Environmental Engineering and Management Journal January 2019, Vol.18, No. 1, 185-194
http://www.eemj.icpm.tuiasi.ro/; http://www.eemj.eu

"Gheorghe Asachi" Technical University of Iasi, Romania

STREAM INPUTS TO LAKE HAZAR (EASTERN ANATOLIA-TURKEY)

Memet Varol

Faculty of Fisheries, Department of Basic Aquatic Sciences, Malatya Turgut Özal University, Turkey
E-mail address: mvarol23@gmail.com, memet.varol@ozal.edu.tr; Phone: +90 422 8461265

Abstract

Lake Hazar is one of the largest and deepest lakes in the Eastern Anatolia Region of Turkey. It is an outstanding natural resource and famous for its blue, clear, deep and alkaline waters. However, a drastic decrease in water quality and water clarity of the lake has occured in recent years. This decrease is mainly a result of nutrient and sediment transport to the lake. This study was conducted to assess water quality of Behrimaz Stream and amounts of freshwater, nutrients, major ions, biological oxygen demand (BOD_5), chemical oxygen demand (COD) and total suspended sediment (TSS) carried by the stream into the lake. It was determined that the stream had a major impact on water regime, nutrient enrichment and siltation of the lake. Annual water discharge, annual total nitrogen (TN) and total phosphorus (TP) loads carried into the lake were estimated to be 29×10^6 m^3, 103.77 t and 5.23 t, respectively. The contribution of TSS load of the Behrimaz Stream to the lake was 24.913×10^3 t y^{-1}. Over 60% of annual TSS load occured in April. About 52% of the annual water discharge, 47% of the TN load and 52% of the TP load occured within two months from March to April. The annual nitrogen and phosphorus loadings to the lake were below permissible loading levels according to Vollenweider's criteria.

Keywords: eutrophication, nutrient enrichment, stream input, suspended sediment, water quality

Received: November, 2014; Revised final: May, 2015; Accepted: May, 2015; Published in final edited form: January, 2019

1. Introduction

Lake Hazar is one of the largest and deepest lakes in Eastern Anatolia, with an average lake surface altitude of 1248 m above sea level, and is about 20 km long and 4 km wide. The lake has a drainage area of 403 km^2, with a surface area of 78.4 km^2. Water volume of the lake is 7×10^9 m^3 at maximum water level. Different figures between 80 m and 300 m are given for its maximum depth whilst average depth of the lake is calculated as 93 m (Şen et al., 1999).

Lake Hazar is an important recreational area with its numerous bays and natural beauty. The lake shore is extensively used for camping and picnicking. Some of the beaches around the lake have been awarded with blue flag by the European Environmental Education Foundation. In addition, the lake has been designated as a Wetland of International Importance under the Ramsar Convention. It has also a great potential for fisheries, bird habitats and water sports. As with many lakes in the world, a drastic decrease in water quality and clarity of the lake has occured in recent years. This decrease is mainly due to human activities, which have risen dramatically in the Lake Hazar basin. Long-termed observations revealed that nutrient concentrations have increased rapidly in the lake water and blue-green algae showed a significant increase in the lake (Şen et al., 1995, 2003). Increased nutrient concentrations are considered the primary cause of algal growth, and thereby loss of clarity in the lake. Suspended sediment is also of concern because nutrients attach to and are transported by sediment particles. Within the Lake Hazar basin, inflows are suspected to be one of the major pathways for nutrient and sediment transport to the lake. Increased development has accelerated this transport through urbanization of wetlands areas, erosion from steep mountain slopes, and household wastewater discharges within the basin (Şen et al., 2003).

Behrimaz Stream is the largest tributary to Lake Hazar, contributing approximately 70% of the total freshwater flow to the lake (Şen et al., 2002). The stream catchment area is 25.55% of the Lake Hazar basin. The land uses within watershed of Behrimaz

Stream are agriculture, forest and rural-residentail, but urbanization is becoming increasingly important, especially in areas adjacent to downstream.

Although some studies on stream water quality within the lake basin have been published, there has been no comprehensive investigation of water, nutrient, major ion and sediment inflows from the major stream watersheds to Lake Hazar during the past years. Researchers (Sağıroğlu and Çetindağ, 1995; Şen et al., 1999, 2002) have recognized that water discharge, nutrient and suspended sediment loads are among the most important factors in maintaining environmental integrity in the Lake Hazar drainage basin. The purpose of this study is to provide a detailed examination of water discharge, nutrient, BOD_5, COD, major ion and sediment loads carried by the Behrimaz Stream into Lake Hazar. The specific objectives of the study are: (a) to assess the surface water quality of the Behrimaz Stream; (b) to estimate monthly water discharge, nutrient, BOD_5, COD, major ion and TSS loads.

2. Material and methods

2.1. Study area

Behrimaz Stream, which is fed by springs originating near Başkaynak Village in the western part of the Behrimaz Plain (Fig. 1), is in the South of Hazar Mountain in Eastern Anatolia Region of Turkey and has a catchment area of 101 km^2. Behrimaz Stream together with several surrounding creeks used to discharge into the Tigris River. In 1960, a concrete weir was built across the stream around Hatunköy and the stream was diverted through a channel into Lake Hazar to provide water supply for the lake (Günek and Yiğit, 1995; Özdemir, 1995a).

The annual mean total rainfall in the period 1991–2003 was 616 mm. However, this amount was 632 mm during the period of the present study. More than 90% of the annual rainfall usually occured from November through May (Fig. 2). Although the climate of the area is continental, it also shows similarities to the Mediterranean type. The annual mean air temperature is 12-14°C. Summers in the area are cooler and less dry than its surrounding areas; winters are rainier and colder (Yiğit and Çitçi, 1995).

The majority (86.6%) of the Behrimaz Stream catchment is used for agricultural purposes. Main crops are wheat, bean, corn and potato. While cereals are cultivated in one-third of agricultural lands, vegetables and food plants are produced in two-thirds of the land (Yiğit and Çitçi, 1995). The increasing applications rate of fertilizer for agriculture in the catchment area is a primary concern. Livestock is raised in the catchment area, especially cattle, sheep and goats. Farm animals generally have had unlimited access to the stream channel, which has further reduced riparian vegetation and destabilizated stream banks. In addition, animal wastes are an important source of nutrient pollution in the Behrimaz Stream catchment. The area is covered with red-brown soils. Predominant soils in the lower Behrimaz Stream basin are lithosolic soils, which are prone to erosion. In addition, stream bank erosion often occurs during high flow periods. Afforestation efforts have been continuing to prevent erosion in these areas since 1968 (Yiğit and Hayli, 1995).

