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Araştırma Makalesi Research Article

ASSESSMENT OF THE STREAM NETWORK POLLUTION IN THE EĞIRDIR LAKE BASIN (TURKEY) USING WATER QUALITY INDEX AND MULTIVARIATE ANALYSIS

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Keywords
WQI (Water Quality Index),
Stream water,
Eğirdir Lake Basin,
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Abstract

Eğirdir Lake which is one of the sources of the drinking water of Isparta (Turkey) is the second largest fresh water lake of Turkey. The most important surface waters in the study area are Pupa, Hoyran, Yalvaç and Çay Streams. Pollutants from point and nonpoint sources are transported into the lake via these four main streams. In this study, stream water quality, seasonal variations and its suitability for drinking usage were evaluated. Parameters which are controlled to chemical variations of stream water, were analyzed with R-mode factor and correlation analysis. According to R-mode factor analysis, EC, NO_3, NO_2, NH_3, BOD, COD in dry season and K, HCO_3, Cl, NH_3, NH_4, orthophosphate, total phosphorus, BOD, COD in wet season are the most important parameters. In addition, Water Quality Index (WQI) was applied to suitability for drinking purpose and evaluation of stream water quality. According to the WQI in dry season, 46.66% of stream water samples exhibited ''good water'', 20% exhibited ''poor water'', and 33.33% exhibited "very poor water". In wet season 46.66% of stream water samples exhibited ''excellent water'', 13.33% exhibited ''good water'', 26.66% indicated ''poor water'' and 13.33% showed "very poor water".

EĞİRDİR GÖLÜ HAVZASI AKARSU AĞINDAKİ KİRLİLİĞİN SU KALİTE İNDEKSİ VE ÇOK DEĞİŞKENLİ ANALİZ YÖNTEMİ İLE DEĞERLENDİRİLMESİ

Anahtar Kelimeler
WQI (Su Kalite İndeksi),
Dere suyu,
Eğirdir Gölü Havzası,
Hidrokimya.

Öz

Eğirdir Gölü Türkiye'nin ikinci büyük tatlı su gölüdür ve Isparta'nın içme suyu ihtiyacının bir kısmı bu gölden sağlanmaktadır. Havza içerisinde akan en önemli yüzey suları Pupa, Hoyran, Yalvaç ve Çay dereleridir. Noktasal ve noktasal olmayan kaynaklardan gelen kirleticiler bu dört ana akış yoluyla göle taşınır. Bu çalışmada, dere sularının kalitesi, mevsimsel değişimleri ve içme kullanımına uygunluğu değerlendirilmiştir. Dere sularının kimyasal varyasyonlarına göre kontrol edilen parametreler R-mod faktörü ve korelasyon analizi ile analiz edilmiştir. R-mod faktörü analizine göre, kurak dönemde EC, NO_3, NO_2, NH_3, BOİ ve KOİ kurak dönemde; K, HCO_3, Cl, NH_3, NH_4, ortofosfat, toplam fosfor, BOİ ve KOİ ise yağışlı dönemde en önemli parametrelerdir. Ayrıca, akarsu su kalitesinin araştırılması ve içme amaçlı kullanıma uygunluğa için Su Kalitesi İndeksi (WQI) uygulanmıştır. Kurak dönem WQI indeksine göre, dere suyu örneklerinin 46.66%'sı "iyi su", 20%'si "zayıf su", 33.33%'ü "çok zayıf su" özelliği göstermektedir. Yağışlı dönemde örneklerin 46.66%'sı "mükemmel su", 13.33%'ü "iyi su", 26.66%'sı "zayıf su" ve 13.33%'ü "çok zayıf su" özelliği göstermektedir.

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1. Introduction

The stream water quality is a matter of serious concern today. Pollution of stream water with toxic chemicals and eutrophication of rivers and lakes with excess nutrients are of great environmental concern worldwide.

The municipal and industrial wastewater discharge constitutes the constant polluting source, whereas, the surface run-off is a seasonal phenomenon, largely affected by climate in the basin (Singh et al. 2005). Seasonal variations in precipitation, surface run-off, groundwater flow, water interception and abstraction have a strong effect on river discharge and subsequently on the concentration of pollutants in river water. Since, stream and surface waters constitute the main inland water resources for domestic, industrial and irrigation purposes, it is imperative to prevent and control the surface water pollution and to have reliable information on the quality of water for effective management (Singh et al. 2005).

Several approaches such as Water Quality Index (WQI) method have been introduced to assess the water chemistry and status of water quality in the river and stream water (Nunes et al. 2003; Subramani 2005; Subramani et al. 2005; Tsegaye et al. 2006; Möller et al. 2007;). WQI is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers. It, thus, becomes an important parameter for the assessment and management of water.

Surface water pollution is identified as the major problem affecting the Lake District of Turkey, too. In recent years, the anthropogenic inputs negatively affect the lake water quality (Şener at al. 2013). Eğirdir Lake is one of the most important lakes in the region where water quality is deteriorated. Therefore, the streams recharging the Eğirdir Lake have been chosen as the study area. The streams in the study area are the important sources that recharging the Eğirdir Lake. However, the quality of these streams is affected by point and nonpoint pollutant sources. Domestic wastewaters of the settlements and agricultural activities are the most important nonpoint pollution sources. Currently, effects of these pollutants on water quality are not exactly known. Hence, this study is extremely important for the region. Many studies have been made related with the Eğirdir Lake (Kesici and Kesici 2006; Bostancı et al. 2007; Güneş 2008; Şener et al. 2013; 2014). In addition, the major and trace elements in sediments of the lake have been determined by Alemdaroğlu et al. (2000). Despite all these studies, a detailed study has not been conducted on the stream water and water qualities that recharging Eğirdir Lake. Therefore, this study is also very important in terms of future of Eğirdir Lake and stream waters having different usage areas such as drinking and usage water.

2. Materials and methods

2.1. Study area

The streams in the study area are located in the Eğirdir Lake catchment area. The Eğirdir Lake is located within the Lake District at latitude 3785004100–3881605500N, longitude 305704300–3084403900E in southwest Turkey (Fig. 1). Eğirdir Lake is the second largest fresh water resource of Turkey. The lake area is 457 km^2. The Eğirdir Lake is a tectonic origin. (Koçyiğit 1983). The recharging of Eğirdir Lake is provided by rainfall and surface-groundwater discharges. The most important streams in the recharging basin of the lake are Pupa Stream, Çay Stream, Hoyran Stream and Yalvac Stream.

Fig. 1. Location and geological maps of the study area. (Şener, 2010)

Pupa Stream; the Pupa Stream to the west of Eğirdir Lake is discharged by a 45 km^2 surface flow. The drainage area of the pupa stream is 202 km^2. Uluborlu bridge and Senirkent bridge flow observation stations are operated on Pupa stream by the State Hydraulic Works, XVIII. Regional Directorate. According to Senirkent bridge flow observation station data, the average monthly flow of this stream is measured as 0.39 m^3/s between the years 1967-2000. Pupa Stream is dry in summer months. It has some major tributaries in the drainage basin. These, Değirmendere Stream, recharging from the source Değirmendere, Şehir Stream which is born from the Kapı Mountain has flow 60 L/s, Suuçan Stream, discharge into the Pupa stream from the Suuçan district in the east of Uluborlu, Dereköy Stream between Dereköy-Kucukkabaca and İleydağı Stream which is from the recharging Ahır Stream in the west of Uluborlu (Şener ,2010). ***Hoyran Stream;*** it originates from the Sultandağ mountain, located to the north east of the basin. It discharges into Eğirdir Lake with a surface flow about 20 km. The maximum flow rate is 0.526 m^3/s (in March). It is dry in July and August months. For many years, the monthly average flow rate is 0.29 m^3/s (Şener 2010). ***Yalvaç Stream;*** this stream is born from the northwest of the Yalvaç district. The length is about 55 km. The Yalvaç Stream is dry in summer. For many years, the average monthly flow rate of the Yalvaç Stream is 2.2 m^3/s (Şener 2010). ***Çay Stream;*** this stream is born from the north east of Gökçehöyük town. For many years, the average monthly flow rate of the Çay Stream is 1.55 m^3/s. In dry months, it is recharge from Aksu Stream (Şener 2010).

