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Utilization of both benthic macroinvertebrates and physicochemical parameters for evaluating water quality of the stream Cekerek (Tokat, Turkey)

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Abstract: *This study examines the applicability of five European biotic indices and the Gammarus:Asellus ratio (G:A), compared with the measurement of physicochemical parameters, in order to determine the water quality at ten sites along the Tokat part of Cekerek stream, in Anatolia, Turkey, during the period February 2002 to January 2003. The biological and chemical results are in good agreement with respect to the water quality. In particular, the G:A ratio was calculated to be high at the first three stations and this result was correlated with the ETBI and the Chandler scores. Consequently, the water quality of Cekerek stream was classified as class I for biological and physicochemical data, except for phosphate, ammonia nitrogen, nitrate and nitrite at the last seven stations. The high concentrations of these chemicals probably result from agricultural runoff and urban sewage. In total, 55 taxa of benthic macroinvertebrates were identified from the Cekerek stream during this study period.*

Key words: *Macroinvertebrate, Cekerek stream, Water quality, Physicochemical analysis, Gammarus: Asellus ratio*

Introduction

The biological richness of the invertebrate fauna in most regions of Anatolia has not been examined yet. Macroinvertebrates have rarely been used to determine the quality of running water in Turkey and biotic indices have not so far been used by governmental institutions (Duran *et al.,* 2003). However, ecological recovery and the rehabilitation of aquatic ecosystems have now become objectives of many such institutions (De Pauw *et al.*, 1992; De Pauw and Hawkes, 1993). For the correct use of biological parameters, the community structure of the fauna in the region must be defined. Following this, the biotic indices might be modified using appropriate regional components of the fauna and then a regional index may be prepared (Cao *et al.*, 1996; Kazanci *et al*., 1997; Bailey *et al.*, 1998; Charvet *et al.*, 1998; Chessman and McEvoy, 1998; Simic and Simic, 1999; Hawkins *et al.*, 2000; Capitulo *et al.*, 2001; Miserendino, 2001; Ravera , 2001; Yoshimura *et al.*, 2001; Halse *et al.*, 2002). In addition, macroinvertebrates are the group of organisms most frequently used in biomonitoring studies of running waters because the responses of macroinvertebrates to organic and inorganic pollution have been extensively documented (Thorne and Williams, 1997; Kazanci and Girgin, 1998; Metcalfe, 1998; Bunn *et al.*, 1999; Hickey and Clements, 1999; Kazanci and Dugel, 2000; Khamar *et al.*, 2000; Solimini *et al.*, 2000; Whiles *et al.,* 2000; Zweig and Rabeni, 2001; Duran *et al.,* 2003).

The major aim of this study was to determine the biological richness of the stream with particular emphasis on the relationship between the structure of the macroinvertebrate community and their physical and chemical environments, and thereby to determine the water quality of the Cekerek stream.

Materials and Methods

Study area: The Cekerek stream is 256 km in length and the total area of its basin is 1452 km^2. The flow ranges from a minimum discharge of 0.69 to a maximum of 63 m^3/s. During the period of study, the water temperature varied from 3.2°C to 21.7°C according to the season and altitude. The selection of sampling locations and sample size in each habitat varies among study reaches because of differences in habitat conditions and coverages. Ten sampling stations were established along a segment of the stream, from 30 km below the source at 1050 msl (station 1, geographical coordinates 40°30'N, 35°37'E), to a point 100 km from the source at 392 msl (station 10, geographical co ordinates 40°03'N, 36°30'E) and their locations are shown in Fig. 1. The stream mainly receives agricultural runoff and urban sewage, with little industrial (textile mill, slaughter house) waste. People use the water of the Cekerek stream mostly for irrigation and fish farming. The riparian vegetation is dominated by trees, which are mainly *Populus* sp. and *Salix* sp. and the aquatic vegetation, which is not very dense. The stream was divided into two sections: Section I (from stations 1 to 3) and section II (from stations 4 to 10). The stations were grouped together because of their similar physical and geological characteristics. The substrate of section I consists of various sizes of rocks and gravel, while the bottom of section II is mostly gravel with a little sand or compacted clay. Experimental data were analyzed using one way ANOVA and any significant difference was determined at $p<0.05$ probability level using Minitab 13.2 statistical software.

