INVESTIGATION OF DRINKING WATER QUALITY IN ISPARTA, SW-TURKEY

SELMA DEMER – ÜMİT MEMİŞ – NEVZAT ÖZGÜR

Süleyman Demirel Üniversitesi, Research and Application Centre for Geothermal Energy, Groundwater and Mineral Resources, 32260, Isparta, Turkey, E-mail: selma@mmf.sdu.edu.tr, jeoumit@hotmail.com, noezguer@mmf.sdu.edu.tr

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Abstract
The study area located in the western part of the Tauride carbonate axis consist mainly of Mesozoic to Tertiary autochthonous and allochthonous rock assemblages, Plio-Quaternary volcanics and pyroclastic deposits. In this study, to determine of the hydrogeochemical features of drinking water system in Isparta and environs a great number of water samples was collected from total 46 locations. According to the hydrogeochemical analyses, the waters in the study area can be considered as Ca-Mg-HCO3 and Ca-HCO3 exchange type waters. It is concluded that the results are comparable with national (Turkish Standards Institution – TS 266 2005) and international (World Health Organisation – WHO 2006, United States-Environmental Protection Agency – US EPA 2002 and European Union – EU 1998) drinking water standards. The results of hydrogechemical analyses show that the Eğirdir Lake waters are dominated in drinking water system of Isparta. Nowadays, the high fluorine contents in drinking waters from Isparta and environs are reduced by mixing process with the waters of Eğirdir Lake so that the drinking waters of Isparta have standard fluorine values in some cases and have fluorine contents below standard values (<0.5 mg/l) in most cases. F^- contents in waters below the standard value (<0.5 mg/l) may give rise to dental and medicine problems. Therefore, mixing operations for the drinking waters used in Isparta must be carried out very carefully.

Keywords: Isparta public water system, water quality, fluoride

1. Introduction

The water is one of the most important basic resources for the human life. The drinking water must have drinkable quality and drinking water standards. Therefore, the quality control of drinking waters is very important. Isparta is located within the Lake District in the SW Turkey, and the drinking water of Isparta is provided from Eğirdir Lake, Gölcük Lake and some springs. In this study, it is aimed to reveal the effect of blending process and chemical features of the drinking waters in the distribution system covering all over Isparta settlement area. Moreover, comparing the results of the in-situ and hydrogeochemical analysis with national and international drinking water standards, water quality of drinking water system of the Isparta city were investigated.

2. Material and Methods

In this study, water samples were collected from the Eğirdir Lake, Gölcük Lake, some springs around Isparta city and also from the water network system of the city. In-situ analyses such as temperature (T), pH, electrical conductivity (EC), total dissolved solids, dissolved oxygen, total hardness, alkalinity and acidity tests have been performed during field studies. After making these measurements, the samples were filtered using 0.45 μm filter papers and preserved for chemical analysis. Each sample was stored in two polyethylene bottles. One of the bottles was acidified with suprapure HNO_3 for determination of cations analyses and another was kept unacidified for the anion analyses. Samples were stored at 4 °C for laboratory analyses. Moreover, water samples have been analysed for their anions, cations and some trace element contents by Inductively Coupled Plasma Optical Emission Spectromety (ICP-OES) and Ion Chromatography (IC) using standard methods (Standard Methods, 2005). In the study of all the samples in-situ and hydrochemical analyses were performed in Süleyman Demirel University, Research and Application Center for Geothermal Energy, Groundwater and Mineral Resources. The Aquachem (Calmbach, 1997) computer code was also used to classify water types and for correlation analysis of water samples.