2.2. Geology

Groundwater and surface water quality depends on both the geological structure of the area and water-rock interaction time. Therefore, lithological units of the study area were firstly determined. The formations in the study area were outcropped as autochthonous and allochthonous (Fig. 2; Table 1; Şener 2010; Şener 2011). The autochthonous units at west of Eğirdir Lake composed of; Menteşe dolomite, Alakilise limestone, Suuçan stream limestone, Beydağları formation, Kapıdağ limestone, Uluborlu formation, İncesu conglomerate members, Zendevi volcanics, Pupa stream conglomerate of terrestrial sediments, and composed of slope debris and alluvium overlying all units as incompatible (Şener 2010; Şener et al. 2013, 2014; Fig. 2). Allochthonous units at west of Eğirdir Lake composed of Isparta stream formation and Isparta ophiolite complex. The autochthonous units at east of the lake composed of Sultandede formation, Kasımlar formation, Menteşe dolomite, Hacıalabaz limestone, Anamasdağ formation, Beydağları formation, Bağkonak formation, Yarikkaya formation, Göksöğüt formation, the slope debris and alluvium. The allochthonous units at east of the lake composed of Yeniceboğazı stream formation, Keçili formation and Hoyran ophiolite (Fig. 2; Table 1; Şener 2010).

2.3. Pollutant sources

Pollutant types in the study area can be grouped into point and nonpoint sources. In the study area, the artificial wetlands, domestic wastewater, industrial activities and uncontrolled landfills are point pollution sources, and agricultural activities are the most important nonpoint pollution source. In this region, pollutants transported into the lake via four main streams. The Eğirdir and Yalvaç district have the greatest wastewater treatment plants in the basin. The excess water of the Eğirdir Lake and the purified wastewater of the Eğirdir sewage treatment plant discharges into the Kovada channel. In addition, in the region, the purified wastewater of the Yalvaç treatment plant discharges into the Yalvaç stream and this streams flow into the lake, too. (Şener et al. 2013). There are nine artificial wetlands (in Senirkent, Uluborlu, Yalvaç, Gelendost and Eğirdir districts) which are described as pollutant sources at present in the study area (Şener et al. 2013). There is no controlled landfill site in the basin. Garbage dumps are disposed on permeable units such as limestone and alluvium. Therefore the leachate generating from the open dump areas mixes into surface or groundwater. Leather Tanneries in Yalvaç district are the most important industrial pollutant within the basin. The wastewater of the 62 enterprises belonging to the tanneries is purified in the Yalvaç treatment plant. But these wastewaters directly flow into the Yalvaç Stream and their drainage canal which in turn reach to Eğirdir Lake. Besides, Asya Fruit Juice Factory is located at out of the basin but wastewater of this factory was purified in the Eğirdir sewage treatment plant. But, sometimes these wastewaters mix to the lake water due to working problems of the Eğirdir treatment plant. (Şener et al. 2013).

Agricultural activities in the basin are the most important nonpoint pollution sources. The most common type of land use within the basin is arable lands which are not irrigated - (Şener et al. 2013). The fertilizers (synthetic and natural) and pesticides are used widely during these agricultural activities.

