Original Research

Monitoring Water Quality Using Benthic Macroinvertebrates and Physicochemical Parameters of Behzat Stream in Turkey

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Abstract

The present work reports the results of an intensive study on water quality and bentic macroinvertebrate fauna of Behzat Stream in Turkey. The research was carried out at five sampling sites of two different sections of the stream between September 1998 and September 2002. A total of 52 macroinvertebrate taxa were recorded. The upper section supported a more diverse community than the lower section. A low macroinvertebrate abundance was observed during summer in the lower section, this would be the result of high values of phosphate and nitrogen ions. In spite of this, Behzat Stream showed good water quality conditions. At the present it is under threat of anthropogenic disturbances, this especially in the lower section.

Keyword: water quality, benthic macroinvertebrates, monitoring, Behzat Stream, biotic index

Introduction

The European Union has obliged member states to establish national freshwater monitoring networks [1]. At the present Turkey does not have a national freshwater monitoring network. The combination of chemical and biological methods constitutes the best approach of biological monitoring studies for indicating water quality. Historically, invertebrates have received considerable attention in the study of running water ecosystems, in particular relationships between macroinvertebrate community structures and environmental variables have been the subject of numerous investigations [2-14]. Also, benthic macroinvertebrates are considered one of the best biological indicators of water quality [15]. Their responses to inorganic or organic pollutants have been used to develop biotic indices. For correct use of biological parameters, the community structure of the local fauna in a region must be appropriately known. Following this, the biotic indices might be modified using members of the local fauna and then the regional index can be adapted [16-27].

The main aims of this study were to determine the biological richness of the stream with particular emphasis on the relationship between the structure of the macroinvertebrate community and the physical and chemical features of their environment and to assess the water quality of the Behzat Stream that receives heavy urban discharge.

Materials and Methods

Study Area

The city of Tokat occupies a central position in fertile areas comprising wide and watery valleys and passageways in between, the whole being separated by mountain ranges from the narrow and damp Black Sea Coast and Central Anatolia's wide and arid expanses. Tokat's climate represents a transition between the Central Black Sea and the Inner Anatolia climates. Winter in the valleys

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is rainy and temperate. The climate is somewhat harsher at high altitude levels and in the southern sections of the province. A culturally rich settlement center, with traces of history all over the land, Tokat lies inland of the middle Black Sea region and it has a population of 828,027. Main income for the area comes from agriculture, livestock and small-scale freshwater fisheries. The total basin area of Behzat Stream is 29 km^2 and the stream is 5 km long. The flow ranges from a minimum discharge of 2 m^3/s to a maximum discharge of 200 m^3/s. During study period, the water temperature varied from 6.1°C to 22.3°C. Five sampling stations were established along a segment of the stream and macroinvertebrate samples were taken monthly from September 1998 to September 2002 (Fig. 1). The stream was divided into two sections: the upper (from stations I to III) and lower (from stations IV to V). The substrate of the upper section (unimpacted area) consists of various sizes of rocks and gravel, while the bottom of the lower section (urbanized and agricultural area) is mostly gravel with a little sand or compacted clay. The stream is affected mainly by urban sewage (expecially in lower section) and agricultural runoff. Main uses of water in the upper section are mostly for irrigation. Riparian vegetation is dominated by trees in the upper section, which are mainly represented by *Populus sp.* and *Salix sp.* In contrast, riparian vegetation is absent in the lower section (except 50 m before the end). The aquatic vegetation is not very dense in the stream (except 50 m before the end) and the dominant species are *Planaria*, *Lymnaea*, *Planorbis*, *Baetis*, *Tipula*, *Similium*, *Chironomus* and *Gammarus*.