3. Results

3.1. Geology and Hydrogeology

The study area is located in the western Taurides (SW Turkey) forming a north ponting cusp, so-called Isparta Angle. The investigated area consist mainly of autochthonous and allochthonous units. The autochthonous units are the Menteşe formation, the Davras limestone, the Çiğdemtepe limestone, the Koçtepe formation, the Kayıköy formation, the Gölcük volcanics. The allochthonous units are the Gökçebağ ophiolitic melange with the recrystalized Akdağ limestone blocks (Karaman, 1990; Yalçınkaya, 1989; Görmüş and Özkul, 1995). Menteşe formation, the Davras limestone, the Çiğdemtepe limestone units are in carbonate compositions. Koçtepe and Kayıköy formations are characterized by flysch type deposits. Gölcük volcanics are separated into (i) extracaldera lavas, corresponding mainly to Pliocene activity; and (ii) intracaldera lavas and pyroclastics (ignimbrite flow and ash/pumice fall deposits) formed during the Quaternary. Extracaldera volcanic rocks mainly comprise lamprophyre (minette), basaltic trachyandesite, trachyandesite, and trachyte (Platevoet et al., 2008, Elitok et al., 2010). All these units are overlain unconformably by alluvial deposits (Figure 1; Demer, 2008). Autochthonous carbonates and flysch type sedimentary rocks form the basement of the area and overlain tectonically by ophiolitic assemblages of the Lycian nappes. Additionally, the residential area of Isparta is made up of Jurrasic to Oligocene sedimentary rocks and Plio-Quaternary (6,75 Ma-24.000a) volcanic rocks. The volcanic rocks are mainly potassic-ultrapotassic in composition with significant amounts of Na. These volcanic rocks are of tephriphonolites, pyroclastics, trachyandesites and trachytes (Özgür et al., 2008; Platevoet et al., 2008; Elitok et al., 2010). The origin of high fluorine contents in waters of Isparta is attributed to mineral phases in volcanic rocks such as pyroxene, hornblende, biotite, sphene, fluorite and glassy groundmass (Pekdeğer et al., 1990; 1992).

The rock units in the investigated area are classified as permeable, semipermeable, slightly permeable, and impermeable rocks (Table 1). Among these hydrogelogical units, the alluvium, volcanic tuffs, and limestones are considered to be aquifers in the area. (Irlayıcı, 1993; Karagüzel and Irlayıcı; 1998; Demer, 2008; Fig. 1).

Table 1. Permeability of the rocks units in the study area

Rock Unit	Permeability
Ophiolitic melange	impermeable (Gz1)
flysch type Koçtepe and Kayıköy formations	impermeable (Gz2)
pyroclastic fall deposits including mainly pumice and volcanoclastic materials	slightly permeable (Ga)
trachytic and trachyandesitic lava flow/domes	semipermeable (Gy)
limestones having karstic structures	permeable (Gç2)
alluvium deposits	permeable (Gç1)

3.2. Hydrogeochemistry

Until 1995, the drinking waters for Isparta city had been supplied by water springs of Andık and Gölcük lake. Since 1995, due to increasing of water demand, Eğirdir lake has been used for drinking water of Isparta city. However, some part of the drinking water demand of Isparta are provided from some springs around the city. Blended water is transferred to various parts of the city (Isparta Municipality, 2001).

In this study, to determine the distribution of water quality in drinking water system, water samples were collected in Isparta and environs (Figure 1) and in situ measurements and hydrogeochemical analyses were performed (Table 2-3). The temperature of the samples varies between 11.1 to 25.4^{o}C, pH values between 7.52 to 8.38, and electrical conductivity values between 240-386 μS/cm. Dissolved

