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Evaluation of water quality variables and their effects on fish life in Asarsuyu Stream (Düzce/Turkey)

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Abstract

Asarsuyu Stream is one of the tributaries of Melen River located in the Western Black Sea Region in Turkey. It has been exposed to intensive industrial activities as well as agricultural and urban discharges. Ichthyofauna of the stream consists of *Squalius pursakensis*, *Barbus tauricus*, *Alburnoides tzanevi*, *Rhodeus amarus*, *Alburnus derjugini*, *Gobio baliki*, *Cobitis splendens*, *Oxynoemacheilus banarescui*, *Gambusia holbrooki*. In order to associate water quality of Asarsuyu Stream with fish life, we monitored some physical and chemical parameters (i.e. temperature, conductivity, salinity, total dissolved solids, pH, dissolved oxygen, nitrite, nitrate, ammonium, phosphate, sulphate, calcium, magnesium, chloride, sodium and potassium) seasonally during February and November 2018. All of the obtained data were compared according to the criteria of SKKY (Water Pollution Control Regulation in Turkey) and evaluated according to the criteria of European Commission on the quality of fresh waters needing protection or improvement in order to support fish life. Our results suggest that dissolved oxygen may play a critical role in fish survival especially during spring and autumn in the study area. According to the classification criteria for nitrogenous compounds, our monitoring stations ranged from I to IV. Especially nitrite and ammonia have been determined to reach critical levels for fish health. Obtained results can be considered as an indicator of organic pollution in the stream. Therefore, the pollutant sources for stream should be controlled in order to conserve the fish populations in Asarsuyu Stream.

Keywords: Water Quality, monitoring, fish health, Melen River Basin

Introduction

The term water quality refers to as all physical, chemical and biological factors affecting certain use of water. In order to assess the suitability of water for various use, physicochemical factors affecting the quality of water should be known (Boyd and Lichtkoppler 1993). All organisms in the nature are influenced by abiotic factors prevailing in their environment. The main biological functions of organism such as feeding, growth and reproduction are closely related to the physical and chemical properties of the surrounding environment. In order to obtain optimum yield in fish production, the relationships between the environmental conditions and fish should be well known (Boyd and Lichtkoppler 1993). Therefore, information about physical and chemical properties of water are required in fisheries biology studies, in order to determine life-history traits of fish species.

Streams, rivers and their drainage basins are main part of surface water ecosystems. Although rivers and streams constitute an significant amount of the land surface, only 0.0001% of the water of the Earth occurs in river channels. In spite of these low quantities, running waters are of enormous significance to humans (Wetzel 2001). Water is required for drinking and personal hygiene, fisheries, agriculture, industrial production, hydropower generation, recreational activities such as angling. Additionally, water has been considered the most suitable medium to clean, disperse, transport and dispose of wastes (domestic and industrial wastes, mine drainage waters, irrigation returns etc.) since ancient times (Chapman 1992, Svobodá et al 1993; Akman et al. 2000). Water use for different purposes impacts on the quality of the aquatic environment (Zalidis et al. 2002). In addition to intentional water uses, several human activities such as deforestation, accidental release of chemical substances, discharge of untreated wastes, excessive use of fertilizers and pesticides have indirect and undesirable effects on the aquatic environments. Therefore, water quality could be considered a strategic factor for many countries affected by both climate change and rising water-demand.

Water is actually a habitat for millions of microscopic and macroscopic living organisms, in addition to its importance as an essential natural resources. The quality of the aquatic environment can be defined by physical condition and chemical composition of water, as well as the composition and state of aquatic biota found in a water body. The quality of the aquatic environments shows temporal and spatial variations, and it is constantly changing in response to daily, seasonal and climatic rhythms. Organisms, including fish, in a particular water-body can adapt to these natural fluctuations of water quality (including temperature) as they occur (Svobodá et al. 1993). Pollution of the aquatic environments means directly or indirectly introduction of substances or energy, and it results in such deleterious effects as harm to living resources, hazards to human health, prevention to aquatic activities including fisheries and recreation, restriction to its use in agricultural, industrial and often economic activities (Chapman 1992).

Fishes are ecologically and commercially important aquatic animals. In many countries, fish provide inexpensive source of animal protein and other essential nutrients for human health (Rose 2000). Physical and chemical properties of water are important factors which affected physiological functions of fish such as feeding, breeding, digestion and excretion (Bronmark and Hansson 2005). One of the main goal of fisheries management is to provide sustainable utilization of resources. Effective fisheries management to ensure sustainability requires information about abiotic conditions including water quality that affect fish populations (Rose 2000). Fish are very sensitive to changes in environmental quality, especially during early life stages (Nikolsky 1963). Thus, understanding of water quality that affects fish populations is critical for predicting population dynamics and effective management.