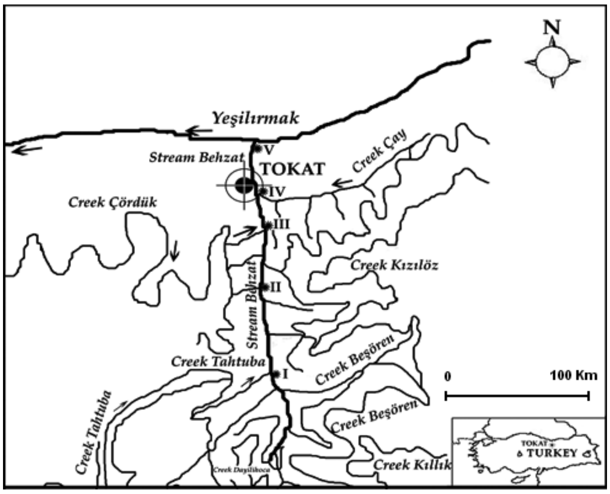

Fig. 1. Locations of Behzat Stream and stations.

Sampling

Macroinvertebrate communities along the stream were sampled monthly from September 1998 to September 2002 at each of the five stations using Surber net samplers (475 µm mesh, area of base 0.09 m^2) [28] and a bottom kick net (500 µm mesh). The samples were taken from an area of nearly 100 m^2 in order to include all possible microhabitats at each station. In some areas with the presence of large stones, these were first picked out and washed into the kick net to remove pupae and other attached macroinvertebrates. In addition, macroinvertebrate samples were separated from the macrophytes and the sediment using sieves (250 µm). All the animals collected were immediately fixed in formaldehyde (4%) in the field and then transferred to 70% ethyl alcohol. The macroinvertebrates were sorted, identified to the lowest possible taxon (species, genus or families) and counted under a stereomicroscope [29-32].

Temperature, dissolved oxygen (Lovibond oxi 200), conductivity (WTW 330i/set) and pH (Hanna HI 991002) were measured in the field using a portable instrument. Analyses of the water and sediment samples were performed seasonally, which was the size of the sample of 1 kg for sediment and 2.5 liter for water. Water samples were filtered through a 0.45 µm Millipore membrane and then acidified to pH ≤ 2 using high purity HNO_3 immediately after sampling [33]. Then, the samples were kept in the refrigerator at 4°C until analysis. All the samples were then evaluated by the Head Office of the City Control Laboratory and Rural Services Tokat Research Institute.

Biotic Indices

From among the great variety of indices and scores available we selected four for our study, which are shown in Table 1. The Chandler Score [34] was used because it

Table 1. Classes of water quality based on some biotic indices: ETBI (Extended Trent Biotic Index), BBI (Belgian Biotic Index), CS (Chandler Score) and Rev.BMWP (Revised Biological Monitoring Working Party).

Class	Significance	ETBI	BBI	CS	Rev.BMWP	Colour
I	Very Clean	10-15	9-10	> 900	>150	Blue
I – II	Clean	9-10	8-9	500-900	100-150	Blue – green
II	Fairly clean	8-9	7-8	300-500	100-150	Green
III	Doubtful	6-7	6-5	110-400	50-100	Yellow
IV	Polluted	3-5	3-5	15-80	25-50	Orange – red

has been claimed to discriminate small changes in water quality well. The Revised Biological Monitoring Working Party [35], – Rev.BMWP score [36], the Extended Trent Biotic Index – ETBI [37] and the Belgian Biotic Index – BBI [38] were chosen because they are easy to use and have been used widely in the past. The *Gammarus*: *Asellus* ratio also was used for evaluating organic pollution. Principal component analysis (PCA) was applied for collected taxa to assess the impact of human activity on the Behzat Stream. Also, experimental data were analyzed using one-way ANOVA and any significant difference was determined at a 0.05 probability level using Minitab 13.2 statistical software.

Results and Discussion

The total of 67 macroinvertebrate taxa were recorded (Table 2) and they were grouped as; Platyhelminthes (5 taxa), Annelida (10 taxa), Mollusca (11 taxa), Crustacea (2 taxa) and insecta (39 taxa). According to the results of the macroinvertebrate survey, the upper section of Behzat Stream was characterized as having Class I water quality with a high species richness dominated by Ephemeroptera, Odonata, Diptera and Coleoptera (Table 2). The Biotic indicies results were calculated for the stations for the first station; 565 (Class I – II) for the Chandler Score and 176 (Class I) for the Rev.BMWP Score, 10.29 (Class I)

Table 2. Systematic list of taxa of macroinvertebrates from Behzat Stream. S= Station.