Sampling: The macroinvertebrate communities along the stream were sampled monthly from February 2002 to January 2003 at each of the ten sites, with a surber sampler (475 μm mesh, area

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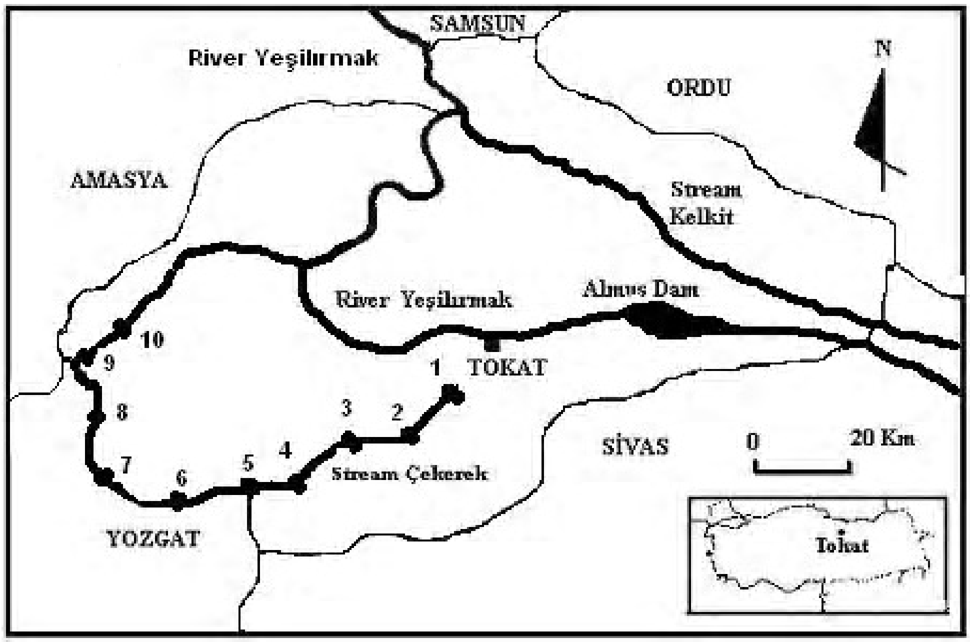

Fig. 1: Locations of the stream Cekerek and sampling stations

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

Class	Significance	ETBI	BBI	NCBI	CS	Rev.BMWP	Colour
I	Very Clean	10 -15	9 –10	<5,19	> 900	>150	Blue
I - II	Clean	9 -10	8 -9	5,19-5,78	500 - 900	100 – 150	Blue - green
II	Fairly clean	8 -9	7 -8	5,79-6,48	300 - 500	100 - 150	Green
III	Doubtful	6 -7	6 -5	6,49-7,49	110 - 400	50 - 100	Yellow
IV	Polluted	3-5	3 - 5	>7,48	15 - 80	25 - 50	Orange – red

of base 0.77m^2) (Surber, 1970) 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. Sampling was restricted in some areas due to the presence of large stones, the larger stones were first picked out and washed into the kick net to remove pupae and other attached macroinvertebrates. In addition, macroinvertebrate samples were taken 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 stereo or a compound microscope.

Temperature, dissolved oxygen, conductivity and pH were measured in the field using a portable instrument. Analysis of the water and sediment samples during the four seasons were also made. The water samples were filtered through a 0.45 μm millipore membrane and then acidified to pH $\leq$ 2 using high purity HNO_3 immediately after sampling (Ballinger, 1979). 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 ity control laboratory.

Biotic indices: From among the great variety of indices and scores available we selected five for our study, which are shown in Table 1. The Chandler Score (Chandler, 1970) was used because it has been claimed to discriminate well for small changes in water quality; the revised biological monitoring working party (Hellawell, 1978), Rev. BMWP score (Walley and Hawkes, 1997), the Extended Trent Biotic Index ETBI (Woodiwiss, 1978), North Carolina Biotic Index NCBI (Lenat, 1993) and the Belgian Biotic Index (BBI) (De Pauw and Vanhooren, 1983) were chosen because they are easy to use and have been used widely in the past. The *Gammarus : Asellus* (G:A) ratio was also used for evaluating organic pollution.