Asarsuyu Stream is one of the tributaries of Melen River located in the Western Black Sea Region in Turkey. The Melen River watershed is used to support the water requirement of İstanbul city, However, there are some important pollution source such as domestic, industrial wastewater and agricultural run-off in the basin (Koklu et al. 2010, Akıner and Akkoyunlu 2012). Asarsuyu Stream drainage basin has been influenced by intensive industrial activities and daily residential plants effluents (Koklu et al. 2010). Although some studies have been carried out on the assessment water quality of Melen Basin, no evaluation has been made for ecological impacts of pollution on the aquatic organisms. The objective of the present study is to determine seasonal changes in water quality variables in Asarsuyu Stream and to evaluate their possible impacts on native fish fauna.

Material and Methods

Study Area and Sampling

Asarsuyu Stream is originated from the northwest of the Bolu Mountains and passes through southern to Düzce, joins Küçük Melen River before draining into the Efteni Lake. The length of the stream is 38 km and its catchment area is approximately 180 km² (Anonymus, 2014). Mean flow of the stream ranged between 0.35 m^3/sn and 130 m^3/sn (Anonymus, 2014). Domestic and industrial wastewater effluent is supposed to be the main threats for Asarsuyu Stream (Koklu et al., 2010). According to literature (Anonymus, 2014) and our samplings, ichthyofauna of the stream consists of *Squalius pursakensis*, *Barbus tauricus*, *Alburnoides tzanevi*, *Rhodeus amarus*, *Alburnus derjugini*, *Gobio baliki*, *Cobitis splendens*, *Oxynoemacheilus banarescui* and *Gambusia holbrooki*.

Three sampling points were selected and water samples were collected seasonally between February and November 2018.

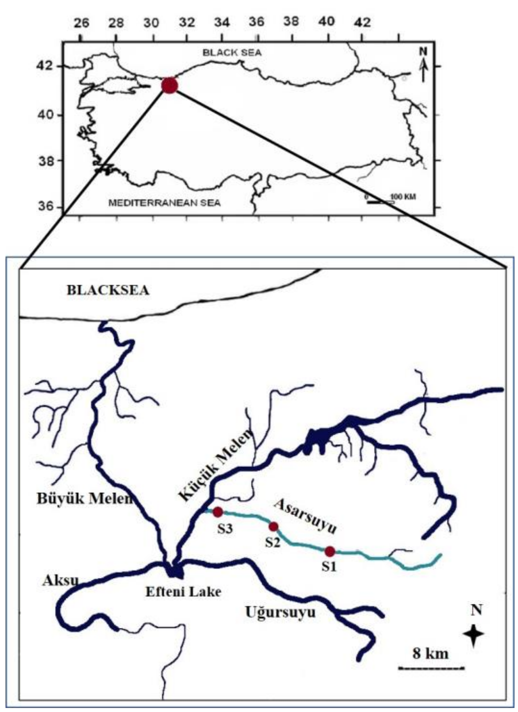

Figure 1. Melen River Basin and sampling stations on Asarsuyu Stream (S1, S2 and S3 stand for sampling points).

The first sampling point (S1) was close upstream, whereas the other sampling points (S2 and S3) were located at downstream and may reflect the urban pollution load of Asarsuyu Stream (Fig. 1 and Table 1).

Table 1. Coordinates and altitude of sampling stations.

Stations	Part of stream	Latitude	Longitude	Altitude (m)
S1	Input of Düzce	40°47'44.90" N	31°14'14.02" E	200
S2	Düzce	40°49'19.70" N	31°11'43.68" E	125
S3	Output of Düzce	40°50'6.67" N	31° 8' 6.11" E	115

Water samples were taken into 1 L polypropylene bottles at each sampling stations, and they were transported to the laboratory in cold chain.

Chemical and Physicochemical Analysis

Physical and chemical parameters of water including temperature (T), electrical conductivity (EC) (25°C), salinity (Sal), total dissolved solids (TDS), dissolved oxygen (DO) and pH were measured in situ using YSI ProPlus Multiparameter water quality meter during field studies. The measurements were carried out once per month from each sampling points.