Phylum	Genus/species	S1	S2	S3	S4	S5
Platyhelminthes	*Dendrocoelum sp.*	x	x	x	-	-
	Polycelis sp.	x	-	x	-	-
	Dugesia polychroa	x	x	x	-	-
	Dugesia lugubris	x	x	x	x	x
	Planaria torva	x	x	x	x	x
Annelida	*Tubifex sp.*	-	-	x	x	x
	Nais sp.	-	-	-	x	x
	Lumbriculus sp.	-	-	-	x	x
	Eiseniella tetraeda	-	-	-	x	x
	Glossiphonia complanata	x	x	x	x	x
	Haementeria sp.	x	x	x	x	x
	Helobdella stagnalis	x	x	x	x	x
	Haemopis sp.	x	x	x	-	-
	Hiruda medicinalis	x	x	x	-	-
	Erpobdella octoculata	x	x	-	x	
Mollusca	*Valvata sp.*	-	-	-	x	x
	Lymnaea peregra	x	x	x	x	x
	Lymnaea stagnalis	x	x	x	x	x
	Planorbis vorneus	x	x	x	x	x
	Planorbis corneus	x	x	x	x	x
	Planorbis corinatus	-	-	-	x	x
	Planorbis planorbis	-	-	x	x	-
	Segmentina sp.	x	x	x	-	-
	Unio sp.	-	x	x		x
	Sphaerium sp	-	-	-	x	x
	Pisidium sp.	-	-	-	x	x
Crustacea	*Asellus sp.*	-	-	-	x	x
	Gammarus sp.	x	x	x	x	x

Continued Table 2

Insects (Sub. Filum Hexa-poda	*Heptagenia sp.*	x	x	x	x	-
	Leptophlebia sp.	x	x	x	-	-
	Baetis sp.	x	x	x	x	x
	Cloeon sp.	x	x	x	-	-
	Gomphus sp.	x	x	x	x	x
	Cordulegaster sp.	x	x	x	x	x
	Calopteryx sp.	x	x	x	x	x
	Coenagrion sp.	x	x	x	x	x
	Platycnemis sp.	-	-	-	x	
	Leuctra sp.	x	-	x	-	-
	Plea leachii	x	x	x	-	-
	Corixa sp.	x	x	x	x	x
	Philopotamus sp.	x	x	x	-	-
	Hyropsyche sp.	x	x	x	x	x
	Lype sp.	x	x	x	-	-
	Glossosoma sp.	x	x	x	-	-
	Tipula sp.	x	x	x	x	x
	Dicranota sp.	x	x	x	x	x
	Dixa sp.	x	x	x	x	x
	Culex sp.	x	x	x	x	x
	Anopheles sp.	x	x	x	x	x
	Thaumalea sp.	x	x	x	x	
	Simulium sp.	x	x	x	x	
	Chironomus spp.	-	-	x	x	x
	Diamesa sp.	x	x	x	x	x
	Atherix sp.	x	x	x	x	
	Cricotopus sp.	x	x	x	x	x
	Stratiomys sp	x	x	x	x	x
	Tabanus sp.	x	x	x	x	x
	Sepedon sp.	-	-	-	x	x
	Limnophora sp.	x	x	x	x	-
	Colymbetes sp.	x	x	x	-	-
	Agabus sp.	x	x	x	x	x
	Dytiscus sp.	x	x	x	x	x
	Hydrophilus piceus	x	x	x	-	-
	Hydrocora caraboides	-	-	-	x	x
	Dryops sp.	x	x	x	x	x
	Esolus parallelepipedus	x	x	x	x	x
	Donacia sp.	-	-	-	x	x