Results and Discussion

The composition of the macroinvertebrate fauna is shown in Table 2 and they were grouped as; Platyhelminthes (3 taxa), Mollusca (5 taxa), Annelida (6 taxa), Crustacea (3 taxa) and Insecta (38 taxa). The most abundant families were Gammaridae (32%), Hydropsychidae (16.2%), Simuliidae (15%), Baetidae (12.9%) and Lymnaeidae (8%). According to the results of the macroinvertebrate survey, section I of the Cekerek stream was characterised as having class I water quality with a high species richness dominated by Ephemeroptera, Plecoptera and

Table - 2: Systematic list of taxa of benthic macroinvertebrates from stream Cekerek

Phylum	Class	Order	Family	Genus/Species
Platyhelminthes	Turbellaria	Tricladida	Tricladidae	*Polycelis* sp.
				Dugesia sp.
				Planaria sp.
Annedlida	Oligochaeta	(Sub) Lumbricina	Lumbricidae	*Eiseniella tetraeda*
	Hirudinea	Rhynchobdellida	Glossiphoniidae	Glossiphonia heteroclita
				Haementeria costata
				Batracobdella sp.
		Arhynchobdellida	Hirudinidae	*Haemopis* sp.
			Erpobdellidae	*Erpobdella octoculata*
Mollusca	Gastropoda	Basommatophora	Lymnaeidae	*Lymnaea peregra*
			Planorbidae	*Gyraulus albus*
				Planorbis planorbis
	Bivalvia	Eulamellibranchiata	Unionidae	*Unio* sp.
			Sphaeriidae	*Sphaerium* sp.
Crustacea	Malacostraca	Amphipoda	Gammaridae	*Gammarus* sp.
		Isopoda	(Subordo) Asellota	*Asellus aquaticus*
		Decapoda	Potamidae	*Potamon* sp.
Insecta (Hexapoda)		Ephemeroptera	Ephemeridae	*Ephemera* sp.
			Caenidae	*Caenis* sp.
			Leptophlebiidae	*Paraleptophlebia* sp.
			Baetidae	*Baetis* sp.
				Cloeon sp.
		Odonata	Gomphidae	*Gomphus pulex*
			Corduliidae	*Cordulia* sp.
		Plecoptera	Taeniopterygidae	*Taeniopteryx* sp.
			Leuctridae	*Leuctra* sp.
			Capniidae	*Capnia* sp.
		Heteroptera	Hydrometridae	*Hydrometra* sp.
			Gerridae	*Gerris* sp.
			Pleidae	*Plea leachii*
			Corixidae	*Corixa* sp.
	Pterygota	Trichoptera	Philopotamidae	*Philopotamus* sp.
			Polycentropidae	*Cyrnus* sp.
			Hydropsychidae	*Hyropsyche* sp.
			Glossosomatidae	*Glossosoma* sp.
		Diptera	Tipulidae	*Tipula* sp.
			Blepharoceridae	*Liponeura* sp.
			Dixidae	*Dixa* sp.
			Chaoboridae	*Chaoborus* sp.
			Culicidae	*Culex* sp.
				Anopheles sp.
			Thaumaleidae	*Thaumalea* sp.
			Simuliidae	*Simulium* sp.
			Chironomidae	*Chironomus* sp.
			Stratiomyiidae	*Stratiomys* sp.
			Tabanidae	*Tabanus* sp.
				Chrysops sp.
			Sciomyzidae	*Sepedon* sp.
		Coleoptera	Gyrinidae	*Gyrinus* sp.
			Haliplidae	*Haliplus* sp.
			Dytiscidae	*Agabus* sp.
				Dytiscus sp.
			Hydrophiliidae	*Hydrobius fuscipes*
			Elminthidae	*Esolus parallelepipedus*
				Oulimnius sp.