Chemical analysis were carried out using "IC (Thermo Scientific Dionex ICS 500+)" instrument available in the Scientific and Technical Research Center of Düzce University. Determination of common inorganic anion and cation content of water was achieved by ion chromatography, a widely used environmental monitoring tool. Dionex IonPac AS18-4µm Column and IonPac CS16 Column were used for anion and cation seperation, respectively.

The obtained data were compared with the limit values reported in the Water Pollution Control Regulation in Turkey (SKKY 2004).

Results

Seasonal changes in values of physical and chemical parameters are given in Table 2.

Temperature passed 20˚C in the summer and the maximum value was recorded as 22.8˚C at the S1. The conductivity, salinity, and TDS slightly increased during summer and autumn. Conductivity was over 600 µS/cm during the summer. pH ranged between 7.50 and 8.25 at S1, 7.55 and 8.41 at S2 and 7.73 and 8.98 at S3. During winter period DO was approximately 10 mg/L at all sampling points, however it decreased dramatically in spring and autumn (minimum 4.15 mg/L at S1, 5.88 mg/L at S2 and 4.60 mg/L at S3).

The highest ammonium-nitrogen (NH_4-N) level was recorded at the S1 during the study period (maximum 3.75 mg/L). Nitrite level ranged from 0.36 to 3.16 mg/L during spring, summer and winter, and increased to the highest record in autumn (5.57 mg/L in S1). Nitrate level ranged from 2.50 (Winter, S1) to 7.40 mg/L (Summer; S2). Chloride concentration varied between 33.04 (Autumn; S2) and 38.28 mg/L (Autumn; S1). The sulphate level was lowest in winter, and highest in spring in all sampling points. Ortophosphate concentration cannot be recorded in winter, however, it ranged from 0.02 to 0.26 mg/L during the rest of the study period. were very low at all stations. The highest level of magnesium was 12.73 mg/L at the S3

Table 2. Seasonal changes in water quality parameters (ND: not detected)

	Winter			Spring			Summer			Autumn		
Parameters	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**
T (˚C)	7.6	8.3	10.9	13.4	12.7	14.0	22.8	21.7	20.4	16.3	17.3	18.7
EC (25˚C) (µS/cm)	563	567	540	557	567	511	616	601	600	593	594	612
Sal (ppt)	0.27	0.28	0.26	0.27	0.28	0.25	0.30	0.29	0.29	0.29	0.29	0.30
TDS (mg/L)	366	369	351	362	366	332	403	390	390	385	384	397
pH	7.85	7.91	8.74	8.28	8.41	8.98	7.73	7.85	8.08	7.50	7.55	7.73
DO (mg/L)	10.91	10.33	10.49	4.15	6.29	4.60	6.66	8.13	8.06	5.70	5.88	6.66
NH_4-N (mg/L)	3.29	1.01	0.93	3.22	1.52	0.90	3.75	0.30	2.32	3.41	1.86	0.07
NO_2-N (mg/L)	ND	1.82	0.36	ND	0.49	0.69	3.16	2.07	2.55	5.57	5.27	3.97
NO_3-N (mg/L)	2.50	4.00	3.41	2.58	4.07	2.93	2.86	7.40	5.81	2.68	7.36	6.48
Cl (mg/L)	34.38	36.75	34.46	33.17	34.01	33.10	36.48	34.46	34.78	38.28	33.04	34.58
SO_4 (mg/L)	46.01	49.42	45.26	136.5	140.4	143.1	116.7	125.9	122.4	107.5	110.6	112.73
PO_4 (mg/L)	ND	ND	ND	0.06	0.13	0.02	0.26	0.15	0.18	0.10	ND	0.17
Mg (mg/L)	10.43	10.63	10.39	11.39	11.38	11.46	11.59	12.35	11.54	11.23	9.51	12.73
Ca (mg/L)	80.19	81.81	76.95	85.45	87.90	77.38	82.80	88.79	84.53	81.76	86.16	87.72
Na (mg/L)	21.93	23.2	21.13	20.68	20.68	20.49	22.25	23.25	24.46	24.30	23.26	23.93
K (mg/L)	1.94	2.75	2.54	2.09	2.55	2.28	2.69	3.34	3.58	4.45	5.33	3.68

during autumn. Calcium concentration varied between 76.95 and 89.78 mg/L. A slight increase was observed in sodium and potassium levels during summer and autumn.