for the ETBI and 9.49 (Class I) for the BBI, for the second station; 559 (Class I – II) for the Chandler Score and 176 (Class I) for the Rev.BMWP Score, 10.25 (Class I) for the ETBI and 9.42 (Class I) for the BBI, for the third station; 549 (Class I – II) for the Chandler Score and 169 (Class I) for the Rev.BMWP Score, 9.96 (Class I-II) for the ETBI and 9.36 (Class I) for the BBI, for the fourth station; 489 (Class II) for the Chandler Score and 110 (Class I-II) for the Rev.BMWP Score, 9.46 (Class I-II) for the ETBI and 8.20 (Class I-II) for the BBI, for the fifth station; 481 (Class II) for the Chandler Score and 102 (Class I-II) for the Rev.BMWP Score, 9.10 (Class I-II) for the ETBI and 8.08 (Class I-II) for the BBI (Table 3).

The principal component analysis (PCA) produced two principal components that collectively explained 78.148% of the variance of land cover among catchments (Table 4). The first axis, explaining 59.516% of variance, was influenced by the physico-chemical parameters, seasons and sections. The second axis, explaining 18.632% of varience, was influenced by abundance, disolved O_2 and hardness. PCA ordination of the reaches according the 20 variables describing physico-chemical parameters provided a strong discriminiation of the five distinct groups (Fig. 2). When the biotic index values are compared with the physico-chemical parameters (Table 5), it can be seen that all biotic indices are sensitive to the slight changes in water quality found within this stream. All biotic indices, abundance, and the physico-chemical parameters differentiate between the stations. These results tested with One-way ANOVA and difference was found between stations ($p < 0.05$).

The results for the *Gammarus:Asellus* ratio are as follows; 16 for the upper section, in which *Asellus* was not recorded at all, and 3.4 for the lower section. The high results of the G:A ratio were in accordance with those reported by Maltby [39] and Meijering [40], in which *Gammarus pulex* is said to be less tolerant of pollution. This result also agrees with the report by MacNeil et al. [41], that clean streams have a higher proportion of *Gammarus* and polluted streams have a higher proportion of *Asellus.* They also suggested that the ratio of abundance of G: A was a good indicator of organic pollution.

Table 3. Classes of water quality based on some biotic indices for the stations of the Behzat Stream.

Stations	ETBI	BBI	CS	Rev. BMWP
S1	10.29 ±1.6 (I)	9.49 ±1.1 (I)	565 ±19.5 (I-II)	176 ±10.7 (I)
S2	10.25 ±1.5 (I)	9.42 ±1.0 (I)	559 ±18.3 (I-II)	176 ±10.4 (I)
S3	9.96 ±1.3 (I-II)	9.36 ±1.0 (I)	549 ±17.2 (I-II)	169 ±10.1 (I)
S4	9.46 ±1.2 (I-II)	8.20 ±0.9 (I-II)	489 ±16.3 (II)	110 ±9.8 (I-II)
S5	9.10 ±1.0 (I-II)	8.08 ±0.8 (I-II)	481 ±16.0 (II)	102 ±9.2 (I-II)

The results of the physico-chemical analyses have been classified for water quality by Turkish Standards [42]. The recommended Turkish Standards values for Class I and Class IV water quality are as follows: Temperature: 12–30°C; pH: 6.5–8.5; Dissolved oxygen (mg/L) 8–3; Conductivity (µS/cm) 400–2000; Total dissolved solids (mg/L) 500–5000; Hardness (mg $CaCO_3$/L) 500– >500; Organic carbon (mg/L) 5–12; Chloride (mg/L) 25–400; Sulphate (mg/L) 200–400; Phosphate (mg/L) 0.02–0.65; Ammonia nitrogen (mg/L) 0.2–2; Nitrate (mg/L) 5–20; Nitrite (mg/L) 0.002–0.05: Lead (µg/L) 10–50; Cadmium (µg/L) 3–10; Iron (µg/L) 300–5000; Copper (µg/L) 20–200; Manganese (µg/L)

Table 4. Axis eigenvalues and weighted correlations between season, abundance and physico-chemical parameter variables of PCA of macroinvertebrate samples variables that explain a significant amount of variation amongst samples following forward selection (*P< 0.05, **P<0.001, ***P<0.001; d.f. -21).