Table - 3: Overall results from the section I and section II of the stream Cekerek. CS (Chandler Score), Rev.BMWP (Revised Biological Monitoring Working Party) ETBI (Extended Trent Biotic Index), BBI (Belgian Biotic Index) and NCBI (North Carolina Biotic Index)

Scores	Section I	Section II
CS	655 Class I-II	530 Class I-II
Rev.BMWP	153 Class I	197 Class I
ETBI	10.27 Class I	8.85 Class II
BBI	7.61 Class II	6.33 Class III
NCBI	5.96 Class I-II	6.39 Class I-II

trichoptera. The overall result for section I was calculated from the following ecological condition categories (Table 3), 655 (Class I-II) for the Chandler score and 153 (Class I) for the Rev.BMWP score, 10.27 (Class I) for the ETBI., 7.61 (Class II) for the BBI and 5.96 (Class I-II) for the NCBI. The scores calculated for section II were: 530 (Class I-II) for the Chandler score and 197 (Class I) for the Rev.BMWP score, 8.85 (Class II) for the ETBI, 6.33 (Class III) for the BBI and 6.39 (Class I-II) for the NCBI. When the biotic index values are compared with the physicochemical parameters (Tables 4 and 5), it can be seen that the Rev.BMWP, NCBI and Chandler score are not very sensitive to the slight changes in water quality found within this stretch of the stream. The ETBI and the BBI differentiate between the sites very well but when the results were tested with one way nova for the biotic index, no difference was found between sections I and II ($p > 0.05$). This could be attributed to the fact that all ten stations have characteristics of the Rhithral zone.

In addition, the results for the *Gammarus : Asellus* ratio are as follows; 52 for section I, in which *Asellus* was not recorded at all and 10.2 for section II. The high results of the G : A ratio were in accordance with those reported by Maltby (1991) and Meijering (1991), in which *Gammarus pulex* is said to be less tolerant of pollution. This result also agrees with the report by MacNeil *et al.* (2002) 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.

A total of 840 individuals were collected covering 25 families in section I and a total of 1965 individuals of 35 families from section II. The mean density of macroinvertebrates differed among stations ($p<0.05$) and between seasons ($p<0.05$). Classification of composite samples for sections I and II showed differences between them based on the presence or absence of some taxa: genera of *Planaria, Caenis, Capnia*, *Similium*, *Philopotamus* and *Hydropsyche* were major indicators and the physico-chemical results mostly suggested Class I water quality for section I. *Gammarus*, *Asellus, Lymnea*, *Similium*, *Planorbis* and *Baetis* were major indicators in section II. This will confirm

Table - 4: Determined seasonal mean parameters and the classes of the water quality from 1 to 3 stations of the stream Cekerek. Water quality value shown in brackets; I: High quality water (Class I), II: Weakly polluted water (Class II), III: Polluted water (Class III), IV: High polluted water (Class IV)