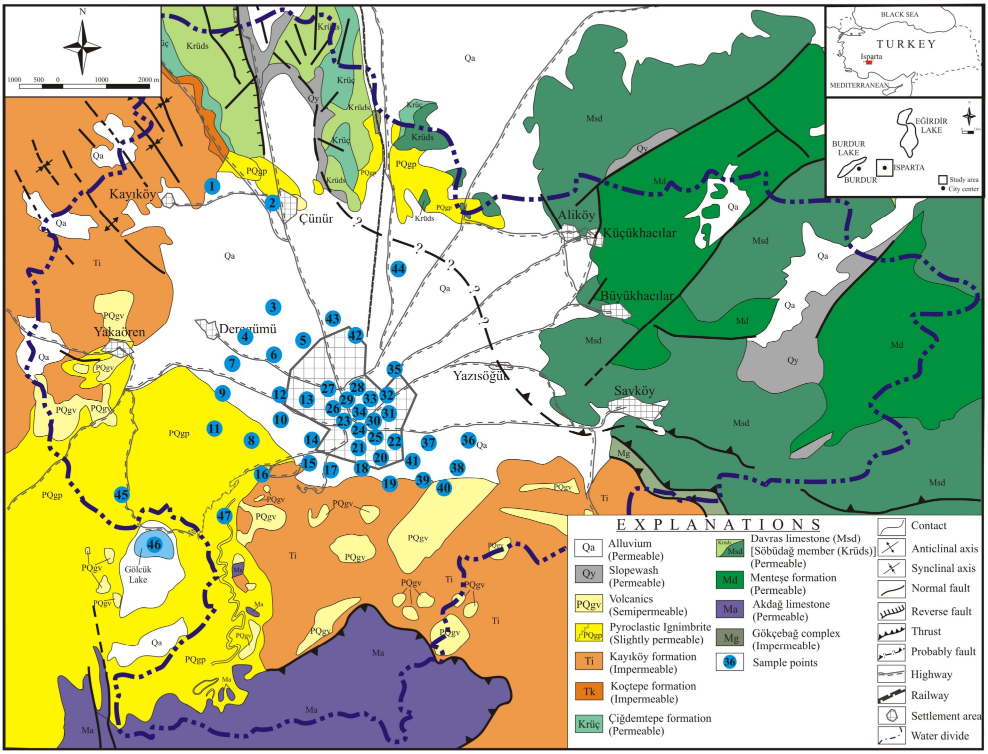

Fig. 1. Geological map of Isparta and environs (compiled from Gutnic et al., 1979; Yalçınkaya et al., 1986; Yalçınkaya, 1989; Irlayıcı, 1993; Görmüş and Özkul, 1995; Poisson et al., 2003; Demer, 2008) and sampling locations.

oxygen and total dissolved solids (TDS) values are between 5.9-9.2 mg/l and 122-198 mg/l, respectively. These waters generally classified as moderately hard waters. Based on the values of in-situ measurements and hydrogeochemical analyses, the water samples (Table 2 and 3) are comparable with national (Turkish Standards Institution – TS 266, 2005) and international (World Health Organisation – WHO, 2006; United States-Environmental Protection Agency – US EPA, 2002 and European Union – EU, 1998) drinking water standards. In the Piper diagram, the waters of Isparta can be considered as Ca-Mg-HCO_3 and Mg-Ca-HCO_3 exchange type waters (Figure 2). In this diagram, some other types of waters such as the waters of Eğirdir Lake as Ca-Mg-HCO_3 type, the waters of Gölcük Lake as Ca-HCO_3 type, Andık spring water as Ca-Na-HCO_3 type and Milas spring water as Ca-HCO_3 exchange water type can be seen. In the Schoeller semi-logarithmic diagram, waters with similar chemistry yield similar peaks. It is clearly seen that the waters generally have similar chemical characteristics with Ca>Mg>Na+K or Mg>Ca>Na+K and HCO3>SO4>Cl chemical compositions (Figure 3).

Figure 4 show that correlation diagrams of major ions versus fluorine ions. These diagrams show that the Eğirdir Lake water is clearly dominated in drinking water system of Isparta due to total ion concentrations. This value also supports the low fluorine contents. It is noteworthy that the Gölcük Lake and Andık spring waters are enriched in fluorine (Table 2). High amount of fluorine were measured in samples taken from Bağlar (13; F: 1,13 mg/l), Yenice (15; F: 1,12 mg/l) and Sidre (19; F: 1,01 mg/l). Therefore, the waters from Andık spring and Gölcük Lake are more dominant in these locations. Although, the measured fluorine contents close to national (TS 266, 2005) and international (WHO, 2006; US EPA, 2002 and EU, 1998) drinking water standards in these locations, these values do not exceed the limit value. This is due to the blending process in the drinking water system of Isparta. The high fluorine contents in drinking waters from Isparta and environs are reduced by mixing process which reach sometimes standard fluorine values and lie under standard fluorine values (<0,5 mg/l). F^- contents in waters below the standard value (<0.5 mg/l) may give rise to dental and medicine problems. Therefore, mixing operations for the drinking waters used in Isparta must be carried out very carefully.