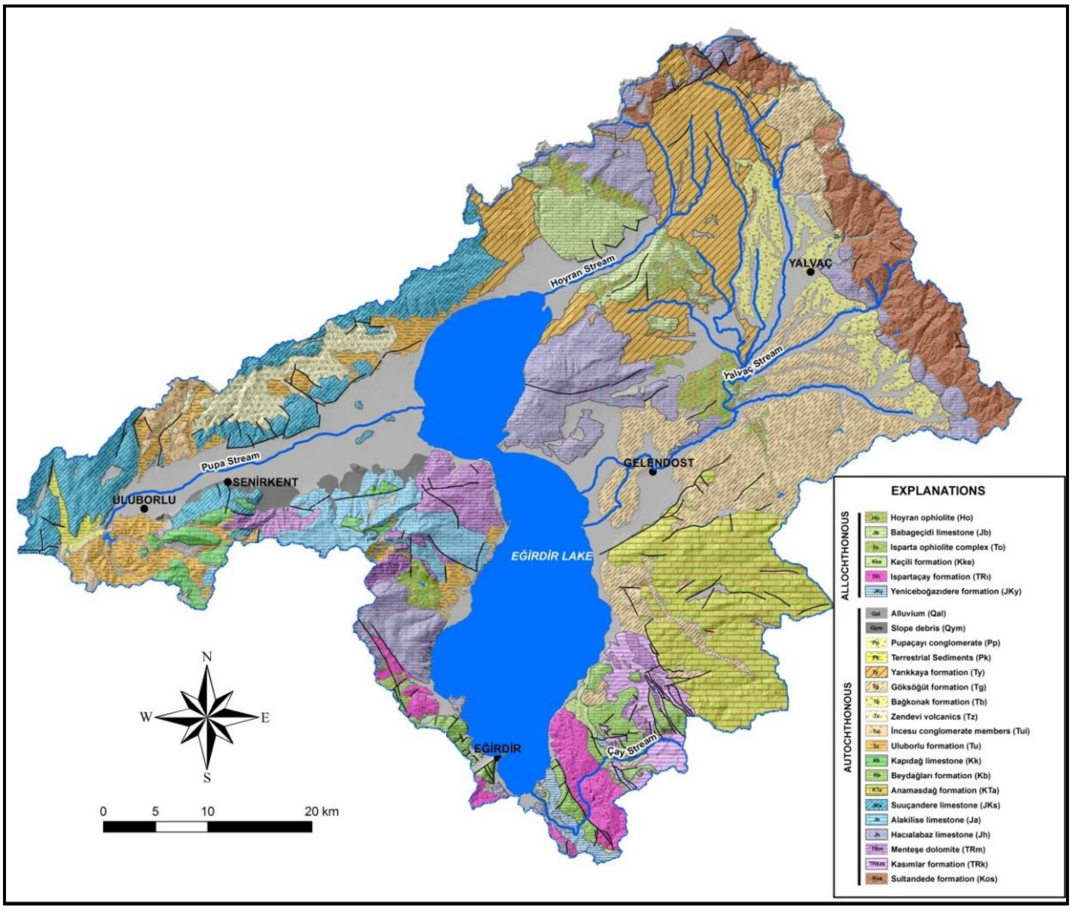

Fig. 2. Location of the water samples in the study area

Table 1. Lithostratigraphic relations of the geologic units and properties

Formation	Age	Lithology
Alluvium (Qal)	Quaternary	Loose clay, silt, sand, gravel and block size material
Slope debris (Qym)	Quaternary	Attached to the loose clay, silt, sand, gravel and block size material
Pupaçayı conglomerate (Pp)	Pliocene (Neogene)	Loosely attached conglomerates
Terrestrial sediments	Pliocene (Neogene)	Clay
Göksöğüt formation (Tg)	Neogene	Conglomerate, sandstone, claystone, siltstone, mudstone, lacustrine limestone
Yarıkkaya formation (Ty)	Neogene	Calcareous shale, clayey limestone, marl, claystone, mudstone
Bağkonak formation (Tb)	Neogene	Poorly sorted conglomerate, sandstone, sandy limestone, mudstone, claystone
Zendevi volcanics (Tz)	Miocene	Gray, dark gray, tuff, aglomera
Hoyran ophiolite (Ho)	Eocene	Limestone blocks in radiolarite, chert, peridotite, serpentinite
Babageçidi limestone (Jb)	Eocene	Limestone blocks in radiolarite, chert, peridotite, serpentinite
İncesu conglomerate members (Tui)	Eocene	Sandstone, sandy clay, limestone intermediate level conglomerate
Isparta ophiolite complex (To)	Eocene	Sandstone, mudstone, limestone, diabase, radiolarite chert blocks
Uluborlu formation (Tu)	Paleocene- Eocene	Sandstone, claystone, siltstone, conglomerate
Anamasdağ formation (KTa)	Cretaceous	Abundantly cracked and cracked locally dolomitic limestone
Keçili formation (Kke)	Cretaceous	Sandstone, claystone, radiolarite, chert
Ispartaçay formation (TRı)	Cretaceous	Radiolarite, chert, sandstone, limestone, mudstone, volcanic clay
Kapıdağ limestone (Kk)	Cretaceous	Medium thick layered, gray cream colored rudimentary limestone
Beydağları formation (Kb)	Jurassic-Cretaceous	Medium thick bedded, gray colored dolomitic limestone
Suuçandere limestone (JKs)	Jurassic-Cretaceous	Ash-colored, middle-layered, fossil-grained limestone
Alakilise limestone (Ja)	Jurassic	Medium-thick bedded, dark gray, chert-intercalated limestone
Hacıalabaz limestone (Jh)	Jurassic	Medium thick bedded gray beige colored dolomite, dolomitic limestone, limestone
Yeniceboğazıdere formation (JKy)	Jurassic	Calciturbidite, chert, radiolarite, shale, cherty micrite
Menteşe dolomite (TRm)	Triassic	Medium thick layered, frequently jointed, dolomite and dolomitic limestone
Kasımlar formation (TRk)	Triassic	Thin, medium, thick bedded, bituminous claystone, siltstone, sandstone shale
Sultandede formation (Kos)	Paleozoic	Quartzite and recrystallized limestone intercalated metaclastic, metasilestone, metaconglomera

2.4. Methods

Sample collection

Total 30 water samples from stream waters and the stream's tributaries were analyzed in October 2010 (dry season) and May 2010 (wet season) for the determination of their major physicochemical properties (Fig. 2; Table 2.). Magellan Explorist 600 manual Global Position System (GPS) were used for Geographical positions of sampling sites. Standard Methods, 1060 Collection and Preservation of Samples was used for the collection of water samples (Eaton et al. 1998). While 1 L polyethylene bottles were used for collecting water samples, 500 mL dark-colored polyethylene bottles were selected for samples for analysis of BOD. During sampling, bottles labeled to avoid misidentification were rinsed in clear spring water several times and then filled to the top to minimize the entrapment of air in water samples (Larsen et al. 2001), and stored at 4 °C in the refrigerator. Sample preservation at the heavy metal analysis was accomplished by adding 1 mL of 1:1 diluted nitric acid (From 65% HNO_3, Merck) as preservative to adjust pH (Sener et al, 2013; Dede et al., 2018). Preservatives were added to the container immediately after collecting the samples. Preserving samples in this way retards biodegradation, hydrolysis, precipitation, and sorption reactions (Tayfur et al. 2008).

Analytical procedure

Physical properties of the water samples such as pH, temperature (T; C), electrical conductivity (EC; lS/cm), and dissolved oxygen (DO; mg/l) were measured in situ with YSI Professional Plus handheld multiparameter instrument that were calibrated with standard solutions. The major chemical constituents were analyzed at the ACME Laboratory (Canada-ISO 9002 Accredited Co.). The major cation and trace metal amounts were determined (Table 2). by inductively coupled plasma mass spectrometry (ICPMS) within group 2C-MS in ACME Laboratory, too. The turbidity of the samples was measured by Hach Turbidimeter. The Argentometric method based on titration of a sample with silver nitrate was used for the determination of chloride (AWWA 1995). The hydroxyl, carbonate, and bicarbonate concentrations were determined by titrimetric method. Spectrophotometer reagents and WTW photoLab Spectral-12 Spectrophotometer were used for the determination of COD, phosphate, total phosphor, nitrite, nitrate, and ammonia. The WTW Oxitop IS 6 Inductive Stirring System was used for the determination of the BOD. SO4 was determined spectrophotometrically by barium sulfate turbidity method (Clesceri et al. 1998; AOAC 1995). All of the analyses except for major cation and trace metal were performed in the Eğirdir Fisheries Research Institute Laboratory (Isparta/Turkey) (Table 2).

Table 2. Descriptive statistics for concentrations of chemical constituents

Parameters	**n (Sample number)**	**Dry Season**				**Wet Season**			
		Min.	**Max.**	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**Mean**	**Std. Dev.**
Ca (mg/L)	15	12.64	71.03	44.39	21.02	10.26	112.96	65.74	29.49
Mg (mg/L)	15	8.97	39.78	24.15	11.46	8.09	33.86	16.50	6.70
Na (mg/L)	15	7.42	25.69	13.95	6.85	5.71	47.26	18.93	11.34
K (mg/L)	15	1.23	8.56	3.51	2.91	1.03	8.58	4.63	2.99
HCO_3 (mg/L)	15	289.05	565.13	390.01	88.23	250.23	602.17	381.63	116.31
CO_3 (mg/L)	15	21.74	39.24	27.93	5.96	20.10	34.20	25.32	5.08
Cl (mg/L)	15	12.42	27.45	17.79	4.41	9.25	23.01	15.62	4.42
SO_4 (mg/L)	15	42.51	95.62	70.45	22.87	34.72	85.63	60.71	21.11
EC	15	367.00	598.00	490.53	90.82	315.00	575.00	446.40	96.98
pH	15	7.70	8.80	8.09	0.32	7.30	8.70	8.00	0.40
NO_3 (mg/L)	15	3.00	4.16	3.59	0.46	1.16	3.71	2.46	0.73
NO_2 (mg/L)	15	0.05	0.10	0.07	0.01	0.02	0.09	0.05	0.01
NH_3(mg/L)	15	0.14	4.25	2.28	1.34	0.26	3.18	1.77	1.20
NH_4 (mg/L)	15	0.22	4.37	1.75	1.59	0.17	3.36	1.43	1.48
Orthophosphate (mg/L)	15	0.15	6.75	2.22	2.44	0.08	5.95	1.48	2.07
Tot.phosphorus (mg/L)	15	0.43	2.80	1.31	0.77	0.25	2.41	0.95	0.80
BOD (mg/L)	15	4.97	15.64	9.67	4.46	3.60	15.00	9.82	4.12
COD (mg/L)	15	12.06	33.00	21.20	7.32	9.87	28.94	18.48	7.20

Water quality index for drinking purposes (WQI);

For computing WQI, three steps were followed. In the first step, according to its relative importance in the overall quality of water for drinking purposes, a weight (wi) has been assigned to each of the 18 parameters. (Ca, Mg, Na, K, HCO_3, CO_3, Cl, SO_4, EC, pH, NO_3, NO_2, NH_3, NH_4, Ort.phosp., Tot. phosp., BOD, COD) (Table 3). Much weight is assigned to parameters which have important health effects and whose presence above certain critical concentration limits could limit the usability of the resource for domestic and drinking purposes (Yidana et al. 2010; Varol and Davraz 2015).

The maximum weight of 5 has been assigned to the parameters like Cl, SO_4, NO_3, NO_2, NH_3, NH_4, Ort.phosp., Tot. Phosp., BOD and COD due to their major importance in water quality assessment (Srinivasamoorthy et al. 2008). HCO_3, CO_3 were given the minimum weight of 1 as it plays an insignificant role in the water quality assessment. Other parameters had a weight between 1 and 5 depending on their importance in water quality determination (Varol and Davraz 2015) (Fig. 4). The Cl concentration in water was relatively high due to evaporation related to the water–rock interaction.

The permissible limit as drinking water to Cl is defined as max 250 mg/L in the WHO (2008) and TS 266 (2005). High Cl ion concentrations in drinking water cause a salty taste and have a laxative effect. (Bhardwaj and Singh 2011). SO_4 which can cause dehydration at high concentrations is one of the least toxic anions. WHO (2008) and TS 266 (2005) defined that maximum permissible limit of SO_4 is 250 mg/L. If the sulfate exceeds this limit, it may cause gastrointestinal irritation and laxative effect at higher level (WHO 1993).