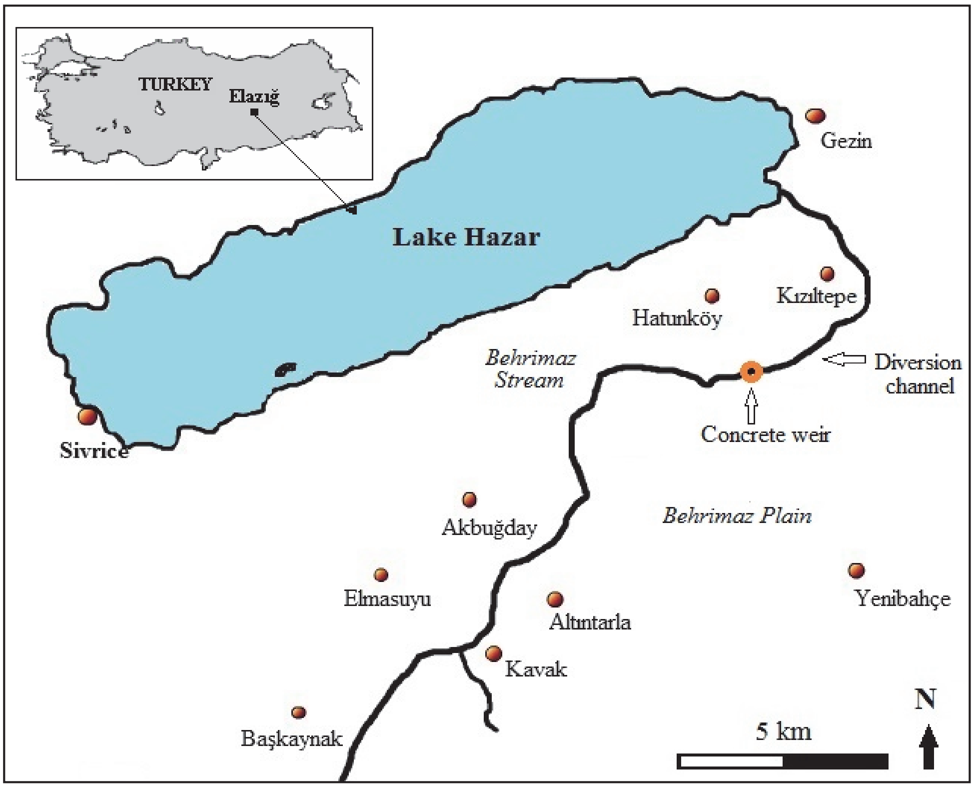

Fig. 1. The map of Lake Hazar and Behrimaz Stream flowing into the lake

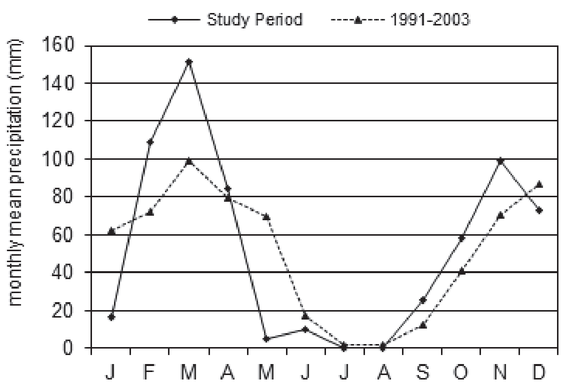

Fig. 2. Monthly mean precipitation (mm) for last 12 years (1991-2003) and for the study period

2.2. Sample collection

Water samples for analysis were taken about 30 meter upstream of stream mouth. Grab water samples (2.5 L) were collected at monthly intervals from sampling site under base-flow conditions, from January 2003 to December 2003. As the stream water was used for irrigation purpose in upstream region of the weir, diversion channel remained completely dry from July 2003 to October 2003. Thus, the samples were not taken during these months. The samples were collected in acid-washed plastic sample bottles.

After rinsing three times with stream water, the bottles were immersed at least 30 cm below the water surface (when the depth allowed), capped to exclude air, and then returned to the laboratory for analysis. Preservation and transportation of the water samples to the laboratory were performed according to standard methods (APHA, 1995).

2.3. Field measurements

Flow was calculated from velocity profile measured by floating a buoyant object along parallel longitudunal transects in a 5 m length section of the stream with uniform width. The results were corrected in accordance with bed material. Dissolved oxygen (DO), electrical conductivity (EC), temperature and pH were measured in the field. Measurements of DO and temperature were made using a portable oxygen meter (YSI 52, Yellow Springs Instruments, OH, USA), pH and EC with a portable pH meter (Model Hanna HI 9812, Hanna Instruments Ltd., UK).

2.4. Chemical analysis

A 500 mL aliquot of each sample was filtered through a 0.45 µm cellulose nitrate membrane, within 6 h of sampling. The unfiltered samples were analysed for total phosphorus (TP), total kjeldahl nitrogen (TKN), biological oxygen demand (BOD_5), chemical oxygen demand (COD) and total suspended sediment (TSS). The filtered samples were used for other chemical parameters. Ammonium nitrogen (NH_4-N), TKN, organic nitrogen (Org-N), nitrite nitrogen (NO_2-N), nitrate nitrogen (NO_3-N), total nitrogen (TN), soluble reactive phosphorus (SRP), TP, BOD_5, COD, chloride (Cl), sulphate (SO_4), sodium (Na), potassium (K), calcium (Ca) and TSS were determined in the laboratory following the standard protocols (APHA, 1995). The analytical data quality was guaranteed through the implementation of laboratory quality assurance and quality control methods, including the use of standard operating procedures, calibration with standards, analysis of reagent blanks, recovery of known additions and analysis of replicates. The laboratory also participated in regular national program on analytical quality control (AQC). Material loads were calculated using the following equation (Eq. 1):

$$L = \sum_{0}^{t} C(t)Q(t)dt \quad (1)$$

where L is load (mg s^{-1}), C is concentration (mg L^{-1}), Q is water discharge (L s^{-1}) and t is time. The loads were firstly calculated as daily load and then converted to monthly and annual loads. The annual volume of suspended sediment carried by the Behrimaz Stream into the lake was calculated by dividing the annual suspended sediment load to specific weight of common suspended sediments (2.65 g cm^{-3}) such as silt and clay (Guy, 1978).

2.5. Statistical analysis

The relationships among the considered variables were tested by using Pearson's coefficient with statistical significance set at $P<0.05$. Correlation analysis and basic statistical analysis were performed by using SPSS 11.5 for Windows.

3. Results and discussion

3.1. Streamflow

In the present study, as expected, streamflow decreased during the summer and autumn months when evaporation rates were high, and increased during spring months when snowmelts and rains begin. The maximum flow (2952 L s^{-1}) was measured in March and the minimum flow (348 L s^{-1}) was in October, with a mean flow of 1404 L s^{-1} (Table 1). Günek and Yiğit (1995) reported the maximum (7.2 m^3 s^{-1}) and minimum flows (0.3 m^3 s^{-1}) around Hatunköy for the Behrimaz Stream in March and September, respectively, between 1950-1960.