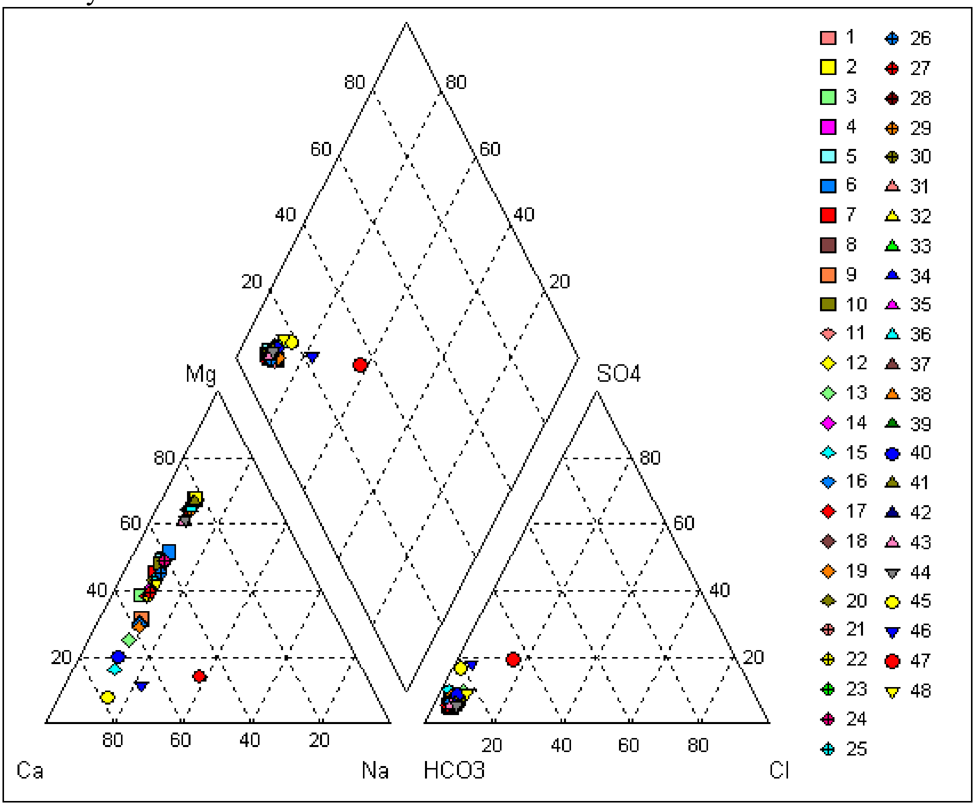

Fig. 2. Piper diagram of the water samples (See Table 2 for locations).

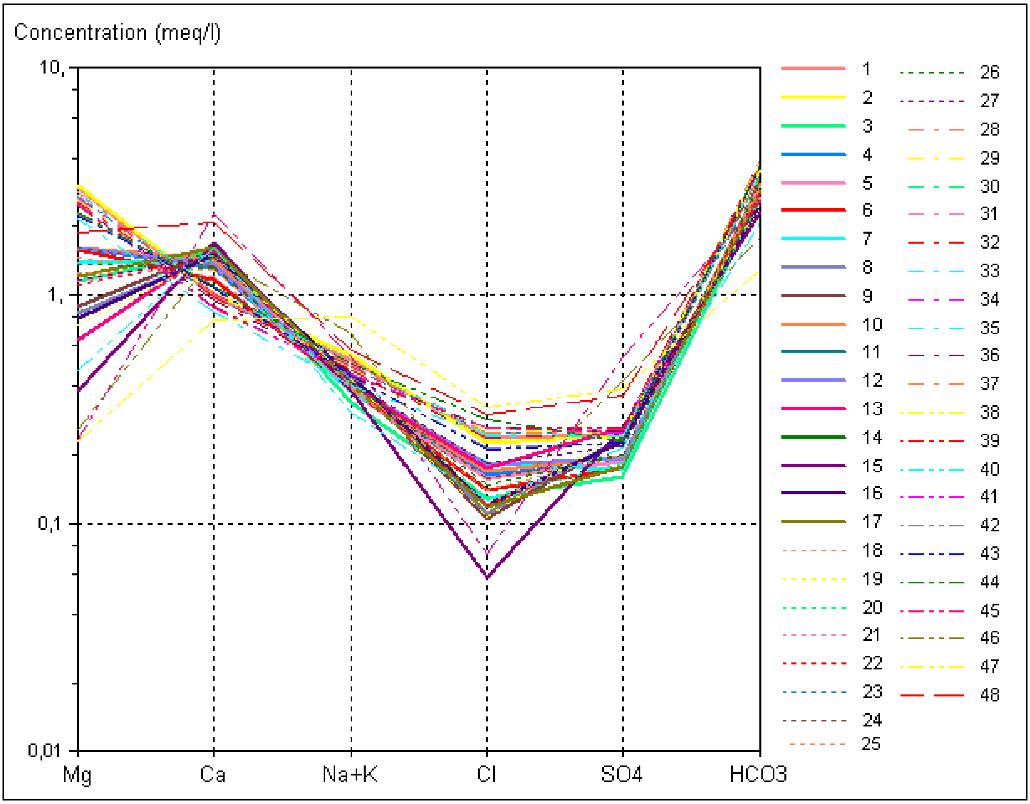

Fig. 3. Schoeller semi-logarithmic diagram of the water samples (See Table 2 for locations).

