae, pupa and adult were identified then at each station, based on their tolerance biological index were calculated (Baur, 1980) seasonally (Table 3). The results confirmed that in all seasons, the lowest biological index mean of Cheshmehali and Damghan dam drainage stations showed significant differences (P<0.05) among the

sampling stations. The results also showed that the maximum total biological indices were recorded for downstream of Cheshmehali river, downstream of Shourtangeh river and downstream of Doab river sampling stations (Fig. 1).

2.3. Biochemical oxygen demand (BOD)

BOD values in the Cheshmehali and Damghan dam drainage stations were recorded significantly (P<0.05) as the lowest in all season. According to the results in all seasons, changing procedures of BOD value along the Damghanroud river are approximately same (Table 4). The minimum (1.21±0.11) and maximum (15.04±1.08) BOD values were recorded at Damghan dam drainage in spring season and at downstream of Doab river in summer season respectively (Table 4). The results also showed that the lowest BOD was recorded for Cheshmehali and Damghan dam drainage sampling stations (Fig. 2).
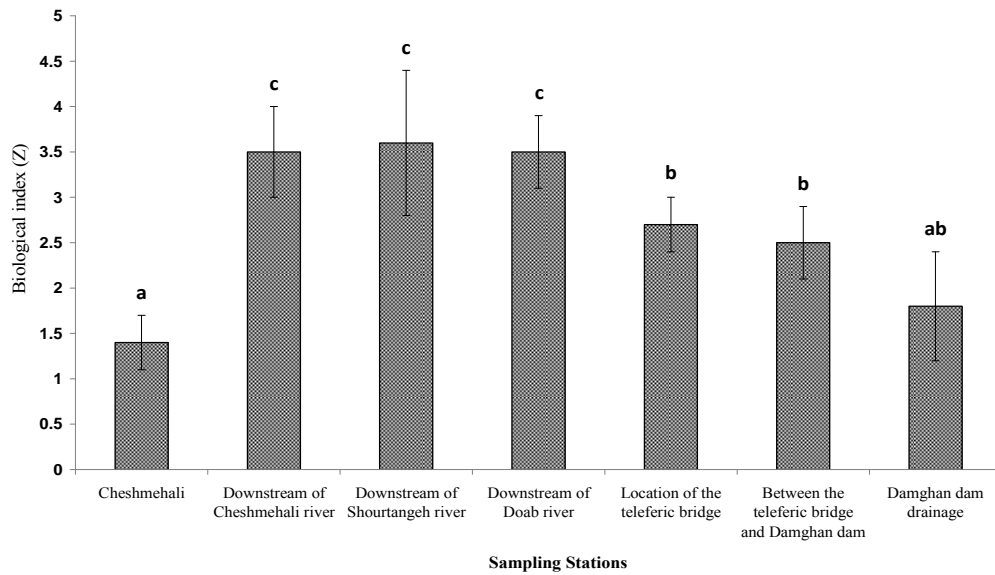
Fig. 1. Comparison of average biological index among studied sampling stations. Means with different letters are significantly different (P < 0.05)

Table 3. Biological index at different sampling stations during the study period

Sampling station number	Location	Spring	Summer	Autumn	Winter
1	Cheshmehali	1.35±0.07 [a]	1.48±0.14 [a]	1.46±0.11 [a]	1.33±0.14 [a]
2	Downstream of Cheshmehali river	3.12±0.13 [b]	3.81±0.18 [c]	3.71±0.25 [c]	3.41±0.22 [c]
3	Downstream of Shourtangeh river	3.22±0.26 [b]	3.79±0.24 [c]	3.55±0.27 [c]	3.68±0.24 [c]
4	Downstream of Doab river	3.15±0.21 [b]	3.74±0.19 [b]	3.67±0.31 [c]	3.41±0.29 [c]
5	Location of the teleferic bridge	2.73±0.16 [b]	2.61±0.13 [b]	2.76±0.25 [b]	2.71±0.17 [b]
6	Between the teleferic bridge and Damghan dam	2.81±0.14 [b]	2.56±0.11 [b]	2.44±0.19 [b]	2.49±0.23 [b]
7	Damghan dam drainage	1.42±0.12 [a]	1.75±0.18 [a]	1.81±0.14 [a]	1.51±0.09 [a]