These differences may be due to the duration of wet season and difference of flow measurement sites. Although more than 90% of the annual rainfall usually occurs from November through May, the highest flow was recorded in March, likely due to snowfalls and melts.

Table 1. Water quality data of Behrimaz Stream, from January 2003 through December 2003

Parameters	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Nov*	*Dec*	*Mean*	*S.D.*
Q (L s^{-1})	960	2016	2952	2830	1035	619	348	472	1404	1051
T (°C)	2.6	2.4	6.6	9	17.2	25.2	4.8	2.6	8.8	8.3
pH	7.9	8.0	8.3	7.9	8.2	8.2	8.3	7.7	8.1	0.2
DO (mg L^{-1})	11.8	11.5	10.2	9.9	8.5	4.6	10.4	11.3	9.8	2.3
EC (µS cm^{-1})	240	220	200	240	200	250	240	230	227.5	19.1
NH_4-N (mg L^{-1})	0.16	2.24	0.36	0.41	1.04	3.01	1.51	0.78	1.19	1.00
TKN (mg L^{-1})	0.52	3.18	1.62	1.24	2.45	5.16	2.80	1.74	2.34	1.43
Org-N (mg L^{-1})	0.36	0.94	1.26	0.83	1.41	2.15	1.29	0.96	1.15	0.52
NO_2-N (µg L^{-1})	19.8	24.2	22.3	24.4	31.3	17.3	21.6	22.8	23.0	4.1
NO_3-N (mg L^{-1})	0.45	1.30	1.42	2.08	2.24	1.45	1.13	0.86	1.36	0.59
TN (mg L^{-1})	0.98	4.50	3.06	3.34	4.72	6.63	3.95	2.62	3.72	1.66
SRP (µg L^{-1})	35.4	45.6	45.1	41.9	45.1	43.24	47.1	45	43.6	3.6
TP (µg L^{-1})	147	149	165	194	267	168	206	160	182.0	40.0
BOD_5 (mg L^{-1})	2	3	3	2	3	4	2	2	2.6	0.7
COD (mg L^{-1})	5.4	6.8	9.2	8.4	10.2	28.8	5.6	6.2	10.1	7.8
Cl (mg L^{-1})	6.6	6.9	5.2	11.1	12.3	14.0	11.6	5.9	9.2	3.4
SO_4 (mg L^{-1})	22.4	30.4	23.1	24.1	25.6	24.7	25.0	22.5	24.7	2.6
Na (mg L^{-1})	11.8	11.2	9.7	13.1	13.2	11.1	12.5	12.4	11.9	1.2
K (mg L^{-1})	0.9	0.9	0.6	0.4	1.1	0.9	1.1	1.0	0.8	0.2
Ca (mg L^{-1})	30.4	36.6	35.7	31.8	44.2	46.9	42.3	37.6	38.2	5.9
TSS (mg L^{-1})	544	351	187	2060	1254	108	243	1064	726.	682

Table 2. Some standards from Turkish Water Pollution Control Regulation (Official Gazette, 1988)

Parameters	*Class I*	*Class II*	*Class III*	*Class IV*	*This study*
Temperature (°C)	25	25	30	> 30	I
pH	6.5-8.5	6.5-8.5	6.0-9.0	<6.0 or >9.0	I
DO (mg L^{-1})	8	6	3	< 3	I
NH_4-N (mg L^{-1})	0.2	1	2	> 2	III
TKN (mg L^{-1})	0.5	1.5	5	> 5	III
NO_2-N (mg L^{-1})	0.002	0.01	0.05	> 0.05	III
NO_3-N (mg L^{-1})	5	10	20	> 20	I
TP (mg L^{-1})	0.02	0.16	0.65	> 0.65	III
BOD_5 (mg L^{-1})	4	8	20	> 20	I
COD (mg L^{-1})	25	50	70	> 70	I
Cl (mg L^{-1})	25	200	400	> 400	I
SO_4 (mg L^{-1})	200	200	400	> 400	I
Na (mg L^{-1})	125	125	250	> 250	I

3.2. Water quality of Behrimaz Stream

A summary of water quality data in this study is given in Table 1.

Water quality standards for all streams in Turkey have been defined by the TWPCR (Turkish Water Pollution Control Regulation). According to the criteria stipulated in the TWPCR, inland surface water resources were classified into four categories, each of which had distinct utilization purposes. Class I waters were classified as high quality waters which could be used for drinking water supplies with simple disinfection. Class II waters on the other hand, were considered as medium quality waters that could be used for drinking water supply only after appropriate treatment. Low quality Class III waters could be used in industrial and agricultural purposes but could not be utilized for drinking purposes under no condition. Class IV waters were highly polluted and could not be used for either municipal or industrial purposes. This classification and some parameters are shown in Table 2 (Official Gazette, 1988).

3.2.1. Physical properties

During the study period water temperature showed high seasonal variations. The mean water temperature in the stream was 8.8°C, with values ranging from 2.4°C in February to 25.2°C in June (Table 1). At the streamgage site, water temperatures remained about at 2.5°C during winter (December, January and February). As expected, the water temperature showed upward trend from March to June due to increasing air temperature. These may be attributed to both the meteorological conditions and the geographical relief of the stream basin. According to the temperature criteria in the TWPCR (Table 2), the stream's water quality was Class I (25°C) for seven measurements and Class II (25-30°C) for one measurement (Official Gazette, 1988).

The mean pH value in the stream was 8.1, ranging from 7.7 to 8.3 (Table 1). The slightly alkaline nature of the stream reflects the fact that the bedrock within this region consists mainly of limestone. Similarly, slightly alkaline values were recorded for creeks in the Hazar Lake Basin (Şen et al., 2002). According to the TWPCR (Table 2), these values placed the stream in Class I (6.5-8.5) water quality category for all measurements (Official Gazette, 1988). Seasonal variation of the pH values did not show great differences. The observed values were within the range (6.5-9.0) to permit all natural processes of aquatic life.

DO is a barometer of the ecological health of the stream. It is the most important parameter for protecting fish since most fish can't survive when DO content is less than 3 mg L^{-1} (Chang, 2005; Novotny, 2002). Maximum and minimum DO concentrations in the Behrimaz Stream ranged from 11.8 mg L^{-1} in January to 4.6 mg L^{-1} in June, with a mean concentration of 9.8 mg L^{-1} (Table 1). According to the TWPCR (Table 2), these concentrations place the stream in Class I (8 mg L^{-1}) for seven measurements and Class II (6 mg L^{-1}) for one measurement (Official Gazette, 1988). A negative correlation was found between DO concentrations and water temperatures in Behrimaz Stream (r= –0.97, P<0.01). The oxygen concentration was very high during winter months but showed a decreasing trend from March to June with the increase of water temperature. The seasonal fluctuation in DO concentration was due to the effect of temperature on the solubility of oxygen in water (Karaer and Küçükballı, 2006). Similiar fluctuations have been observed in other streams of the world (Bellos and Sawidis, 2005; Odokuma and Okpokwasili, 1997).