Table 2. Results of in-situ analysis of waters from the study area.

Number	Location	T (°C)	pH	EC (µS/cm)	O_2 (mg/l)	TDS (mg/l)	Total hardness (°f)
1	M. Tönge	21,5	8,38	377	6,80	194	21,6
2	Çünür	23,6	8,32	379	6,70	193	23,4
3	Fatih	21,3	7,94	289	7,80	146	14,4
4	Zafer	19,7	8,11	319	8,80	162	19,8
5	Bahçelievler	20,2	8,06	313	7,40	160	16,2
6	Yedişehitler	22,1	8,02	303	7,30	154	16,2
7	M. Türkeş	18,6	8,04	296	8,20	153	16,2
8	Işıkkent	19,0	7,95	272	7,90	138	14,4
9	Batıkent	17,4	8,02	271	7,80	138	12,6
10	Hızırbey	17,7	8,09	317	7,80	162	16,2
11	Binbirevler	16,7	8,04	268	7,80	137	14,4
12	Gülistan	21,1	8,08	320	7,60	163	16,2
13	Bağlar	16,7	7,86	251	8,00	129	12,6
14	Doğancı	16,7	7,97	297	8,40	153	14,4
15	Yenice	14,8	7,63	246	9,20	125	12,6
16	Dere	20,9	8,17	270	6,60	138	12,6
17	Keçeci	20,8	7,99	289	7,10	147	14,4
18	Emre	20,4	8,02	320	7,90	162	16,2
19	Sidre	19,0	8,01	269	8,00	137	14,4
20	Gülcü	21,2	7,93	306	7,60	155	16,2
21	Sülübey	17,5	7,97	292	8,20	148	14,4
22	Hisar	20,7	7,98	293	6,60	149	12,6
23	Çelebiler	22,6	8,21	385	6,20	196	16,2
24	Kurtuluş	24,0	7,99	319	6,70	163	14,4
25	Turan	21,3	7,98	305	6,80	156	14,4
26	Yayla	19,6	8,05	308	6,90	158	16,2
27	Pirimehmet	22,5	7,97	296	7,20	151	14,4
28	İstiklal	21,5	8,22	376	6,50	192	19,8
29	Kutlubey	23,3	8,19	379	6,50	193	19,8
30	İskender	22,4	8,22	384	6,30	198	18,0
31	Sermet	21,8	8,20	376	6,10	192	18,0
32	Karaağaç	19,9	8,32	375	6,70	191	19,8
33	Kepeci	20,4	8,28	377	7,80	192	19,8
34	Gazi Kemal	24,0	8,18	383	6,50	196	21,6
35	Davraz	22,3	8,20	376	7,20	192	21,6
36	Vatan	24,3	8,11	386	6,70	197	21,6
37	Gülevler	22,5	8,19	385	7,10	196	19,8
38	Ayazmana	22,6	8,17	386	7,50	197	19,8
39	Halıkent	22,4	8,21	385	6,70	197	19,8
40	Ayazmana Spring	14,1	7,52	240	7,70	122	10,8
41	H. Sultan	21,6	8,22	386	7,00	196	19,8
42	Anadolu	23,2	8,14	358	6,80	183	18,0
43	Modernevler	20,5	8,23	362	8,70	185	19,8
44	Sanayi	25,4	8,15	366	7,10	187	19,8
45	Milas Spring	11,1	7,56	348	5,90	179	18,0
46	Gölcük Lake	21,0	8,13	248	6,70	126	10,8
47	Andık*	10,8	7,70	235	-	-	-
48	Eğirdir Lake **	21,0	8,70	402	-	-	-

* Davraz et. al. (2008), ** DSİ (1999–2006)

Table 3. Results of the hydrogeochemical analyses of waters from the study area.