Variable	PC 1	PC 2
Eigenvalue	13.093	4.099
% of Var.	59.516	18.632
Cum.%	59.516	78.148
Average abundance	-0.641**	-0.263*
Temperature (°C)	0.455*	0.755**
pH	0.793**	-0.289
Dissolved oxygen (mg/l)	0.857***	-0.468*
Conductivity (mS/cm)	0.514**	-0.135
Total dissol. solids (mg/l)	0.912***	0.030
Hardness (mg CaCO3/l)	-0.520**	0.626**
Organic carbon (mg/l)	0.950***	0.057
Chloride (mg/l)	0.979***	-0.163
Sulphate (mg/l)	0.860***	-0.376*
Phosphate (mg/l)	0.859***	-0.179
Ammonia nitrogen (mg/)	0.738***	0.617**
Nitrate (mg/l)	0.747***	0.636**
Nitrite (mg/l)	0.796***	0.418
Lead (mg/l)	0.568**	-0.444*
Cadmium (mg/l)	0.706***	-0.425*
Iron (mg/l)	0.921***	0.081
Copper (mg/l)	0.914***	-0.318*
Chemical OxygenDemand	0.783***	0.387*
Grease – Oil	0.778***	-0.547**
sections	0.854***	-0.480**
seasons	0.469*	0.646***

100–3000; Zinc (μg/L) 200–2000; and Boron (μg/L) 1000–1000. The values of the physico-chemical parameters measured in the Behzat Stream, and their water quality classes, are given in Table 5 for sections. All parameters were found to be Class I water quality except Ammonia nitrogen, Nitrate, Nitrite, Chemical Oxygen Demand (COD) and Phosphate. Phosphate was Class II and Class III in all seasons (except Autumn in section I). These high amounts of phosphate are thought to be mainly a result of the use of detergents which include phosphate. COD was Class I except in summer, Class II in both sections. Urban sewage and organic pollution are increased the COD. Ammonia Nitrogen, Nitrate and Nitrite were Class II in summer in both sections. The use of agricultural fertilizers and urban sewage are believed to increase the Ammonia nitrogen, Nitrate, Phosphate Nitrite and COD concentrations because the absence of freshwater plants might affect the increase in Nitrogen ion concentrations in the stream. Trace metal concentrations indicated Class I water quality for all ten stations. The concentrations of anions and metals detected in the sediments were a little higher than those in the stream water indicated in the tables, but the difference was not statistically significant (One-way ANOVA $p>0.05$).

A total of 22200 individuals were collected, covering 52 taxa in the upper section, and a total of 16510 individuals of 48 taxa from the lower section. The mean abundance of macroinvertebrates differed among stations ($T= 5.42$, $p=0.015$) and among seasons ($T= 6.91$, $p=0.006$). The community was dominated by insect larvae 59% (Table 2.). The substrate and flow at both sites might be limited the abundance of the general fauna. This is in agreement with Kelly-Quinn et al. [14] in the Caver River. Major temporal changes were observed in the community structure of the macroinvertebrate fauna between the seasons. The observed summer abundance decrease indicated that the macroinvertebrate fauna become dominated by a few species during late summer (particularly *Chironomus* and *Nais*) (Table 5). Although warm water and high value of some Ammonium ions might be limiting for many species, these conditions favoured *Chironomus* [6] and *Ephemeroptera* Kelly-Quinn et al. [14]. Seasonal changes in the fauna abundance of stream were found to significant enough ($T= 6.91$, $p=0.006$) that the abundance of fauna shows a generalized pattern among the studies low in the winter (expecially from December to February) and then slowly built up until March after there was a rapid increase in May nearly everywhere [13, 27, 43]. But in this study the lowest abundance occurred during summer (Table 5). Some authors [44, 45] observed the same results in some eastern Australian streams. In addition, Nagumo et al. [46] and Mols et al. [47] reported that high nitrogen affects water quality and communities. This lowest summer abundance in the Behzat stream would be the result of high values of Phosphate, Ammonia nitrogen, Nitrate and Nitrite.