Parameters		Autumn	Winter	Spring	Summer
Temperature (°C)		9.7 ± 0.4 (I)	3.2 0.2 (I)	10.2 ± 0.5 (I)	18.7 ± 0.6(I)
pH		6.57 ± 0.1 (I)	6.76 ± 0.15 (I)	7.18 ± 0.2 (I)	5.49 ± 0.18 (I)
Dissolved oxygen (mg/l)		11.41 ± 0.16 (I)	13.06 ± 0.2 (I)	10.92 ± 0.13 (I)	9.18 ± 0.1 (I)
Conductivity (µS/cm)		890 ± 22 (I)	1100 ± 46 (I)	1250 ± 55 (I)	730 19 (I)
Total dissol. solids (mg/l)		372±31 (I)	535±39 (I)	486±32 (I)	512±49 (I)
Hardness (mg $CaCO_3$/l)		165±13 (I)	135±17 (I)	192±11(I)	20343±23 (I)
Organic carbon (mg/l)		2.23±0.16 (I)	2.16±0.24 (I)	2.820.40 (I)	3.08±0.56 (I)
Chloride (mg/l)		2.9±0.25 (I)	1.6±0.1 (I)	1.5±0.03 (I)	3.1±0.46 (I)
Sulphate (mg/l)		60.8±5.4 (I)	60.6±5.7(I)	70.1±7.3 (I)	53.3±4.2 (I)
Phosphate (mg/l)		0.06±0.01 (II)	0.12±0.05 (II)	1.21±0.54 (IV)	1.360.62 (IV)
Ammonia nitrogen (mg/l)		0.09±0.0 (I)	0.170.01 (I)	0.04±0.0 (I)	0.19±0.1 (I)
Nitrate (mg/l)		2.45±0.6 (I)	2.1±0.06 (I)	4.3±0.93 (I)	4.96±1.96 (I)
Nitrite (mg/l)		0.003±0.0 (I)	0.001±0.0 (I)	0.007±0.0 (I)	0.008±0.0 (I)
Lead (µg/l)	Water	2.42±0.22 (I)	3.17±0.2 (I)	3.39±0.9 (I)	2.740.10 (I)
Lead (µg/l)	Sediment	2.86±0.22 (I)	3.72±0.2 (I)	4.09±0.9 (I)	2.690.10 (I)
Cadmium (µg/l)	Water	0.9±0.1 (I)	1.15±0.3 (I)	1.07±0.2 (I)	1.280.3 (I)
Cadmium (µg/l)	Sediment	1.09±0.1 (I)	1.29±0.3 (I)	1.13±0.2 (I)	1.130.3 (I)
Iron (µg/l)	Water	45.2±1.85 (I)	39.79±1.7 (I)	58.25±2.01 (I)	63.292.87 (I)
Iron (µg/l)	Sediment	47.3±1.8 (I)	41.29±1.8 (I)	59.15±2.01 (I)	64.12.82 (I)
Copper (µg/l)	Water	4.09±0.12 (I)	3.2±0.2 (I)	3.45±0.8 (I)	4.720.1 (I)
Copper (µg/l)	Sediment	4.35±0.6 (I)	3.54±0.3 (I)	3.43±0.3 (I)	4.92±0.1 (I)
Manganese (µg/l)	Water	10.19±1.2 (I)	11.7±1.14 (I)	16.60±1.26 (I)	17.841.46 (I)
Manganese (µg/l)	Sediment	11.25±1.25 (I)	12.3±1.36 (I)	17.50±1.42 (I)	18.421.66 (I)
Zinc (µg/l)	Water	0.46±0.02 (I)	0.32±0.03 (I)	0.23±0.2 (I)	0.580.04 (I)
Zinc (µg/l)	Sediment	0.56±0.045 (I)	0.39±0.03 (I)	0.31±0.3 (I)	0.460.03 (I)
Boron (µg/l)	Water	0.11±0.09 (I)	0.12±0.01 (I)	0.38±0.03 (I)	0.530.05 (I)
Boron (µg/l)	Sediment	0.18±0.09 (I)	0.13±0.01 (I)	0.31±0.03 (I)	0.49±0.04 (I)

Table - 5: Determined seasonal mean parameters and the classes of the water quality from 4 to 10 stations of the stream Cekerek. Water quality value shown in brackets; I: High quality water (Class I), II: weakly polluted water (Class II), III: Polluted water (Class III), IV: High polluted water (Class IV)