Number	Location	Ca^{2+} (mg/l)	Na^{+} (mg/l)	K^{+} (mg/l)	Mg^{2+} (mg/l)	Cu (ppb)	Zn (ppb)	Pb (ppb)	Cl^{-} (mg/l)	NO_3^{-} (mg/l)	SO_4^{2-} (mg/l)	NO_2^{-} (mg/l)	PO_4^{2-} (mg/l)	HCO_3^{-} (mg/l)	F^{-} (mg/l)	Water type
1	M. Tönge	19.92	9.75	3.50	35.97	3.0	46.0	6.0	8.43	0.21	11.81	<0.01	<0.01	213.5	0.16	Mg-Ca-HCO3
2	Çünür	20.32	10.31	3.59	36.97	3.0	16.0	6.0	8.04	0.15	11.51	<0.01	<0.01	213.5	0.13	Mg-Ca-HCO3
3	Fatih	31.36	5.83	3.32	13.98	7.0	86.0	6.0	4.55	1.29	7.64	<0.01	<0.01	158.6	0.44	Ca-Mg-HCO3
4	Zafer	26.49	7.03	3.22	19.62	3.0	25.0	7.0	5.77	0.80	8.93	<0.01	<0.01	176.9	0.37	Mg-Ca-HCO3
5	Bahçelievler	27.44	6.86	3.05	19.77	3.0	50.0	5.0	5.55	0.94	8.96	<0.01	<0.01	164.7	0.35	Mg-Ca-HCO3
6	Yedişehitler	32.42	7.03	3.30	19.23	4.0	67.0	8.0	4.99	0.99	8.42	<0.01	<0.01	176.9	0.39	Mg-Ca-HCO3
7	M. Türkeş	27.64	6.34	3.85	16.74	3.0	91.0	6.0	6.49	1.14	8.18	<0.01	<0.01	189.1	0.43	Ca-Mg-HCO3
8	Işıkkent	29.70	7.46	3.94	10.05	4.0	142.0	6.0	3.92	0.87	11.39	<0.01	<0.01	158.6	0.87	Ca-Mg-HCO3
9	Batıkent	31.39	7.61	4.18	10.77	3.0	15.0	6.0	3.74	0.76	11.37	<0.01	<0.01	158.6	0.91	Ca-Mg-HCO3
10	Hızırbey	28.79	7.01	3.11	19.76	41.0	67.0	9.0	6.01	0.97	9.41	<0.01	<0.01	189.1	0.41	Mg-Ca-HCO3
11	Binbirevler	29.56	7.08	3.74	9.48	4.0	25.0	6.0	3.73	0.94	10.59	<0.01	<0.01	158.6	0.86	Ca-Mg-HCO3
12	Gülistan	27.11	7.31	3.32	19.61	6.0	101.0	7.0	6.37	0.88	9.29	<0.01	<0.01	176.9	0.34	Mg-Ca-HCO3
13	Bağlar	31.72	6.76	4.12	7.68	2.0	26.0	4.0	6.22	1.88	12.69	<0.01	<0.01	140.3	1.13	Ca-Mg-HCO3
14	Doğancı	28.97	7.18	3.74	14.84	2.0	18.0	5.0	4.66	1.27	9.14	<0.01	<0.01	176.9	0.55	Ca-Mg-HCO3
15	Yenice	33.83	6.41	3.92	4.67	2.0	53.0	6.0	2.05	1.97	12.63	<0.01	<0.01	140.3	1.12	Ca-HCO3
16	Dere	30.40	7.39	4.68	9.63	2.0	186.0	7.0	4.25	0.77	11.03	<0.01	<0.01	152.5	0.94	Ca-Mg-HCO3
17	Keçeci	32.26	7.20	3.81	14.59	4.0	173.0	5.0	4.18	1.33	8.59	<0.01	<0.01	176.9	0.57	Ca-Mg-HCO3
18	Emre	24.40	7.05	3.35	17.75	3.0	78.0	10.0	5.53	0.89	9.52	<0.01	<0.01	189.1	0.46	Mg-Ca-HCO3
19	Sidre	29.58	7.37	4.14	8.98	7.0	82.0	7.0	3.80	0.96	12.33	<0.01	<0.01	152.5	1.01	Ca-Mg-HCO3
20	Gülcü	29.62	7.27	3.67	16.48	2.0	37.0	4.0	4.58	1.04	8.77	<0.01	<0.01	158.6	0.50	Ca-Mg-HCO3
21	Sülübey	29.24	6.98	3.69	14.07	2.0	40.0	6.0	4.35	1.12	10.26	<0.01	<0.01	183.0	0.67	Ca-Mg-HCO3
22	Hisar	29.35	7.28	3.80	13.51	1.0	45.0	2.0	4.25	1.11	10.29	<0.01	<0.01	176.9	0.68	Ca-Mg-HCO3
23	Çelebiler	19.93	9.23	3.28	32.94	11.0	40.0	10.0	8.77	0.20	12.21	<0.01	<0.01	195.2	0.17	Mg-HCO3
24	Kurtuluş	26.99	7.42	3.49	19.66	31.0	37.0	6.0	5.60	1.02	9.57	<0.01	<0.01	189.1	0.50	Mg-Ca-HCO3
25	Turan	25.73	6.86	3.39	15.28	3.0	39.0	7.0	4.94	1.09	9.56	<0.01	<0.01	176.9	0.56	Ca-Mg-HCO3
26	Yayla	26.30	7.47	3.46	16.61	3.0	14.0	3.0	5.26	1.12	9.66	<0.01	<0.01	189.1	0.57	Mg-Ca-HCO3
27	Pirimehmet	29.30	7.35	3.85	14.26	2.0	75.0	4.0	6.49	1.39	10.45	<0.01	<0.01	158.6	0.77	Ca-Mg-HCO3
28	İstiklal	22.00	8.87	3.30	32.34	4.0	10.0	6.0	8.64	0.31	11.98	<0.01	<0.01	219.6	0.22	Mg-Ca-HCO3
29	Kutlubey	20.28	9.08	3.22	31.30	3.0	3.0	7.0	8.66	0.25	11.95	<0.01	<0.01	225.7	0.17	Mg-Ca-HCO3
30	İskender	20.15	9.34	3.34	34.36	4.0	56.0	5.0	9.15	0.20	12.33	<0.01	<0.01	201.3	0.19	Mg-Ca-HCO3