Conductivity in a stream can vary as a function of flow. As flow decreases, the concentration of total dissolved solids can increase, thereby increasing the conductivity. The mean conductivity in the Behrimaz Stream was 227.5 µS cm^{-1}, with values ranging from 200 µS cm^{-1} to 250 µS cm^{-1} (Table 1). Conductivity can be used as a passive tracer to quantify or trace the mixing and dilution processes along the stream (Gomes and Wai, 2014). In the present study, the highest values occured in January, June, November and December, the time of low flow. Because of dilution process, the lowest conductivity values occured in February, March and May, the period of high flow. Conductivity has long been used as an important parameter in deciding whether water resources are suitable for irrigation water or not (Karakoç et al., 2003). Conductivity values placed the stream in the Class I (0-250 µS cm^{-1}) water quality category for all measurements to Turkish Environment Legistation (Official Gazette, 1991).

3.2.2. Nutrients

Villages within the Behrimaz Stream basin are not connected to the sewerage system. Thus, domestic wastewaters from settlements cause pollution of the stream. Also, agricultural pollution related to excessive use of fertilizers has resulted in large phosphate and nitrogen loads to reach the stream and drain into the lake. NH_4-N concentrations ranged from 0.16 mg L^{-1} in January to 3.01 mg L^{-1} in June, with a mean concentration of 1.19 mg L^{-1} (Table 1). According to the NH_4-N criteria in the TWPCR (Table 2), the stream's water quality was Class I (0.2 mg L^{-1}) for one measurement, Class II (1 mg L^{-1}) for three measurements, Class III (2 mg L^{-1}) for two measurements and Class IV (>2 mg L^{-1}) for two measurements (Official Gazette, 1988). NH_4-N has shown strong positive relationship with TKN (r= 0.97, P<0.01), TN (r= 0.87, P<0.01) and BOD_5 (r= 0.71, P<0.05). Major sources of high concentrations of ammonium in the stream are likely fertilizers and household wastewater discharges. In the Behrimaz Stream watershed, ammonium sulfate fertilizer is commonly used in fields and the stream receives ammonium via surface runoff and return flows from irrigation.

Organic nitrogen (Org-N) concentrations in the Behrimaz Stream varied from 0.36 to 2.15 mg L^{-1}, with a mean concentration of 1.15 mg L^{-1} (Table 1). The highest Org-N concentration was detected in June with the lowest concentration in January. Agriculture and cattle grazing are the major activities that impact this area and are probably the major source of organic nitrogen in the stream. Correlation analysis showed that organic nitrogen has a positive significant relationship with COD (r= 0.84, P<0.01), tempareture (r= 0.83, P<0.05) and also BOD_5 (r= 0.79, P<0.05) and a negative significant relationship with DO (r= –0.90, P<0.01).

TKN is the sum of Org-N, NH_4-N and NH_3-N, because of that TKN concentrations displayed variations similar to that of NH_4-N and Org-N. Maximum and minimum TKN concentrations in the Behrimaz Stream ranged from 5.16 mg L^{-1} in June to 0.52 mg L^{-1} in January, with a mean concentration of 2.34 mg L^{-1} (Table 1). The stream's water quality was Class II (1.5 mg L^{-1}) for two measurements, Class III (5 mg L^{-1}) for five measurements and Class IV (>5 mg L^{-1}) for one measurement (Official Gazette, 1988). TKN has shown strong positive relationship with TN (r= 0.94, P<0.01), OrgN (r= 0.87, P<0.01), BOD_5 (r= 0.79, P<0.05), COD (r= 0.79, P<0.05) while it is negatively correlated with dissolved oxygen (r= –0.77, P<0.05).

The mean NO_2-N concentration in the Behrimaz Stream was 23.0 µg L^{-1}, which ranged from 19.8 to 31.3 µg L^{-1} (Table 1). These concentrations placed the stream in Class III (0.05 mg L^{-1}) for all measurements (Official gazette, 1988). Maximum concentrations of NO_2-N were detected in spring. Maximum concentration of NO_3-N (2.24 mg L^{-1}) in the Behrimaz Stream was recorded in May, minimum concentration of NO_3-N (0.45 mg L^{-1}) was in January, with a mean concentration of NO_3-N was 1.36 mg L^{-1} (Table 1). The stream's water quality was Class I (5 mg L^{-1}) for all measurements (Official Gazette, 1988). Kincheloe et al. (1979) and Camargo et al. (2005) have stated the maximum permissible limit of nitrite nitrogen as 2 mg L^{-1} for protection most sensitive freshwater species. Recognizing that the toxic effects of nitrite or nitrate on warm or cold-water fishes could rarely occur in nature, no restrictive criteria are recommended by USEPA. However, nitrite nitrogen at or below 5 mg L^{-1} and nitrate nitrogen at or below 90 mg L^{-1} would have no adverse effects on most of the warm water fishes (USEPA, 1986). In the present study NO_2-N and NO_3-N values were found below the maximum permissible levels. In addition, nitrite and nitrate concentrations in the stream water were below the maximum permissible levels of 1 and 10 mg L^{-1} for drinking water, respectively (USEPA, 2009). The peak concentrations NO_3-N in the Behrimaz Stream coincided with the times (generally from the end of March to the beginning of June) when fertiliser and manure were being applied. NO_3-N values generally displayed similar variations similar to that of NO_2-N. Correlation analysis showed that NO_3-N has a positive significant relationship with TP (r= 0.73, P<0.05).

Concentrations of TN ranged from 6.63 mgL^{-1} in June to 0.98 mg L^{-1} in January, with a mean concentration of 3.72 mg L^{-1} (Table 1). Stream TN concentrations were dominated by NO_3-N during January, March, April and May, by NH_4-N during February, June, November, and by Org-N in December. Excessive nitrogen contributes to eutrophication causing an excessive growth of algae that depletes dissolved oxygen through the decomposisiton process (Davie, 2003). Reduced nitrogen is formed, as ammonia is oxidized in freshwater sytems causing oxygen depletion (Sharma and Ahlert, 1977). Nitrogen is derived from treated sewage, animal wastes, atmospheric deposition, or fertilizers applied on agricultural land or lawns (Chang, 2005). Total nitrogen has shown strong positive relationship with BOD_5 (r= 0.80, P<0.05), tempareture (r= 0.78, P<0.05), COD (r= 0.77, P<0.05) and chloride (r= 0.72, P<0.05) while it is negative correlated with dissolved oxygen (r= –0.82, P<0.05). Major sources of TN in the stream are fertilizers, cattle grazing and household wastewater discharges.