The most important causes of the surface and groundwater pollution are the nitrogen compounds and inorganic chemical pollution. Nitrogen compounds in the form of nitrate (NO_3) and nitrite (NO_2) ions are present in stream water. Phosphate (PO_4) enters the stream waters with domestic wastewater. There are increase in concentration of PO_4 and NO_3 in lakes where phytoplankton productivity and eutrophication enhanced (Vyas et al. 2006). Nitrite is more toxic to all living creatures than nitrate (Samatya et al. 2006). The main sources of nitrogen-containing compounds are the fertilizers and domestic wastes and they are converting to nitrates in the soil. WHO (2008) defined maximum permissible concentration for nitrate as 50 mg/L in drinking water. The blue baby or methemoglobinemia disease in infants, gastric carcinomas, abnormal pain, central nervous system birth defects, and diabetes are related to the consumption of water with high nitrate concentration (Vasanthavigar et al. 2013; Varol and Davraz 2015).

These parameters which have an effect on health are therefore given 5 weight values. Bicarbonate HCO_3 is given the minimum weight of 1 as it plays an insignificant role in the water quality assessment. Other parameters like pH, Ca, Mg, Na, and K were assigned to weight between 1 and 5 depending on their importance in water quality determination (Varol and Davraz 2015).

In the second step, the relative weight (*Wi*) from the following Eq. (1) is computed: Calculated relative weight (*Wi*) values of each parameter in Table 3 are given.

$$Wi = wi / \sum_{i=1}^{n} wi \qquad (1)$$

Where *Wi* is the relative weight, *wi* is the weight of each parameter, *n* is the number of parameters.

In the third step, a quality rating scale (*qi*) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the WHO (2008) and TS 266 (2005) and the result is multiplied by 100 (Eq. 2):

$$qi = (Ci/Si) \times 100 \qquad (2)$$

where qi is the quality rating, *Ci* is the concentration of each chemical parameter in each water sample in milligrams per liter. *Si* is the drinking water standard for each chemical parameter in milligrams per liter according to the guidelines of the WHO (2008) and TS 266 (2005). For computing the WQI, the SI is first determined for each chemical parameter, which is then used to determine the WQI as per the following Eqs. (3, 4)

$$SIi = Wi \times qi \qquad (3)$$

$$WQI = \sum SIi \qquad (4)$$

where SI*i* is the subindex of *i* th parameter, qi is the rating based on concentration of *i* th parameter, *n* is the number of parameters.

Correlation matrix; The correlation analysis to determine the relationships between physicochemical characteristics of water samples were used (Parizi and Samani 2013). Correlation structure between the variables was studied using the Spearman R coefficient (Wunderlin et al. 2001). A high correlation coefficient (near 1 or 1) means a good positive relationship between two variables and its value around zero means no relationship between them at a significant level of $p< 0.05$. More precisely, it can be said that parameters showing $r >0.7$ are considered strongly correlated whereas r between 0.5 and 0.7 shows moderate correlation.

FA (Factor analysis); The aim of the factor analysis is to explain the observed relationship as a new set of variables called factors. R-mode factor analysis (Varimax Rotation with Kaiser Normalization) to extract the factors was carried out via SPSS-15 software. Factor analysis on the combined datasets provided three and four factors with eigenvalue >1 that can explain approximately in dry and wet seasons 88.06 and 87.63% of the data variability, respectively. Factor loadings are classified by Liu et al. (2003) as “strong” (>0.75), “moderate” (0.75–0.50) and “weak” (0.50–0.30) respectively. A positive factor score for a given location indicates a significant control of the source represented by the factor on the hydrochemistry at the location of the sample. A negative factor score on the other hand indicates little or no contribution of the factor to the hydrochemistry (Yidana and Yidana 2010).

3. Results and Discussion

3.1. Hydrochemistry

The major hydrochemical components were analyzed for two seasons (October 2009 and May 2010). A statistical summary of chemical parameters was given in Table 3 for the dry and wet seasons. According to the table, EC varied from 367 to 598 µS/cm in dry season and varied from 315 to 575 µS/cm in wet season. pH of the stream water samples in the study area varied from 7.7 to 8.7 in dry season (October 2010), from 7.3 to 8.7 in wet season (May 2010). HCO_3 was the most dominant ion. After that Ca, Mg, Na, K, SO_4 and Cl were the ions with the lowest concentration in the water of study area in dry and wet seasons (Table 3).

3.2. Hydrochemical types of waters

Hydrochemical facies help to explain the mechanisms of flow and transport in surface and ground water systems (Alam et al. 2012). In this study, Piper diagram (Piper 1944) was used because it is the most widely used graphic (Fig. 3). This graph shows the characteristics of large sample groups and their relationships with each other (Srivastava and Ramanathan 2008). Accordingly, in the study area Mg–Ca–HCO_3 and Ca–HCO_3 were observed as the dominant water types because of water– rock interaction in the Piper diagram (Fig. 3). These findings indicate that surface waters interact with limestone and dolomitic units commonly found throughout the basin. In addition, no changes have been identified in the water classes for dry and wet season measurements in the study area.

Table 3. Relative weight of chemical parameters

Chemical parameters	WHO Standards (2008) Standards	Turkish Drinking Water Standard (TS 266) (2005)	Weight (wi)	Relative weight (Wi)
Ca^{+2} (mg/L)	300	-	3	0.041
Mg^{+2}(mg/L)	-	-	3	0.041
Na^{+} (mg/L)	200	200	4	0.055
K^{+} (mg/L)	-	-	2	0.027
HCO_3^- (mg/L)	-	-	1	0.013
CO_3^- (mg/L)	-	-	1	0.013
Cl^- (mg/L)	250	250	5	0.069
SO_4^{2-}(mg/L)	250	250	5	0.069
EC µS/cm	-	2500	4	0.055
pH	6.5–8.5	6.5–9.5	4	0.055
NO_3^- (mg/L)	50	50	5	0.069
NO_2^- (mg/L)	3.0	0.50	5	0.069
NH_3 (mg/L)	0	0	5	0.069
NH_4 (mg/l)	1.5	0.50	5	0.069
*Ort.phosphates	-	-	5	0.069
**Tot. phosphorus	0.1	-	5	0.069
**BOD	5	-	5	0.069
COD	-	-	5	0.069
			∑wi= 72	∑wi= 1

* Alobaidy et al. 2010; (WHO, 2004)
** http://www.water-research.net/index.php/glossary

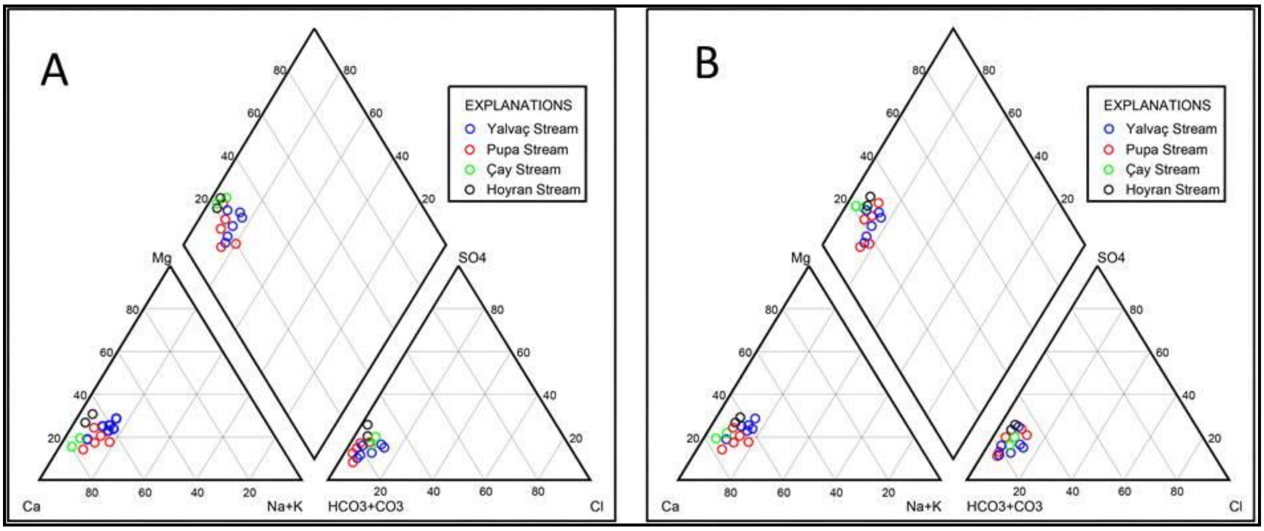

Fig. 3. Piper diagrams of Eğirdir Lake tributaries in dry (A) and wet season (B) (Piper, 1944)

3.3. Evaluation of stream water quality

In the study area, the assessment of stream water quality was carried out to identify its suitability to especially drinking purposes.