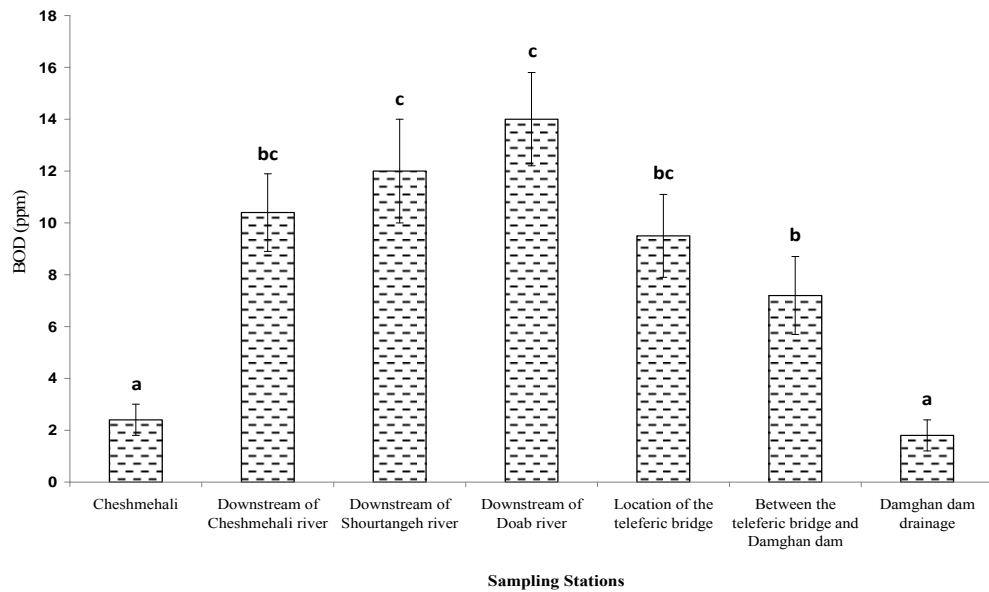Values with the same superscript letters in a column are not significantly different at the 0.05 level.

Fig. 2. Comparison of average BOD among studied sampling stations. Means with different letters are significantly different (P < 0.05)

Table 4. BOD parameter at different sampling stations during the study period

Sampling station number	Location	Spring	Summer	Autumn	Winter
1	Cheshmehali	1.94±0.19 [a]	2.35±0.34 [a]	2.24±0.25 [a]	2.52±0.26 [a]
2	Downstream of Cheshmehali river	9.45±0.8 [bc]	11.19±1.12 [bc]	10.13±1.2 [bc]	10.29±1.41 [bc]
3	Downstream of Shourtangeh river	10.51±0.84 [c]	13.37±0.68 [c]	12.69±1.55 [bc]	11.38±1.47 [bc]
4	Downstream of Doab river	10.77±0.89 [c]	17.04±1.08 [d]	14.43±1.62 [c]	13.21±1.17 [c]
5	Location of the teleferic bridge	8.37±0.48 [bc]	10.12±1.48 [bc]	10.28±1.24 [bc]	9.28±1.29 [bc]
6	Between the teleferic bridge and Damghan dam	6.53±0.71 [b]	8.13±1.09 [b]	7.24±1.23 [b]	7.13±1.28 [b]
7	Damghan dam drainage	1.21±0.11 [a]	2.16±0.21 [a]	2.06±0.15 [a]	1.92±0.24 [a]

Values with the same superscript letters in a column are not significantly different at the 0.05 level.