SRP concentrations ranged from 47.1 to 35.4 µg L^{-1}, with a mean concentration of 43.6 µg L^{-1} in Behrimaz Stream (Table 1). The mean natural concentration of SRP of unaffected rivers of the world was reported to be 10 µg L^{-1} by Meybeck and Helmer (1989). The mean concentrations of Behrimaz Stream was obtained to be higher. Agricultural activities and household wastewater are likely major sources for high concentrations of SRP in the Behrimaz Stream. No seasonally significant changes were observed in SRP concentrations in the stream.

Phosphorus is frequently the limiting nutrient for plant growth in freshwater systems and plays a key role in eutrophication. The increase in phosphorus concentrations in the running waters leads to eutrophication and depletion of dissolved oxygen concentrations (Davie, 2003; Kannel et al., 2007). Concentrations of TP ranged from 267 µg L^{-1}in May to 147 µg L^{-1} in January, with a mean concentration of 182 µg L^{-1} (Table 1). According to the criteria in the TWPCR (Table 2), the stream's water quality was Class II (0.16 mg L^{-1}) for three measurements and Class III (0.65 mg L^{-1}) for five measurements (Official Gazette, 1988). To control eutrophication, the USEPA (1986) recommended a limit of 0.05 mg L^{-1} for total P in streams that enter lakes. All sample concentrations were above the recommended upper concentration limit of 0.05 mg L^{-1}. Potential sources for high concentrations of phosphorus in the Behrimaz Stream are probably household wastewater discharges and agricultural practices. Our farm survey indicated that P fertiliser is predominantly applied from the end of March to the beginning of June. Thus, TP peak concentration in the stream coincided with times when fertiliser was being applied. One of the main source of TP in runoff is soils with high phosphorus levels. Suspended particles tend to have adsorbed phosphorus. In the Behrimaz Stream, high TP concentrations in April and May were clearly related to TSS. In addition, the TP showed upward trend from February to May due to increasing flow rate.

3.2.3. BOD_5 and COD

High values of BOD and COD indicate water pollution, which linked to sewage effluents discharged from town, industry or agricultural practice (Bellos and Sawidis, 2005). The elevated levels of BOD and COD lower lower the concentration of the dissolved oxygen in a water body resulting in a bad water quality and stress to the resident aquatic life (Kannel et al., 2007). The mean BOD_5 in the Behrimaz Stream was 2.6 mg L^{-1}, which ranged from 2 to 4 mg L^{-1} (Table 1). BOD_5 is positively correlated with chemical oxygen demand (r= 0.83, P<0.05) and temperature (r= 0.76, P<0.05) and negatively correlated with dissolved oxygen (r= –0.78, P<0.05). BOD_5 values placed the stream in the Class I (4 mg L^{-1}) for all measurements (Official Gazette, 1988). The mean COD in the stream was 10.1 mg L^{-1}, which ranged from 5.4 to 28.8 mg L^{-1} (Table 1). According to the criteria in the TWPCR (Table 2), the stream's water quality was Class I (25 mg L^{-1}) for seven measurements and Class II (50 mg L^{-1}) for one measurement (Official Gazette, 1988). COD value is positively correlated with temperature (r= 0.89, P<0.01) and negatively correlated with dissolved oxygen (r= –0.95, P<0.01). The highest COD values occured during the highest organic periods in May and June. Agricultural activities and domestic wastewaters were the two main reasons for the high BOD and COD values in Behrimaz Stream.

3.2.4. Major ions

In the present study, sulfate concentrations in the stream ranged from 30.4 mg L^{-1} in February to 22.4 mg L^{-1} in January, with a mean concentration of 24.7 mg L^{-1} (Table 1). According to the criteria in the TWPCR (Table 2), these concentrations place the stream in the Class I (200 mg L^{-1}) for all measurements (Official Gazette, 1988). The mean sulfate concentration in the world rivers was reported to be 11.2 mg L^{-1} by Wetzel (1975) and between 9.6 and 16.5 mg L^{-1} by Meybeck and Helmer (1989). Mean sulfate concentration of Behrimaz Stream is higher than mean of world rivers due to probably difference of bedrock lithology. No seasonally significant changes were observed in sulfate concentrations in the stream. During the study sulfate concentrations in the stream were found below the maximum permissible level of 250 mg L^{-1} for drinking water (USEPA, 2009).

The highest chloride (14 mg L^{-1}) concentration was recorded in June, the lowest concentration (5.2 mg L^{-1}) was in March (Table 1). Chloride is considered a conservative chemical species in water, and is therefore considered a good indicator of the amount of effluent being discharged at any given time (Kim et al., 2002). Maximum chloride concentration for drinking water is 250 mg L^{-1} (USEPA, 2009). All Cl values recorded were below the maximum permissible level for drinking water. A negative correlation between chloride and oxygen was determined (r= –0.77, $P<0.05$) and a positive correlation between chloride and temperature was found (r= 0.79, $P<0.05$). The chloride showed upward trend from April to June due to decreasing flow. Chloride concentrations placed the stream in the Class I (25 mg L^{-1}) for all measurements (Official Gazette, 1988). The highest sodium concentration (13.2 mg L^{-1}) in the Behrimaz Stream was detected in May, the lowest concentration (9.7 mg L^{-1}) was in March, the time of the highest flow (Table 1). Sodium has shown strong positive relationship with TSS (r= 0.73, $P<0.05$). The stream's water quality was Class I (125 mg L^{-1}) for all measurements (Official Gazette, 1988). Seasonal variation of the Na values did not show great differences. Potassium concentrations generally are much lower than sodium concentrations in most natural water (Hem, 1985). In the present study, too, potassium concentrations were lower than sodium concentrations. Potassium concentrations in the Behrimaz Stream ranged from 0.4 mg L^{-1} in April to 1.1 mg L^{-1} in May, with a mean concentration of 0.8 mg L^{-1} (Table 1). The concentrations of potassium increased with decreasing flow (r= –0,88, $P<0.01$).

The highest calcium concentration was measured as 46.9 mg L^{-1} in June, while the lowest concentration was recorded as 30.4 mg L^{-1} in January, with a mean concentration of 38.2 mg L^{-1} (Table 1). Calcium is a major constituent of carbonate rocks (Hem, 1985), such as limestone and dolomite, and it dissolves readily in water; therefore, the calcium concentration in water from areas with carbonate rocks tends to be higher than in other areas. The Behrimaz Stream Basin is composed primarily of limestone rocks, thus calcium concentrations are generally high. Correlation analysis showed that calcium has a positive significant relationship with temperature (r= 0.72, $P<0.05$).