According to the criteria of Water Pollution Control Regulation in Turkey (SKKY 2004), the monitored stations are classified as I-IV during the monitoring period (Table 3). High ammonium and extreme nitrite concentrations, as well as low dissolved oxygen levels, have caused dramatical decline in water quality. According to SKKY's rule of "The lowest quality class determines the class of the group", Asarsuyu Stream can be considered as Class IV (Very Polluted Water) in terms of Physical and Inorganic Chemical Parameters.

Table 3. Water quality classification of Asarsuyu Stream according to criteria of Water Pollution Control Regulation in Turkey (SKKY, 2004)

Parameters	Sampling Sites		
	S1	**S2**	**S3**
T	I-II	I-II	I-II
TDS	I	I	I
pH	I-II	I-II	I-II
DO	I-III	I-III	I-III
NH_4-N	IV	II	I-II-III
NO_2-N	I-IV	IV	IV
NO_3-N	I	I-II	I-II
Cl	II	II	II
SO_4	I-II	I-II	I-II
Na	I	I	I

Discussion

Water quality is a significant factor for fish life. Feeding, growth and breeding activities of fishes are closely related to the physicochemical properties of the aquatic environment (Nikolsky, 1963). In this study, certain water quality parameters of Asarsuyu Stream were measured in order to evaluate the environmental conditions which affected fish life.

Temperature is a very important parameter for aquatic life since it affects the rate of biochemical reactions and dissolution of gases and changes the viscosity and density of water, as well. The metabolic rates of aquatic organisms, mainly fish, varies with temperature. For example, carp can successfully survive in a wide temperature range, however its feeding (8-10°C) and breeding (15°C) activities occur only at certain temperatures (Nikolsky, 1963). In Asarsuyu Stream, water temperature varied between 7.6°C and 22.8°C. Ichthyfauna of Asarsuyu Stream mainly consists of cyprinid fish. The optimal temperature for feeding of cyprinid fish is 23°C (Svobodá et al 1993), and water temperature in the Asarsuyu Stream is appropriate for native fish fauna.

TDS (total dissolved solids) is referred the quantity of dissolved materials in water, while salinity is defined total amount of salts dissolved in water (Köse et al., 2014). Conductivity is a measure of the ability of water to pass an electrical current, and it is affected by the presence of dissolved solids. TDS and salinity levels in water are closely related to conductivity levels: when the TDS and salinity value in water rise, the conductivity value will also increase, and these parameters considered as an indicator of general water quality (Köse et al., 2014). Sewage wastes and irrigation returns could raise the levels of these parameters because of the presence of chloride, phosphate, and nitrate (Wetzel 2001; Manahan 2011). Inorganic minerals dissolved in water lead to changes in osmotic pressure in aquatic organisms, and many aquatic species cannot resist osmotic pressure changes (Jobling 1995). The ecological stability in the water is disrupted in case EC reaches 3000 µS/cm (Svobodá et al 1993). The EC values of the waters suitable for fisheries are generally ranged between 150 and 170 µS/cm (Bremond and Vuichard 1973). However, obtained TDS values indicated Class I quality of water in Asarsuyu Stream and EC was found between 511 and 616 µS/cm. These are not critical values for native fish fauna. The main reason for the recorded high values of TDS and EC can be considered as runoff from industrial and urban areas in the basin.

Dissolved oxygen is one of the most important parameter for monitoring the water quality (Wetzel 2001). The amount of dissolved oxygen in water depends on the current temperature, density of dissolved salts, and biological processes of the aquatic organisms (Svobodá et al, 1993). Despite the detected high dissolved oxygen levels during the winter, Asarsuyu Stream has low level of oxygen values especially during the spring. Bremond and Vuichard (1973) stated that the minimum concentration of dissolved oxygen required for the survival of Cyprinid fish should be at least 5.0 mg/L. According to the limit values in surface waters for the protection of fish health in European Communities Regulations , measures are required to ensure that the amount of dissolved oxygen does not decrease below 6 mg/L for salmonids and below 4 mg/L for cyprinids (EC 2006). The minimum dissolved oxygen level measured in the Asarsuyu Stream was 4.15 mg/L during spring. The obtained data indicated that oxygen may be a critical factor for fish survival especially during spring and autumn in the study area.

Another chemical parameter affecting aquatic organisms is pH, and it is considered as an indicator of acidity of water. Optimum pH values for many fish species are ranged between 6.5 and 8.5 (Arrignon 1976; Dauba 1981), however pH values >10.8 and <5.0 are lethal for cyprinids, especially carp (Svobodá et al 1993). According to the European Communities Regulations, pH should between 6 and 9 for salmonids and cyprinids (EC 2006). In the present study, pH values ranged from 7.50 and 8.98, and these pH values are appropriate for fish health.