Evaluation of water quality index (WQI)

Water quality indices aim to reach simple and clear information on the quality and possible uses of a given water body. The first WQI was developed in the United States by Horton (1965) and applied in Europe since the 1970s, initially in the United Kingdom. Many authors have integrated water quality variables into indices (Naik and Purohit 2001; Said et al. 2004; Boyacioglu 2007; Karami et al. 2009;

Bhatt et al. 2010; Tomas et al. 2013; Varol and Davraz 2015) (Table 4). In this study, WQI was computed at three steps, and results were evaluated with WHO (2008) (Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, HCO_3^{-}, CO_3^{-}, Cl^{-}, SO_4^{2-}, EC, pH, NO_3^{-}, NO_2^{-} , NH_3, Ort.phosphates, Tot. phosphorus, BOD, COD)and TS 266 (2005) (NH_4) (Table 3).

Table 4. According to the WQI type of water (Sahu and Sikdar 2008)

Range	Type of water
< 50	Excellent water
50–100.1	Good water
100–200.1	Poor water
200–300.1	Very poor water
> 300	Water unsuitable for drinking purposes

According to this, water quality types were determined with WQI method. The computed WQI values ranged from 55.85 to 244.61 for dry season and 35.91 to 209.40 for wet season. The WQI range and type of water were classified in Table 4. The chemical analysis results of waters indicate that the majority of the samples exceeds the permissible limit by TS 266 (2005) and WHO (2008).

According to the Table 5 in dry season, 46.66% of stream water samples exhibited ‘‘good water’’, 20% ‘‘poor water’’ and 33.33% “Very poor water”. In wet season 46.66% of stream water samples exhibited ‘‘excellent water’’, 13.33% ‘‘good water’’, 26.66% ‘‘poor water’’ and 13.33% “Very poor water”. The dry season samples exhibited “Very poor water” quality in greater percentage (33.33%) when compared with wet season (13.33%). Results of our study indicated that land use, agricultural activities and industrial activities significantly influence stream water quality variations (Fig. 4).

3.4. Evaluation of inorganic pollution parameters

Inorganic pollution parameters may be present as natural in surface and groundwater, and these metals are associated with natural processes or human activities (Al-Khashman 2007; Şener et al. 2013). The concentrations of Al, As, Cr, Fe and Pb of the stream water samples were analyzed and the results were represented in Table 6. According to the analysis results; Al, As, Cr, Fe and Pb concentrations were found to be more than limit values for drinking water given by WHO (2008).

Al concentration varied between 0.13 and 0.46 mg/L in the dry season and between 0.01 and 0.24 mg/L in the wet season. The highest value of Al (0.46 mg/L) in dry season was measured at the sampling site E5 which is located in the south of the Pupa Stream discharge point. And in wet season it was measured at the sampling site E8 which is located in the south of the Yalvaç Stream discharge point.

As concentrations were determined to be between 0.01 and 0.026 mg/L in dry season and 0.01 mg/L in all locations in wet season. According to the results of dry and wet season analysis, the amount of As measured in stream waters was above the limit value in all sample points. Cr ion concentrations of the stream waters in the study area were between LOD and 0.01 mg/L in the dry season.

Table 5. According to the WQI, type of waters in dry and wet season in the study area

Sample No.	Dry season		Wet Season	
	∑ SI	Type of water	∑ SI	Type of water
E1	224,45	Very poor water	172,47	Poor water
E2	226,10	Very poor water	192,47	Poor water
E3	223,67	Very poor water	194,40	Poor water
E4	266,76	Very poor water	222,32	Very poor water
E5	268,02	Very poor water	232,07	Very poor water
E6	127,54	Poor water	51,42	Good water
E7	124,40	Poor water	37,25	Excellent water
E8	80,51	Good water	194,20	Poor water
E9	105,47	Poor water	48,28	Excellent water
E10	84,42	Good water	41,14	Excellent water
E11	77,38	Good water	37,55	Excellent water
E12	59,70	Good water	43,82	Excellent water
E13	92,13	Good water	58,12	Good water
E14	59,96	Good water	44,27	Excellent water
E15	60,74	Good water	46,58	Excellent water

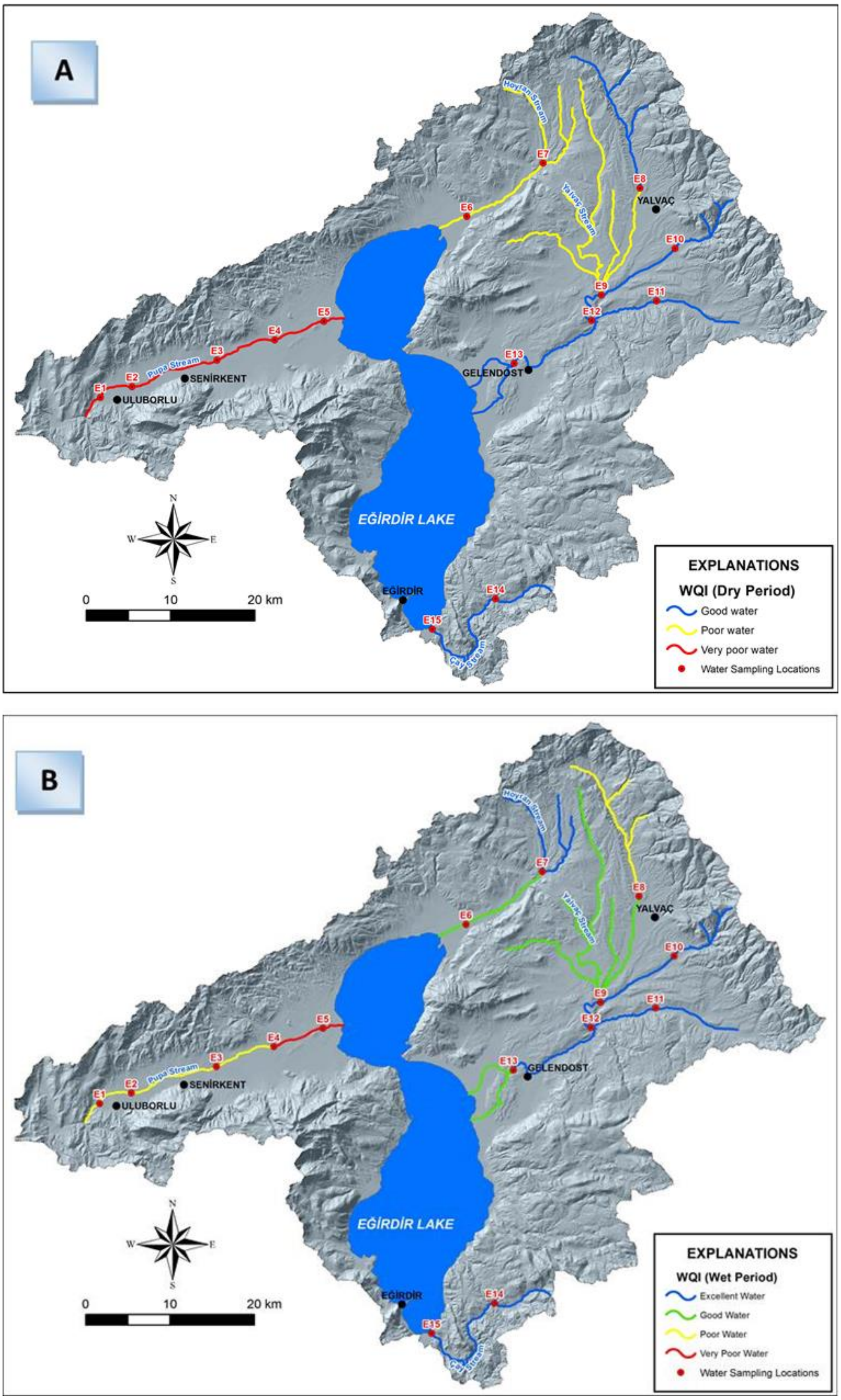

Fig. 4. Spatial distribution map of the WQI in dry (A) and wet (B) period

between LOD and 1.23 mg/L in the wet season. Also, the highest Cr parameter value (1.23 mg/L) measured in the study area was at the E10 sampling point in the wet season. The E10 sampling point is located on the Yalvaç Stream. This parameter did not exceed the limit values for other samples in dry and wet periods.