3.2.5. Suspended sediment

Erosion has become a serious threat for the stream as a result of insufficient protective vegetation and tree plantation together with unsustainable use of agricultural lands. Soil and streambank erosion have caused increased suspended sediment loads for the stream, subsequently to drain to Lake Hazar.

The amount of TSS in a stream also affects the aquatic fauna. Fish and invertebrates have difficulty breeding when high sediments clog spawning habitat. The amount of TSS is often associated with the amount of discharge and level of treatment. TSS, in most cases, is clay and silt particles, but may be organic in content, resulting in high oxygen demand (Chang, 2005). Suspended sediment in the stream ranged from 2060 to 108 mg L^{-1}, with a mean concentration of 726 mg L^{-1} (Table 1). High values were detected during high rainfall and flow periods in spring, while low values were recorded during dry season. Berner and Berner (1987) reported major rivers have an average suspended solid concentration of 100 to 1000 mg L^{-1}, with a world mean estimated to be 360 mg L^{-1}. The mean concentration of TSS (726 mg L^{-1}) in the Behrimaz Stream was recorded to be higher than the world mean. The primary source of sediment is streambank erosion, surface geology and soils. Severe streambank erosion occured about 1 km upstream of stream mouth after a flood in April. Predominant soils in the lower Behrimaz Stream Basin are lithosolic soils, which are prone to erosion particularly when coupled with cultivated fields, moderate to steep slopes, and intense precipitation (Özdemir, 1995b).

3.3. Stream inputs to Lake Hazar

Monthly and annual amounts of water, nutrients, BOD_5, COD, major ions and suspended sediment carried by the Behrimaz Stream into the Lake Hazar are given in Table 3. Loads of nutrients, BOD_5, COD, major ions and suspended sediment were higher in February, March and April because of high flows, while they were lower in other months because of low flows. The relationship between loads and water discharge were consistently significant for all parameters (r>0.74, $P<0.05$) except for NH_4-N (r= 0.32, $P<0.05$).

Total annual water discharge carried by the Behrimaz Stream into Lake Hazar was estimated to be 29.233x10^6 m^3. About 52% of water input into Lake Hazar was in March (7.906x10^6 m^3) and April (7.335x10^6 m^3) (Table 3). Şen et al. (2002) reported that the amount of water discharged by the Behrimaz Stream was about 27x10^6 m^3 yr^{-1}. This value was confirmed by this study. The stream has been flowing into Hazar Lake to provide water source since 1960. Thus, Behrimaz Stream is very important for the water budget of the lake. Total annual loads of NH_4-N, Org-N, NO_2-N, NO_3-N and TKN were calculated to be 27.25, 31.30, 0.69, 44.53 and 58.55 t yr^{-1}, respectively (Table 3). An important portion of annual loads of NH_4-N, Org-N, NO_2-N, NO_3-N and TKN was carried during high streamflow periods. The highest TN load (about 23.6% of total annual load) was transported in April (24.510 t) while the lowest load (about 2.4% of total load) was carried in January (2.532 t). The annual load of TN entering Lake Hazar was calculated to be 103.77 t yr^{-1} (Table 3). About, 26.26%, 30.16%, 0.66% and 42.92% of the annual load of TN entering the lake was in form of NH_4-N, OrgN, NO_2-N and NO_3-N, respectively.

Table 3. Monthly and annual total amounts of water, nutrients, major ions and suspended sediment (t, ton)

Parameters	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Nov*	*Dec*	*Total*
Q (m^3)	2,571,264	4,877,107	7,906,637	7,335,360	2,772,144	1,604,448	902,016	1,264,205	29,233,181
(%)	(8.80)	(16.68)	(27.05)	(25.09)	(9.48)	(5.49)	(3.09)	(4.32)	(100)
NH_4-N (t)	0.41	10.93	2.85	3.01	2.88	4.83	1.36	0.97	27.25
(%)	(1.51)	(40.09)	(10.44)	(11.03)	(10.58)	(17.72)	(5.00)	(3.62)	(100)
TKN (t)	1.34	15.51	12.81	9.10	6.79	8.28	2.53	2.20	58.55
(%)	(2.28)	(26.49)	(21.88)	(15.54)	(11.60)	(14.14)	(4.31)	(3.76)	(100)
Org-N (t)	0.93	4.58	9.96	6.09	3.91	3.45	1.16	1.21	31.30
(%)	(2.96)	(14.65)	(31.83)	(19.45)	(12.49)	(11.02)	(3.72)	(3.88)	(100)
NO_2-N (t)	0.05	0.12	0.18	0.18	0.09	0.03	0.02	0.03	0.69
(%)	(7.28)	(17.18)	(25.62)	(25.91)	(12.52)	(3.93)	(2.77)	(4.08)	(100)
NO_3-N (t)	1.14	6.33	11.20	15.24	6.20	2.32	1.02	1.08	44.53
(%)	(2.57)	(14.21)	(25.14)	(34.21)	(13.93)	(5.22)	(2.29)	(2.43)	(100)
TN (t)	2.53	21.96	24.18	24.51	13.08	10.63	3.56	3.31	103.77
(%)	(2.44)	(21.16)	(23.30)	(23.62)	(12.61)	(10.24)	(3.43)	(3.19)	(100)
SRP (t)	0.09	0.22	0.36	0.31	0.13	0.07	0.04	0.06	1.27
(%)	(7.16)	(17.47)	(28.01)	(24.15)	(9.83)	(5.43)	(3.30)	(4.41)	(100)
TP (t)	0.38	0.73	1.30	1.42	0.74	0.27	0.19 (3.54)	0.20	5.23
(%)	(7.21)	(13.88)	(24.93)	(27.21)	(14.15)	(5.14)		(3.86)	(100)
BOD_5 (t)	5.14	14.63	23.72	14.67	8.32	6.42	1.80	2.53	77.23
(%)	(6.66)	(18.94)	(30.71)	(19.00)	(10.77)	(8.31)	(2.34)	(3.27)	(100)
COD (t)	13.89	33.16	72.74	61.62	28.28	46.21	5.05	7.84	268.78
(%)	(5.17)	(12.34)	(27.06)	(22.92)	(10.52)	(17.19)	(1.88)	(2.92)	(100)
Cl (t)	16.97	33.65	41.12	81.42	34.10	22.46	10.46	7.46	247.64
(%)	(6.85)	(13.59)	(16.60)	(32.88)	(13.77)	(9.07)	(4.23)	(3.01)	(100)
SO_4 (t)	57.60	148.26	182.64	176.78	70.97	39.63	22.55	28.45	726.88
(%)	(7.92)	(20.40)	(25.13)	(24.32)	(9.76)	(5.45)	(3.10)	(3.91)	(100)
Na (t)	30.34	54.62	76.46	96.09	36.59	17.81	11.28	15.68	338.87
(%)	(8.95)	(16.12)	(22.56)	(28.36)	(10.80)	(5.26)	(3.33)	(4.63)	(100)
K (t)	2.37	4.39	4.51	2.71	2.94	1.46	0.95	1.26	20.59
(%)	(11.49)	(21.32)	(21.89)	(13.18)	(14.27)	(7.09)	(4.60)	(6.14)	(100)
Ca (t)	78.17	178.50	282.27	233.26	122.53	75.28	38.16	47.53	1,055.70
(%)	(7.40)	(16.91)	(26.74)	(22.10)	(11.61)	(7.13)	(3.61)	(4.50)	(100)
TSS (t)	1398.77	1711.87	1478.54	15110.84	3476.27	173.28	219.19	1345.11	24,913.87
(%)	(5.61)	(6.87)	(5.93)	(60.65)	(13.95)	(0.70)	(0.88)	(5.40)	(100)