Sulphate is one of the natural anions in water, and its natural sources include gypsum and rain water. The increased amounts of sulphate in aquatic environments due to various industrial, agricultural and domestic wastes are considered as an indicator of pollution. Sulphate concentration exceeding 250 mg/L in water indicates serious contamination (Nisbet and Verneaux 1970). In the present study, sulphate concentrations were found between 45.26 and143.08 mg/L at each observation points. Therefore, the amount of sulphate is not at a level that poses a risk to fish health.

Chloride is an important chemical component of all natural waters and is usually found in very low concentrations. Chloride content varies usually between 10-20 mg/L in freshwater environments (Wetzel, 2001). In Asarsuyu Stream, chloride concentration ranged from 33.04 to 38.28 mg/L which indicated class II water quality in terms of chloride (SKKY 2004). The obtained chloride values seem to be convenient for fish.

Calcium and magnesium ions are among the most abundant components of natural waters. Both calcium and magnesium have important role for primer productivity in aquatic environments. Calcium content in natural waters can reach up to 150 mg/L. When the calcium content is around 25 mg/L, the productivity rate reach the maximum value, and calcium concentrations below 12 mg/L cause decreace in productivity twice (Nisbet and Verneaux 1970; Bremond and Vuichard 1973). Magnesium concentration in waters suitable for fisheries should be less than 14 mg/L (Alabaster and Lloyd 1980). In the present study, maximum calcium and magnesium concentrations were found 88.79 mg/L and 12.73 mg/L, respectively. These values seem to be suitable for both optimum productivity of water and fish health.

Phosphate is a limiting factor for primary productivity in aquatic ecosystems (Wetzel, 2001). It is transported to water by decomposition of organic materials, washing of fertilizers used in agriculture, discharge of domestic and industrial wastewaters to aquatic environments. Nisbet and Verneaux (1970) stated that the high primer productivity occurs in waterbodies containing phosphate concentration of 0,15-0,30 mg/L and phosphate levels exceeding 0.30 mg/L are considered polluted water. Excessive pollution and eutrophication occur in aquatic ecosystems when the phosphate content exceeds 0.50 mg/L. Orthophosphate amounts were found varying between 0.02 and 0.26 mg/L in Asarsuyu Stream, and these values seem to be convenient for fish,

The amount of nitrate in surface waters is usually less than 1 mg/L, and rarely up to 5 mg/L (Anonymous 1981). Nitrate salts are important since they encourage the development of algae and green plants, thus provide nutrients and breeding environments for fish such as carp. Although the toxicity of nitrate is low, it has toxic effects for carp when its concentration in water exceeds 80 mg/L (Svobodá, et al., 1993). However, when the nitrate nitrogen in the water exceeds 46 mg/L, methemoglobinemia occurs in fish (Nikolsky 1963). Asarsuyu Stream has class I and II water quality in terms of nitrate (SKKY 2004). Nitrate levels were found between 2.50 and 7.40 mg/L, and these values seems to be convenient for fish, especially cyprinids.

Although surface waters contain ammonia as a result of microbiological activities, ammonia in water can sometimes be an indicator of pollution. According to Nisbet and Verneaux (1970), waters contained ammonium higher than 1 mg/L are considered to be extremely polluted. In the present study, ammonium levels varied between 0.30 and 3.75 mg/L. Extreme ammonia levels were observed especially at S1, and this section of the Asarsuyu Stream is not suitable for fish due to ammonia pollution.

Nitrite is the intermediate product of the nitrogen cycle. In addition to nitrates, nitrites contribute to the development of phytoplankton, and thus primer productivity. Nisbet and Vernaeux (1970) suggests that if the amount of nitrite in the water exceeds 1 mg/L, pollution has started. In the present study, nitrite concentration ranged from 0.36 to 5.57 mg/L. Nitrite levels have peaked especially during summer and autumn, These excessive nitrite levels which indicated the nitrite pollution in water can be considered as a risk to fish health.

In conclusion, dissolved oxygen and nitrogenous compounds, especially nitrite and ammonium, are critical parameters for fish health in Asarsuyu Stream. These results can be considered as an indicator of organic pollution in the river. We can suggest that the pollutant sources for stream should be controlled in order to conserve the fish populations in Asarsuyu Stream.

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