Another inorganic pollution parameter is Fe in the study area. The Fe ion was between 0.09 and 4.39 mg/L in the dry season and between 0.01 and 3.46 mg/L in the wet season. The Fe parameter exceeded the limit value at sampling points E4, E5, E6, E7, E8, E9, E10, E11, E12, E13 in the dry season. The highest value obtained in the dry period (4.39 mg/L) was at the E11 sampling point. The E11 sampling point is located on the Yalvaç Stream. According to the results of the wet season analysis, the Fe ion exceeded the limit value only at E8 and E11 sampling points. Both of these sampling points are located on the Yalvaç stream.

One of the major contaminants in the study area was lead (Pb) ion. At the sampling points, the Pb ion ranged from LOD to 0.02 mg/L in the dry season and from LOD to 0.01 mg/L in the wet season. In the dry season, the Pb ion was above the drinking water standards (WHO 2008) at sampling points E6, E7, E9, E10, E11, E12 and E13. In the dry season, these sampling points were located on Hoyran and Yalvaç Streams. In the wet season, the Pb content of stream waters exceeded the limit value only at E8 sampling point. This sampling point is located on Yalvaç Stream. In general, intensive agricultural activities are carried out in areas where inorganic pollutant parameters are high in the study area (Şener et al. 2013).

Table 6. Inorganic pollution parameter values (mg/L) of the stream waters

		Minimum	Maximum	Mean	Std. Deviation	WHO (2008) Limit value
Al	Dry Season	0.13	0.46	0.2413	0.10183	0.2
	Wet Season	0.01	0.24	0.0637	0.07182	
As	Dry Season	0.01	0.02	0.0153	0.00516	0.01
	Wet Season	0.01	0.01	0.0091	0.00180	
Cr	Dry Season	<0.0005 (LOD)*	0.01	0.0040	0.00507	0.05
	Wet Season	<0.0005 (LOD)	1.23	0.0844	0.31726	
Fe	Dry Season	0.09	4.39	2.1620	1.87002	0.3
	Wet Season	0.01	3.46	0.4263	1.06179	
Pb	Dry Season	<0.0005 (LOD)	0.02	0.0067	0.00816	0.01
	Wet Season	<0.0005 (LOD)	0.01	0.0008	0.00125	

* LOD: Limit of detection

3.5. Evaluation of correlation matrix

The water quality parameters were grouped for two different seasons (dry and wet season). The each parameter was assigned a numerical value in the data file and was correlated with all the measured parameters. The correlation matrices for EC, pH, NO_3, NO_2, NH_3, NH_4, orthophosphate, total phosphorus, BOD, COD and major ions in both the dry and wet season were prepared (Tables 7a, b). Ca showed high negative correlation with orthophosphate and showed low positive correlation with Na, K and pH in dry season. In addition, Ca showed moderate positive correlation with Na in wet season. Mg showed high positive correlation with HCO_3, Cl, pH, NH_4 and total phosphorus in dry season. In addition, Mg showed low negative correlation with SO_4, EC and pH in wet season. Na showed high positive correlation with K in dry season. Also, Na showed moderate positive correlation with NH_3 and EC, in wet season. K showed high positive correlation with total phosphorus in dry season. In addition, K showed high positive correlation with HCO_3, Cl, NH_3, NH_4 and total phosphorus in wet season (Tables 7a, b). HCO_3 showed high positive correlation with CO_3, Cl, NH_4, orthophosphate and total phosphorus in dry and wet season. CO_3 showed high positive correlation with Cl, NH_3, NH_4 and orthophosphate in dry season. In addition, showed high positive correlation with Cl, SO_4 and orthophosphate in wet season. Cl showed high positive correlation with NH_4 and orthophosphate in dry season. In addition to, showed high positive correlation with NO_3, NH_3, NH_4 and orthophosphate in wet season. SO_4 showed moderate positive correlation with pH and orthophosphate dry and wet seasons (Tables 7a, b). EC showed high positive correlation with NO_3, NO_2, NH_3 in dry season. Additively, showed moderate positive correlation with NH_3 in wet season. pH showed moderate positive correlation with NO_2 in wet season. NO_3 showed high positive correlation with NH_3, NH_4 in dry season. NO_2 indicated moderate positive correlation with NH_3, NH_4 in dry season. In addition, showed moderate positive correlation with NH_3, NH_4, orthophosphate and total phosphorus in wet season. NH_3 showed high positive correlation with NH_4 in dry season. In addition, showed high positive correlation with NH_4 and total phosphorus in wet season. NH_4 showed high positive correlation with orthophosphate and total phosphorus in dry and wet season (Tables 7a, b). Orthophosphate showed moderate positive correlation with total phosphorus in wet season. BOD showed high positive correlation with HCO_3, CO_3, Cl, EC, NO_3, NH_3, NH_4 and total phosphorus in dry season. In addition, showed high positive correlation with K, HCO_3, Cl, NH_3, NH_4 and total phosphorus in wet season (Tables 7a, b). COD showed high positive correlation with HCO_3, CO_3, Cl, EC, NO_3, NH_3, NH_4 and BOD in dry season. In addition, it showed high positive correlation with K, CO_3, Cl, NH_3, orthophosphate and BOD in wet season.

This situation showed that, the seasonal changes in ion distributions of the water samples are due to precipitation and dissolution with anthropogenic inputs in the study area (Tables 7a, b).

3.6. Evaluation of Factor analysis (FA)

The variables for factor analysis in this study were selected as EC, pH, NO_3, NO_2, NH_3, NH_4, orthophosphate, total phosphorus, BOD, COD and major ions in both dry and wet season. (Table 8). Three factors for dry season and four factors for wet season were determined to the statistically represent the parameters influencing chemical compound of streams.

Dry season (Oct-2010)

Factor 1 of stream waters in the study area was characterized by the strong load of EC, NO_3, NO_2, NH_3, BOD, COD, moderate load of HCO_3, CO_3, Cl, NH_4 and total phosphorus and weak load of orthophosphate in dry season. This factor accounted for 40.64% of the total variance in dry season (Table 8). Strong loads and moderate load represent the anthropogenic pollution sources.

Factor 2 showed that 25.41% of the total variance in dry season had strong positive load on SO_4, and orthophosphate, had moderate positive load on Mg, HCO_3, CO_3, Cl and had weak load of pH, NH_4 and COD in dry season. This factor can be attributed to the secondary pollution sources of the stream systems. The presence of strong positive load on orthophosphate in this factor indicates towards their origin from the runoff of the agricultural field and solid waste disposal activities of study area. The SO_4 sources might come from the breakdown of organic substances of weathered soils, leachable sulfate from fertilizers and other human influences like sulfuric salts in domestic wastewater (Bahar and Yamamuro 2008). The presence of moderate positive load of Mg ion indicated from rock–water interaction processes in the study area. Moderate positive loads, HCO_3, CO_3 and Cl's that Factor 2 represents the natural hydrogeochemical evolution of stream water by water–rock interaction which can be explained by the dissolution of rocks and minerals in sediments by chemical weathering. In addition the presence of weak load indicates anthropogenic origin.