Annual TP and SRP loads were estimated to be 5.23 and 1.27 t yr^{-1}, respectively (Table 3). The lowest TP load (about 3.5% of total load) was transported into the lake in November (0.19 t) while the highest load (about 27.2% of total load) was in April (1.42 t). It was determined that the 24.3% of the annual load of total phosphorus was in form of SRP. NO_3-N and SRP is most easily used by most rooted plants and algae. However, 42.916% and 24.3% of the P and N entering the lake is the form of NO_3-N and SRP, respectively. Thus, a small portion of the nutrient load is considered to be bioavaliable to algae in the lake.

The annual nitrogen and phosphorus loadings were calculated for the lake surface area, and these figures were compared to the permissible and dangerous loading values according to Vollenweider's criteria. Vollenweider (1968) suggested permissible and dangerous loading levels for a lake with an average depth of 100 m to be 6.0 and 12.0 g N m^{-2} yr^{-1} and 0.40 and 0.80 g P m^{-2} yr^{-1}. In Lake Hazar the calculated phosphorus load into the lake is only 0.066 g P m^{-2} yr^{-1} and for nitrogen 1.323 g N m^{-2} yr^{-1} (Table 4). These values are permissible values for Lake Hazar according to Vollenweider (1968).

Total annual loads of BOD_5 and COD were estimated to be 77.23 and 268.78 t yr^{-1} respectively. The highest BOD_5 and COD loads were transported in March (23.72 and 72.74 t, respectively) while the lowest loads were carried in November (1.80 and 5.05 t, respectively) (Table 3).

The annual loads of sulfate, chloride, sodium, potassium and calcium were estimated as 726.88, 247.64, 338.87, 20.59 and 1,055.70 t yr^{-1}, respectively (Table 3). Whilst 50% of annual loads of chloride and sodium and 49% of annual loads of sulfate and calcium were transported in March and April, 43% of annual load of potassium was carried into the lake in February and March. The annual load of TSS was very high because of soil erosion and bank erosion in Behrimaz Stream catchment during high rainfall periods. During the one year of study, the Behrimaz Stream transported 24.913x10^3 tons of TSS to Lake Hazar. About, 60% of annual load of TSS was carried in April (15.110x10^3 t yr^{-1}) (Table 3). Sağıroglu and Çetindağ (1995) reported that total TSS load of Kürk Stream and Mangal Brook for Lake Hazar was 80x10^3 t yr^{-1}.

The TSS loads of Behrimaz Stream are much higher than that of Sağıroglu and Çetindağ (1995) because Behrimaz Stream has greater water discharge and catchment than Kürk Stream and Mangal Brook. The volume of TSS carried by Behrimaz Stream into the lake were estimated 9.4x10^3 m^3 during the present study period. Most of TSS consisted of silt and clay particles that were dispersed in the coastal area of the lake, affecting light transmissivity.

Table 4. Estimated nitrogen and phosphorus loadings to the Lake Hazar and calculated critical loading values according to Vollenweider (1968)

Area (km²)	***Mean depth (m)***	***Annual Loads ($t\ y^{-1}$)***		***Calculated annual loading values ($g\ m^{-2}\ y^{-1}$)***		***Permissible values ($g\ m^{-2}\ y^{-1}$) (for 100 m depth)***		***Dangerous values ($g\ m^{-2}\ y^{-1}$) (for 100 m depth)***	
		N	P	N	P	N	P	N	P
78.4	93	103.768	5.230	1.323	0.066	6.0	0.40	12.0	0.80

4. Conclusions and recommendations

This study examined both water quality of the Behrimaz Stream and amounts of inflow, nutrients, major ions and suspended sediment carried by the stream into Lake Hazar. The results show the following:

According to the criteria stipulated in the TWPCR, Behrimaz Stream exhibited Class I (high quality water) for temperature, pH, DO, EC, NO_3-N, BOD_5, COD, SO_4, Cl and Na, and Class III (polluted water) for NH_4-N, TKN, NO_2-N and TP.

Strong negative correlations between the DO and the organic-related parameters such as TKN, OrgN, TN, BOD_5 and COD were found. About 52% of water input into Lake Hazar occurred in March and April.

Agricultural activities, household wastewater discharges and cattle grazing were major sources of nutrients in the Behrimaz Stream. About 47% of TN and 52% of TP were carried into lake in March and April.

The annual nitrogen and phosphorus loadings are permissible values for Lake Hazar according to Vollenweider's criteria.

About 43% and 24% of the P and N entering the lake were the form of NO_3-N and SRP, respectively. Thus, a small portion of the nutrient load is considered to be bioavailable to algae in the lake.

The concentration of cations followed Ca >Na > K, while the anions followed SO_4 > Cl. Major ratio of annual loads of sulfate, chloride, sodium, potassium and calcium was carried during high streamflow periods.

Behrimaz Stream was the major contributor of TSS to Lake Hazar. About, 60% of annual load of TSS was carried in April. The primary source of TSS was soil erosion and streambank erosion. The volume of TSS carried by Behrimaz Stream into the lake were estimated to be 9.4×10^3 m^3 during the present study period. Possible reasons for the poor water quality in Behrimaz Stream include agricultural activities, wastewater discharges, cattle grazing and soil erosion, all of which are known as sources of pollution in the basin. Based on these facts, a pollution control programme to address these problems should be carried out in short term, as follows.

1. All villages within the Behrimaz Stream basin should be connected to the sewerage.

2. Unauthorized agricultural land use should be curtailed, and the usage of fertilizers and pesticides should be better controlled.

3. Soil-erosion control projects should be developed and implemented within the Behrimaz Stream basin as soon as possible.