Classification of composite samples for the stations showed differences between them based on the pres-

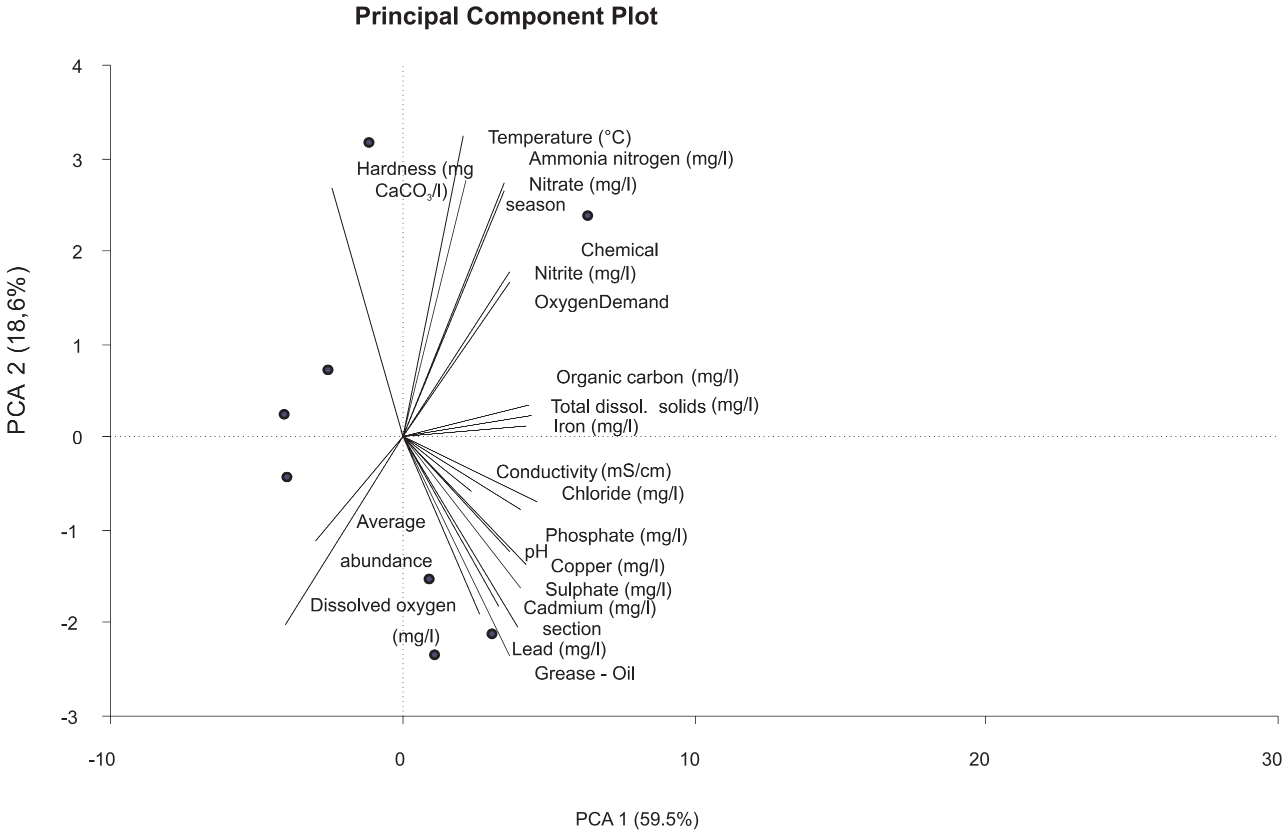

Fig. 2. Results of principal component analysis (PCA) of physico-chemical parameters, seasons and sections.

Table 5. Determined seasonal mean parameters and classes of water quality for the Upper (US) and Lower (LS) sections of Behzat Stream. Water quality value shown in brackets – I: High quality water, II: weakly polluted water, III: Polluted water, IV: Highly polluted water.