Factor 3 explained the lowest proportion of 22.00% of the total variance had strong positive loading on Na, K, pH and had moderate positive loading on Mg and total phosphorus in dry season. Also, had weak loading on Ca, HCO_3, NH_4 in dry season. Factor 3 indicated that stream water chemistry was controlled by the pH, Na and K variation in the system. This factor had moderate positive load on Mg and total phosphorus represented the contribution from agricultural area.

Wet season (May-2010)

As different from the dry season, four factors were determined with R-mode factor analysis in wet season. Factor 1 was characterized by the strong load of K, HCO_3, Cl, NH_3, NH_4, orthophosphate, total phosphorus, BOD, COD, moderate load of CO_3, EC, NO_2 and weak load of Mg and SO_4. This factor accounted for 47.83% of the total variance in wet season (Table 8). Factor 1 represented the water quality parameters related to chemical contamination. This factor had weak load on Mg and SO_4 represented the contribution of nonpoint source pollution from agricultural areas. Factor 2 explained a significant proportion of 14.65 % of the total variance in wet season, had strong positive load on Ca and Na, had moderate positive load on EC and had weak load of NH_3 in wet season. Factor 2 represented the natural hydrogeochemical evolution of stream water by water–rock interaction. In addition, the weak loading in Factor 2 represented the contribution from agricultural areas.

Factor 3 explained a significant proportion of 14.28% of the total variance in wet season. This factor had strong positive load on NO_3 and had moderate positive load on SO_4. These were significantly originated from anthropogenic-induced pollution sources rather than natural processes. This factor had weak load on Ca, Mg, CO_3, NO_2, COD. Factor 4 explained a significant proportion of 10.86% of the total variance in wet season. This factor had strong positive load on pH. This showed that they originated from rock–water interaction. The positive load of pH values showed that the major ion concentration was controlled by pH variations in the study area. This factor had weak load on HCO_3, SO_4, NO_2 and represented the contribution from agricultural areas.

Table 7. Pearson's correlation matrix (r) and Sig. (2-tailed) (p) values (dry and wet season)

a.Dry Season		**Ca**	**Mg**	**Na**	**K**	**HCO_3**	**CO_3**	**Cl**	**SO_4**	**EC**	**pH**	**NO_3**	**NO_2**	**NH_3**	**NH_4**	**Ort.pho.**	**Tot. Pho.**	**BOD**	**COD**
Ca	**r**	1																	
	p																		
Mg	**r**	-0.23	1																
	p	0.39																	
Na	**r**	0.37	0.47	1															
	p	0.17	0.07																
K	**r**	0.29	0.66	**0.86**	1														
	p	0.29	**0.00**	**0.00**															
HCO_3	**r**	-0.45	**0.81**	0.21	0.33	1													
	p	0.09	**0.00**	0.44	0.23														
CO_3	**r**	-0.46	0.49	-0.23	-0.17	**0.80**	1												
	p	0.07	0.06	0.40	0.54	**0.00**													
Cl	**r**	**-0.56**	**0.73**	0.05	0.14	**0.94**	**0.88**	1											
	p	**0.02**	**0.00**	0.85	0.60	**0.00**	**0.00**												
SO_4	**r**	-0.47	0.61	-0.07	0.05	0.49	0.41	0.54	1										
	p	0.07	**0.01**	0.78	0.85	0.06	0.12	**0.03**											
EC	**r**	-0.19	0.21	0.07	-0.00	0.60	0.60	0.56	-0.28	1									
	p	0.48	0.43	0.78	0.97	**0.01**	**0.01**	**0.02**	0.31										
pH	**r**	0.27	**0.78**	0.47	0.64	0.46	0.25	0.35	0.51	-0.09	1								
	p	0.32	**0.00**	0.07	**0.00**	0.08	0.36	0.19	**0.04**	0.73									
NO_3	**r**	-0.24	0.29	0.18	0.07	0.68	0.63	0.66	-0.16	**0.94**	-0.06	1							
	p	0.38	0.28	0.51	0.79	**0.00**	**0.01**	**0.00**	0.56	**0.00**	0.83								
NO_2	**r**	-0.21	0.04	-0.38	-0.18	0.44	0.54	0.39	-0.24	**0.72**	-0.15	0.63	1						
	p	0.44	0.86	0.16	0.50	0.09	**0.03**	0.14	0.37	**0.00**	0.59	**0.01**							
NH_3	**r**	-0.11	0.32	0.00	-0.02	0.66	**0.81**	0.69	0.01	**0.75**	0.24	**0.78**	0.61	1					
	p	0.68	0.23	0.99	0.93	**0.00**	**0.00**	**0.00**	0.95	**0.00**	0.37	**0.00**	**0.01**						
NH_4	**r**	-0.43	**0.73**	0.20	0.34	**0.91**	**0.78**	**0.85**	0.25	0.68	0.40	**0.70**	0.53	**0.74**	1				
	p	0.10	**0.00**	0.45	0.21	**0.00**	**0.00**	**0.00**	0.35	**0.00**	0.13	**0.00**	**0.03**	**0.00**					
Ort.phosp.	**r**	**-0.72**	0.66	-0.16	-0.06	**0.85**	**0.87**	**0.93**	0.68	0.45	0.29	0.51	0.36	0.57	**0.77**	1			
	p	**0.00**	**0.00**	0.54	0.83	**0.00**	**0.00**	**0.00**	**0.00**	0.09	0.29	**0.05**	0.18	**0.02**	**0.00**				
Tot. Phosp	**r**	-0.19	**0.72**	0.51	**0.70**	**0.72**	0.39	0.59	0.00	0.54	0.41	0.58	0.41	0.48	**0.85**	0.42	1		
	p	0.48	**0.00**	**0.04**	**0.00**	**0.00**	0.14	**0.02**	0.99	**0.03**	0.12	**0.02**	0.12	0.06	**0.00**	0.11			
BOD	**r**	-0.34	0.49	0.19	0.21	**0.79**	**0.74**	**0.79**	-0.04	**0.86**	0.10	**0.92**	0.63	**0.80**	**0.87**	0.63	**0.77**	1	
	p	0.20	0.06	0.47	0.44	**0.00**	**0.00**	**0.00**	0.87	**0.00**	0.72	**0.00**	**0.01**	**0.00**	**0.00**	**0.01**	**0.00**		
COD	**r**	-0.37	0.27	-0.13	-0.20	**0.72**	**0.87**	**0.76**	0.02	**0.88**	-0.02	**0.89**	**0.70**	**0.88**	**0.74**	0.69	0.43	**0.87**	1
	p	0.17	0.31	0.62	0.47	**0.00**	**0.00**	**0.00**	0.92	**0.00**	0.93	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	0.10	**0.00**	