Acknowledgments

I would like to thank the editor and other two anonymous reviewers for their constructive suggestions. I also thank Dr. Karolina Fucikova for improving the English of this manuscript.

References

APHA, (1995), *Standard Methods for the Examination of Water and Wastewater*, 16th Edition. American Public Health Association, Washington, D.C., New York.

Bellos D., Sawidis T., (2005), Chemical pollution monitoring of the River Pinios (Thessalia-Greece), *Journal of Environmental Management*, **76**, 282-292.

Berner E.K., Berner R.A., (1987), *The Global Water Cycle: Geochemistry and Environment*, Prentice Hall Publisher, New Jersey.

Camargo J.A., Alonso A., Salamanca A., (2005), Nitrate toxicity to aquatic animals: A review with new data for freshwater invertebrates, *Chemosphere*, **58**, 1255-1267.

Chang H., (2005), Spatial and temporal variations of water quality in the river and its tributaries, Seoul, Korea, 1993-2002, *Water, Air, and Soil Pollution*, **161**, 267-284.

Davie T., (2003), *Fundamentals of Hydrology*, Psychology Press, Routledge, New York.

Gomes P.I.A., Wai O.W.H., (2014), Sampling at mesoscale physical habitats to explain headwater stream water quality variations: Its comparison to equal-spaced sampling under seasonal and rainfall aided flushing states, *Journal of Hydrology*, **519**, 3615-3633.

Guy H.P., (1978), *Fluvial Sediment Concepts*, USGS TWRI Book 3.

Günek H., Yiğit A., (1995), *Hydrographic Properties of Lake Hazar Basin*, Proc. of the 1st Lake Hazar and its Environment Symposium, Elazığ, Turkey.

Hem J.D., (1985), *Study and Interpretation of the Chemical Characteristics of Natural Water*, U.S. Geological Survey Water-Supply Paper 2254, US.

Kannel P.R., Lee S., Kanel S.R., Khan S.P., Lee Y.S., (2007), Spatial-temporal variation and comparative assessment of water qualities of urban river system: a case study of the river Bagmati (Nepal), *Environmental Monitoring and Assessment*, **129**, 433-459.

Karaer F., Küçükballı A., (2006), Monitoring of water quality and assessment of organic pollution load in the Nilüfer Stream, Turkey, *Environmental Monitoring and Assessment*, **114**, 391-417.

Karakoç G., Erkoç F.Ü., Katırcıoğlu H., (2003), Water quality and impacts of pollution sources for Eymir and Mogan Lake (Turkey), *Environment International*, **29**, 21-27.

Kim K., Lee J., Oh C., Hwang G., Kim J., Yeo S., Kim Y., Park S., (2002), Inorganic chemicals in an effluent-

dominated stream as indicators for chemical reactions and stream flows, *Journal of Hydrology*, **264**, 147-156.
Kincheloe J.W., Wedemeye G.A., Koch D.L., (1979), Tolerance of developing salmonid eggs and fry to nitrate exposure, *Bulletin of Environmental Contamination and Toxicology*, **23**, 575-578.
Meybeck M., Helmer R., (1989), The quality of rivers - from pristine stage to global pollution, *Palaeogeography, Palaeoclimatology, Palaeoecology*, **75**, 283-309.
Novotny V., (2002), *Water Quality: Diffusion Pollution and Watershed Management*, Hoboken, NJ, Wiley.
Odokuma L.O., Okpokwasili G.C., (1997), Seasonal influences in the organic pollution monitoring of the New Calabar River, Nigeria, *Environmental Monitoring and Assessment*, **45**, 43-56.
Özdemir M.A., (1995a), *Geomorphology of Lake Hazar Basin and Formation of Lake,* Proc. of I. Lake Hazar and its Environment Symposium, Elazığ, Turkey.
Özdemir M. A., (1995b), *Erosion Problem in Lake Hazar Basin (Elazığ) and its Precautions*, Proc. of the 1st Lake Hazar and Its Environment Symposium, Elazığ, Turkey.
Official Gazette, (1991), Gazette of Republic of Turkey, Water Pollution Control Legislation Communique on Technical Procedures. No. 20748/1991, Government Printing Office, Ankara.
Official Gazette, (1998), Water Pollution Control Legislation, Gazette of Republic of Turkey No. 19919/1988, Government Printing Office, Ankara, Turkey.
Sağıroğlu A., Çetindağ B., (1995), *Siltation of Lake Hazar by Mogal and Kürk Streams*, Proc. of the 1st Lake Hazar and its Environment Symposium, Elazığ, Turkey.
Sharma B., Ahlert R. C., (1977), Nitrification and nitrogen removal, *Water Research*, **11**, 897-925.
Şen B., Topkaya B., Nacar V., (1995), *Trophic Status and Algae of Lake Hazar*, Proc. of the 1st Lake Hazar and its Environment Symposium, Elazığ, Turkey.
Şen B., Alp M.T., Özrenk F., Ercan Y., Yıldırım V., (1999), A study on the amounts of plant nutrients and organic matter carried into Lake Hazar (Elazığ-Turkey), *Fresenius Environmental Bulletin*, **8**, 272-279.
Şen B., Koçer M.A.T., Alp M.T., (2002), Some physical and chemical properties of running waters flowing into the Lake Hazar, *Science and Engineering Journal of Firat University*, **14**, 241-248.
Şen B., Alp M.T., Koçer M.A.T., (2003), *Lake Hazar and its Properties*, The 12th National Fisheries and Aquaculture Symposium, Elazığ, Turkey.
USEPA, (1986), Quality Criteria for Water, 1986 (Gold Book), Office of Water Regulations and Standards, EPA 440/5–86–001, United States Environmental Protection Agency, Washington DC.
USEPA, (2009), National Primary Drinking Water Regulations, EPA 816-F-09-004, United States Environmental Protection Agency.
Vollenweider R.A., (1968), Scientific fundamentals of the eutrophication of lakes and flowing waters with particular reference to phosphorus and nitrogen as factors in eutrophication, OECD Technical Report DAS/CSI/68, Paris, On line at: https://www.amazon.com/Scientific-fundamentals-eutrophication-particular-phosphorus/dp/B0007JAS6A
Wetzel R.G., (1975), *Limnology*, W.B. Saunders Company, Philadelphia, USA.
Yiğit A., Çitçi M.D., (1995), *Agricultural Activities in Lake Hazar and Behrimaz Watersheds*, Proc. of the 1st Lake Hazar and its Environment Symposium, Elazığ.
Yiğit A., Hayli S., (1995), *Geographical Features of Rural Settlements in Lake Hazar and Behrimaz Watersheds*, Proc. of the 1st Lake Hazar and its Environment Symposium, Elazığ.