Parameters	Autumn		Winter		Spring		Summer	
Stations	US	LS	US	LS	US	LS	US	LS
Average abundance	106±12.1	74±5.5	125±12.5	88±8.3	137±15.6	119±14.2	85±9.5	59±5.4
Temperature (°C)	14.3±1.2	14.8±0.9	7.2±0.5	6.1±0.2	13.1±0.9	13.8±1.1	20.4±1.4	22.3±1.5
pH	6.51±0.3	8.52±0.9	6.62±0.5	8.53±0.8	7.87±0.6	7.89±0.5	6.75±0.4	8.74±0.5
Dissolved oxygen (mg/l)	11.8±1.5	9.9±1.2	11.6±1.5	10.2±1.3	10.9±1.5	9.92±1.1	8.9±1.09	7.2±0.8
Conductivity (μS/cm)	256 ±18	411 ±32	850 ±38	910 ±37	1000 ±51	1150 ±58	537 ±38	1055 ±59
Total dissol. solids (mg/l)	235±17.2	380±25.3	285±11.9	435±19.2	390±22.1	487±22.9	395±20.9	520±23.1
Hardness (mg $CaCO_3$/l)	185±9.2	135±8.1	160±7.6	125±5.8	205±10.6	160±8.5	200±9.9	150±8.7
Organic carbon (mg/l)	0.8±0.0	2.21±0.0	0.6±0.0	1.54±0.0	1.3±0.0	2.63±0.01	1.71±0.01	2.98±0.02
Chloride (mg/l)	0.76±0.0	2.95±0.0	0.82±0.0	3.89±0.02	1.23±0.0	4.65±0.04	1.42±0.0	5.86±0.06
Sulphate (mg/l)	30.3±1.5	82.3±2.52	19.2±0.9	65.5±2.6	21.3±1.7	73.4±3.01	29.7±1.8	77.8±2.98
Phosphate (mg/l)	0.003±0.0	0.06 ±0.0 (II)	0.006±0.0	0.72±0.0 (III)	0.004±0.0	1.65±0.0 (III)	0.004±0.0	1.47±0.0 (II)
Ammonia nitrogen (mg/)	0.004±0.0	0.07±0.0	0.009±0.0	0.15±0.0	0.008±0.0	0.09±0.0	0.35±0.0	0.70±0.0 (II)
Nitrate (mg/l)	0.4±0.0	2.42±0.01	0.6±0.0	2.35±0.02	0.7±0.0	3.35±0.02	8.65±0.07 II	16.75±1.4 (II)
Nitrite (mg/l)	-	0.002±0.0	-	0.001±0.0	-	0.002±0.0	0.001±0.0	0.018±0.0 (II)
Lead (μg/l)	1.75±0.0	1.98±0.0	2.1±0.01	2.48±0.01	0.95±0.0	2.12±0.01	1.32±0.0	2.42±0.01
Cadmium (μg/l)	1.23±0.0	2.18±0.01	0.75±0.0	1.87±0.01	1.76±0.0	3.48±0.03	1.25±0.0	2.12±0.01
Iron (μg/l)	35.1±2.35	53.2±3.78	27.6±2.15	47.2±2.89	43.4±2.61	58.7±3.73	49.3±3.07	62.9±4.1
Copper (μg/l)	0.75	5.48	1.17	6.48	3.4	10.2	2.17	8.7
Chemical OxygenDemand	6	23.6	-	15.8	-	19.7	2	211.7 (III)
Grease – Oil	-	0.001	-	0.001	-	0.002	-	0.001

ence or absence of some taxa (Table 2): genera of *Dugesia, Heptagenia, Leuctra,* S*imulium*, *Philopotamus* and *Hydropsyche* were major indicators and the physico-chemical results suggested mostly Class I water quality for upper section. *Gammarus*, *Asellus*, *Lymnea*, *Planorbis Baetis* and *Chironomus* were major indicators in the lower section. This will confirm that *Asellus*, *Lymnea*, *Planorbis* and *Baetis* species are often dominant and frequent in weakly polluted, Class II, quality water. This was confirmed by the chemical results having high values of Ammonia nitrogen, Nitrate, Nitrite, Chemical Oxygen Demand (COD) and Phosphate in the lower section.

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