b.Wet Season		**Ca**	**Mg**	**Na**	**K**	**HCO_3**	**CO_3**	**Cl**	**SO_4**	**EC**	**pH**	**NO_3**	**NO_2**	**NH_3**	**NH_4**	**Ort.phosp.**	**Tot. Phosp.**	**BOD**	**COD**
Ca	**r**	1																	
	p																		
Mg	**r**	0.08	1																
	p	0.77																	
Na	**r**	0.60	0.03	1															
	p	**0.01**	0.89																
K	**r**	0.11	0.41	0.43	1														
	p	0.68	0.12	0.10															
HCO_3	**r**	**-0.15**	0.11	0.03	**0.73**	1													
	p	0.58	0.68	0.89	**0.00**														
CO_3	**r**	**-0.28**	0.31	**-0.03**	0.56	**0.75**	1												
	p	0.30	0.25	0.89	**0.02**	**0.00**													
Cl	**r**	0.11	0.28	0.27	**0.84**	**0.90**	**0.72**	1											
	p	0.68	0.29	0.33	**0.00**	**0.00**	**0.00**												
SO_4	**r**	**-0.22**	**-0.03**	**-0.39**	0.15	0.66	**0.74**	0.55	1										
	p	0.42	0.91	0.14	0.57	**0.00**	**0.00**	**0.03**											
EC	**r**	0.30	**-0.20**	0.55	0.60	0.40	0.08	0.51	**-0.17**	1									
	p	0.26	0.45	**0.03**	**0.01**	0.13	0.75	**0.05**	0.53										
pH	**r**	0.35	**-0.34**	**-0.02**	0.24	0.50	0.14	0.41	0.52	0.19	1								
	p	0.19	0.21	0.92	0.38	**0.05**	0.61	0.12	0.04	0.49									
NO_3	**r**	0.33	0.29	**-0.08**	**-0.03**	0.02	0.31	0.20	0.41	**-0.25**	0.23	1							
	p	0.21	0.29	0.76	0.89	0.92	0.25	0.47	0.12	0.35	0.39								
NO_2	**r**	0.30	0.26	0.16	0.66	0.69	0.44	**0.79**	0.41	0.40	0.58	0.46	1						
	p	0.26	0.35	0.56	**0.00**	**0.00**	0.09	**0.00**	0.12	0.13	**0.02**	0.08							
NH_3	**r**	0.28	0.47	0.50	**0.90**	0.67	0.46	**0.83**	0.07	0.67	0.14	0.10	0.69	1					
	p	0.30	0.07	**0.05**	**0.00**	**0.00**	0.08	**0.00**	0.80	**0.00**	0.59	0.72	**0.00**						
NH_4	**r**	**-0.18**	0.21	0.21	**0.83**	**0.90**	0.64	**0.86**	0.37	0.49	0.28	**-0.02**	0.69	**0.80**	1				
	p	0.52	0.44	0.44	**0.00**	**0.00**	**0.00**	**0.00**	0.16	0.06	0.29	0.94	**0.00**	**0.00**					
Ort.phosp.	**r**	**-0.11**	0.38	0.13	0.66	**0.75**	**0.91**	**0.83**	0.63	0.19	0.18	0.48	0.66	0.64	**0.76**	1			
	p	0.69	0.16	0.62	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	0.49	0.50	0.06	**0.00**	**0.00**	**0.00**				
Tot. Phosp.	**r**	**-0.13**	0.19	0.24	**0.76**	**0.72**	0.34	0.66	0.07	0.49	0.23	**-0.09**	0.63	**0.76**	**0.92**	0.54	1		
	p	0.63	0.47	0.38	**0.00**	**0.00**	0.20	**0.00**	0.78	0.06	0.40	0.74	**0.01**	**0.00**	**0.00**	**0.03**			
BOD	**r**	**-0.18**	0.47	0.26	**0.83**	**0.75**	0.63	**0.77**	0.22	0.44	**-0.02**	**-0.11**	0.45	**0.83**	**0.85**	0.68	**0.76**	1	
	p	0.51	0.07	0.34	**0.00**	**0.00**	**0.01**	**0.00**	0.42	0.09	0.92	0.69	0.08	**0.00**	**0.00**	**0.00**	**0.00**		
COD	**r**	0.14	0.40	0.32	**0.75**	0.69	**0.78**	**0.87**	0.44	0.50	0.08	0.22	0.56	**0.77**	0.65	**0.81**	0.39	**0.70**	1
	p	0.61	0.13	0.23	**0.00**	**0.00**	**0.00**	**0.00**	0.09	**0.05**	0.76	0.42	**0.02**	**0.00**	**0.00**	**0.00**	0.15	**0.00**	

Table 8. Results of the R-mode factor analysis on the chemical parameters

	Component (dry season)			**Component (wet season)**			
	Factor 1	**Factor 2**	**Factor 3**	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**
Ca	-0.21	-0.69	0.31	-0.13	0.87	0.37	0.17
Mg	0.20	0.61	0.74	0.32	0.07	0.39	-0.73
Na	0.01	-0.25	0.88	0.25	0.80	-0.10	-0.10
K	-0.01	-0.09	0.97	0.90	0.28	0.01	-0.05
HCO_3	0.62	0.64	0.40	0.90	-0.18	0.11	0.32
CO_3	0.66	0.67	-0.05	0.72	-0.38	0.42	-0.06
Cl	0.60	0.74	0.22	0.91	0.10	0.28	0.16
SO_4	-0.29	0.92	0.15	0.38	-0.55	0.55	0.40
EC	0.96	-0.01	0.02	0.54	0.56	-0.33	0.25
pH	-0.10	0.37	0.76	0.20	0.09	0.28	0.87
NO_3	0.94	0.06	0.10	-0.02	0.05	0.91	0.02
NO_2	0.80	0.02	-0.23	0.66	0.24	0.44	0.33
NH_3	0.83	0.23	0.08	0.86	0.44	0.08	-0.12
NH_4	0.73	0.48	0.39	0.96	-0.03	-0.04	0.12
Ort.phosp.	0.46	0.87	0.03	0.80	-0.15	0.49	-0.05
Tot. Phosp.	0.59	0.14	0.67	0.83	0.09	-0.22	0.09
BOD	0.92	0.22	0.23	0.92	-0.00	-0.08	-0.25
COD	0.91	0.31	-0.12	0.79	0.13	0.35	-0.13
Initial Eigenvalues	7.31	4.57	3.96	8.61	2.63	2.57	1.95
% of Variance	40.64	25.41	22.00	47.83	14.65	14.28	10.86
Cumulative %	40.64	66.06	88.06	47.83	62.48	76.76	87.63

4. Conclusions

Stream water quality for drinking purposes in the Eğirdir Lake Basin were evaluated since waters which is a major source of water for domestic, agricultural and industrial activities in the study area. The hydrogeochemical and water quality studies conducted in the stream water of the study area provides the following conclusion:

- The statistical analyses were applied for understanding the stream water quality variations. The correlation analysis for EC, pH, NO_3, NO_2, NH_3, NH_4, orthophosphate, total phosphorus, BOD, COD and major ions were applied to describe the degree of relation in hydrochemical parameters in dry and wet season. In the study area, some groups of species showed a moderate to strong correlation ($r> 0.7$). The cause of this situation was postulated that the concurrent increase/decrease in the cations is the result mainly of dissolution/precipitation reaction and anthropogenic inputs.

- The factor analysis was performed to evaluate seasonal variations in the chemical composition of stream water. According to the factor analysis results, in dry season, Factor 1 represented anthropogenic pollution sources. Factor 2 can be attributed to the secondary pollution sources of the stream waters. The presence of strong positive load on orthophosphate in this factor indicates that this originates from the agricultural field. Factor 3 represented the natural hydrogeochemical evolution of stream water by water–rock interaction. This factor had moderate positive load on Mg and total phosphorus representing the contribution of agricultural areas. In wet season, Factor 1 represented the water quality parameters related to chemical contamination. Factor 2 represented the natural hydrogeochemical evolution of stream water by water–rock interaction. Factor 3 and Factor 4 represented the contribution of nonpoint source pollution in the study area.

- Also, Piper diagram to determine hydrogeochemical facies of water were used. Accordingly, in the study area Mg–Ca–HCO_3 and Ca–HCO_3 were the dominant water types due to water– rock interaction.

- WQI was applied to determine the stream water quality. According to the WQI, during dry season, 46.66% of stream water samples exhibited "good water", 20% "poor water" and 33.33% "Very poor water". In wet season 46.66% of stream water samples exhibited "excellent water", 13.33% "good water", 26.66% "poor water" and 13.33% "Very poor water". The dry season samples exhibited "Very poor water" quality in greater percentage (33.33%) when compared with wet season (13.33%). Results of this study indicates that land use, agricultural and industrial activities significantly influence water quality variations.

- The Eğirdir Lake is an indispensable water source for our country and region, and this lake recharging by the streams. This study shows that the basin requires a proper understanding of the many environmental factors and hydrogeological characteristics of the lake and streams. Agricultural activities are the most common pollution effects in the Eğirdir Lake basin. The protection of lake and stream water quality can be accomplished by controlling of the potential contaminant sources and by managing land use in basin. Therefore, the obtained results with this study should be taken into consideration and required preventions should be taken for sustainable usage of the lake.

Conflict of Interest

No conflict of interest was declared by the authors.

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