4. Discussion

The results of the current study recorded the lowest Biological index and BOD values at upstream point (Station #1) and downstream point (Station #7) of the Damghanroud river while these values were significantly higher at the intermediate sampling stations. This matter indicates that the river in origination and termination areas has the minimum pollution. Because at the origination area there are no any pollutant source and the termination area self-purification phenomenon remove pollution along the river. Self-purification potential is a capability by which rivers are enabled to dilute, lessen or eliminate the undesirable effects of entered pollutants. Precise specification of such capability may be considered as a powerful instrument in rivers sustainable management (Mehrdadi *et al.*, 2006; De los Rios Escalante *et al.*, 2015). The capacity of the self-purification is closely related with the characteristics of the river including the flow discharge, flow rate, sediment-load and creatures in the rivers. For a certain river, the capacity of the self-purification is determined. When the total amount of pollutants is beyond the self-purification capacity of the river, the river will be polluted. The self-purification is an index to estimate the pollution accommodation of the river (Tian *et al.*, 2012). Water self-purification and the improvement of water quality are necessary for the self- maintenance of the entire aquatic ecosystem, as they provide for the remediation of the habitats of aquatic species (Wei *et al.*, 2009). The role of self-purification increases due to the deterioration of natural water quality and increased anthropogenic load on water bodies and streams (Ostroumov, 2005).

The effects of anthropogenic disturbances in the receiving systems can be assessed by measuring changes in community structural parameters including biodiversity indicators, biotic indices, community structure and beta-diversity. Beta-diversity is generally expected to be low among harsh sites because few species from the potential regional species pool are adapted to survive the harsh environmental conditions (Kabir *et al.*, 2015). According to the results, in summer season the highest biological index value recorded at the sampling stations # 2 and # 3 where mainly receive organic pollutions from the Cheshmehali recreational center that effect on the benthos biodiversity and invertebrate fauna community. Indices are useful tools to communicate with managers because they reduce complex scientific data, integrate different types of information, and produce results that can be easily interpreted in the perspective of water quality management (Wilson and Jeffrey, 1994). One of the major advantages of biomonitoring with benthic invertebrates is the possibility to detect changes in water quality that occur at the time of sampling as well as changes that have occurred within a longer period before sampling, due to the relatively sedentary life style and long life spans of these organisms (Rosenberg and Resh, 1996; Schwoerbel, 1999; Rezaei Tavabe *et al.*, 2010). The use of the benthic invertebrate fauna as an indicator for a qualitative classification of freshwater systems has increased in many regions of the world within the last years (Roldan, 2003). Therefore, organic pollution has the potential to affect the biological integrity of aquatic systems, decreases the quality of waters and may directly affect aquatic invertebrate fauna.

Biochemical oxygen demand (BOD) is a measure of the quantity of oxygen used by microorganisms in the oxidation of organic matter in a given water sample at certain temperature over a specific time period. The results showed that in summer season, the highest (17.04±1.08 ppm) and the least (2.16±0.21 ppm) BOD value was for sampling stations # 4 and #7 respectively. This matter may reflect urban wastewater of the Doab village and wastewater of livestock culture near to the river while in the station # 7 self-purification of the river decreases BOD value about 8 times. River water usually is of the highest quality in its headwater reaches, becoming dirtier along its length as it passes

through different land uses and used for a variety of purposes (Kotti *et al.,* 2005; Maidment, 2016). A high level of BOD deteriorates river water quality by rapid decomposition of biodegradable organic matter and the subsequent depletion of dissolved oxygen (Hur and Cho, 2012). Threshold values for pollutant load in wastewater, established independently of the river flow rate, do not protect from pollution since the mechanisms that determine water quality are mixing, transport and species reactions occurring in the receiving water body (Campolo *et al.,* 2001). Contamination generated from upstream development, agriculture wastewater and human activity introduces a significant amount of nutrients and organic into rivers, thus, accelerates the hypoxia or eutrophication process, spoils the public water resources, and caused high BOD (Rezaei Tavabe *et al.,* 2010). The BOD prediction in the rivers becomes a complex exercise when the wastewater from a town or catchment area flows into the river in the form of a continuous sheet discharge (Swaroop, 1993).

5. Conclusion

Continuous water quality biomonitoring is essential for efficient management of rivers and for the prompt control of pollution. According to biomonitoring and water BOD measurement findings, Damghanroud river has relatively polluted situation and is classified in β-mezosaprobe class. Sampling stations # 1 and # 7 are free of pollution while the stations # 2 and #3 are the most polluted region along the river; because the station # 1 has no pollutant resource but station # 2 and # 4 receives directly different types of wastewater from different usages. Stations 5 and 6 have moderate pollution situation; because these stations in spite of receiving pollutants but have relatively self-purification opportunity. Aquatic insect species and their frequency that mainly relate to pollution regions I and II, indicate to avarage biological condition at Damghanroud river.

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