Parameters		Autumn	Winter	Spring	Summer
Temperature n (°C)		13.3 ± 0.3 (I)	6.2 ± 0.1(I)	11.3 0.25(I)	21.7 ± 0.4(I)
pH		7.88 ± 0.14 (I)	7.76 0.12 (I)	7.82 ± 0.17 (I)	8.19 ±0.2 (I)
Dissolved oxygen (mg/l)		10.23 ± 0.14 (I)	12.22 ± 0.18 (I)	10.83 0.18 (I)	8.38 ± 1.16 (I)
Conductivity (mS/cm)		710 ± 49 (I)	980 5x2 (I)	440 ± 32 (I)	890 ± 44 (I)
Total diss. solids (mg/l)		276±38 (I)	495±34 (I)	435±29 (I)	499±45 (I)
Hardness ($CaCO_3$mg/l)		120±15 (I)	116±19 (I)	163±10 (I)	190±21 (I)
Organic carbon (mg/l)		4.63±0.26 (I)	4.160.14 (I)	3.12±0.10 (I)	5.08±0.59 (I)
Chloride (mg/l)		19.9±2.5 (I)	17.6±1.9 (I)	15.5±1.3 (I)	18.1±1.5 (I)
Sulphate (mg/l)		122±13.2 (I)	100.6±7.7(I)	170.1±14.3 (I)	193.3±17.2 (I)
Phosphate (mg/l)		3.6±0.10 (IV)	2.16±0.7 (IV)	3.210.14 (IV)	4.36±0.21 (IV)
Ammonia nitrogen (mg/l)		0.67±0.10 (II)	1.01±0.24 (II)	1.24±0.35 (II)	1.450.20 (II)
Nitrate (mg/l)		4.45±0.9 (I)	3.1±0.06 (I)	3.30.93 (I)	12.26±1.9 (II)
Nitrite (mg/l)		0.026±0.01 (II)	0.029±0.02 (II)	0.0320.01 (II)	0.047±0.03 (II)
Lead (µg/l)	Water	3.62±0.22 (I)	5.270.28 (I)	4.0±0.9 (I)	3.14±0.10 (I)
Lead (µg/l)	Sediment	4.11±0.28 (I)	5.39±0.29 (I)	4.21±0.9 (I)	3.330.10 (I)
Cadmium (µg/l)	Water	1.1±0.11 (I)	2.050.6 (I)	1.47±0.22 (I)	1.62±0.2 (I)
Cadmium (µg/l)	Sediment	1.13±0.11 (I)	2.21±0.64 (I)	1.53±0.25 (I)	1.670.2 (I)
Iron (µg/l)	Water	75.5±2.8 (I)	59.392.7 (I)	78.65±2.9 (I)	83.45±3.87 (I)
Iron (µg/l)	Sediment	77.3±2.81 (I)	61.13±2.73 (I)	77.05±2.91 (I)	88.753.92 (I)
Copper (µg/l)	Water	4.82±0.12 (I)	6.250.2 (I)	4.41±0.8 (I)	5.12±0.1 (I)
Copper (µg/l)	Sediment	5.62±0.14 (I)	7.63±0.3 (I)	6.11±0.9 (I)	6.480.27 (I)
Manganese (µg/l)	Water	18.89±1.2 (I)	16.71.14 (I)	21.60±1.26 (I)	27.83±3.06 (I)
Manganese (µg/l)	Sediment	21.07±1.25 (I)	17.2±1.16 (I)	22.22±1.29 (I)	28.763.12 (I)
Zinc (µg/l)	Water	0.66±0.03 (I)	0.520.06 (I)	0.43±0.2 (I)	0.68±0.05 (I)
Zinc (µg/l)	Sediment	0.71±0.031 (I)	0.71±0.07 (I)	0.52±0.29 (I)	0.750.06 (I)
Boron (µg/l)	Water	0.18±0.09 (I)	0.220.01 (I)	0.68±0.03 (I)	0.81±0.04 (I)
Boron (µg/l)	Sediment	0.19±0.092 (I)	0.23±0.01 (I)	0.73±0.031 (I)	0.89±0.043 (I)

that *Asellus*, *Lymnea*, *Planorbis* and *Baetis* species (except *B. alpinus*) 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 and phosphate in section II.

The results of the physicochemical analysis have been classified for water quality in by the Turkish standards (1988). The recommended Turkish standards values for class I and class IV water quality were 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) 100-3000; zinc (µg/l) 200-2000; boron (µg/l) 1000-1000.The values of the physicochemical parameters measured in Cekerek Stream, and their water quality classes, are given in Table 3 for section I. All parameters were found to be class I water quality except phosphate which was class II in autumn and winter and class IV water quality in spring and summer. These high amounts of phosphate are thought to be mainly a result of the use of detergents which include phosphate. The physico-chemical parameters of Section II and the classes of water quality they indicate are given in Table 4. All parameters were found to be class I water quality except ammonia nitrogen, nitrate, nitrite and phosphate. Ammonia nitrogen was class II in four seasons, nitrate was class I throughout, except in summer when it was class II, Nitrite was class II in all seasons. Phosphate was found to be class IV in all seasons. The use of agricultural fertilizers and urban sewage are believed to increase the ammonia nitrogen, nitrate, phosphate and nitrite 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. Trace metal concentration denoted in the sediment because, river sediment absorb most of the heavy metal ions in river water. 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 (p>0.05). All physicochemical parameters determined in the Cekerek stream are similar to those reported in the River Yesilirmak and the Kelkit stream (Tuzen *et al.,* 2002; Duran *et al.,* 2003).

Further biomonitoring studies to reveal the status of the macroinvertebrate fauna of the Cekerek stream are probably required. The water quality of the Cekerek stream was class I and class II for biological and physicochemical data except in terms of phosphate, ammonia nitrogen, nitrate and nitrite. The higher levels of these chemicals probably arise from agricultural runoff and urban sewage. In general it is indicated that the Cekerek stream has a good biological richness and not polluted yet.

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