Table 3. (continued)

Number	Location	Ca^{2+} (mg/l)	Na^{+} (mg/l)	K^{+} (mg/l)	Mg^{2+} (mg/l)	Cu (ppb)	Zn (ppb)	Pb (ppb)	Cl^{-} (mg/l)	NO_3^{-} (mg/l)	SO_4^{2-} (mg/l)	NO_2^{-} (mg/l)	PO_4^{2-} (mg/l)	HCO_3^{-} (mg/l)	F^{-} (mg/l)	Water type
31	Sermet	19.79	8.49	3.15	30.62	3.0	34.0	9.0	8.91	0.26	12.04	<0.01	<0.01	207.4	0.22	Mg-Ca-HCO3
32	Karaağaç	19.86	8.78	3.30	31.15	14.0	58.0	7.0	8.47	0.28	11.91	<0.01	<0.01	219.6	0.19	Mg-Ca-HCO3
33	Kepeci	21.52	9.25	3.37	32.94	3.0	26.0	6.0	8.49	0.29	11.91	<0.01	<0.01	219.6	0.18	Mg-Ca-HCO3
34	Gazi Kemal	20.35	9.10	3.31	32.88	28.0	23.0	5.0	8.89	0.20	12.46	<0.01	<0.01	231.8	0.18	Mg-Ca-HCO3
35	Davraz	16.93	7.48	2.90	26.17	5.0	31.0	6.0	8.75	0.30	11.61	<0.01	<0.01	207.4	0.23	Mg-Ca-HCO3
36	Vatan	19.05	8.50	3.12	29.89	11.0	58.0	7.0	9.24	0.18	12.18	<0.01	<0.01	237.9	0.20	Mg-Ca-HCO3
37	Gülevler	19.94	9.35	3.42	34.37	5.0	83.0	5.0	8.86	0.18	12.00	<0.01	<0.01	237.9	0.18	Mg-Ca-HCO3
38	Ayazmana	17.52	8.51	3.09	30.06	5.0	71.0	6.0	9.09	0.20	11.92	<0.01	<0.01	231.8	0.18	Mg-Ca-HCO3
39	Halıkent	17.82	8.37	3.09	30.18	6.0	76.0	5.0	9.25	0.15	12.50	<0.01	<0.01	225.7	0.18	Mg-Ca-HCO3
40	Ayazmana spring	32.10	5.86	2.03	5.72	<1.0	2.0	4.0	4.48	5.23	10.28	<0.01	<0.01	128.1	0.21	Ca-HCO3
41	H. Sultan	17.63	8.53	3.11	30.55	5.0	25.0	4.0	9.25	0.17	12.02	<0.01	<0.01	219.6	0.20	Mg-Ca-HCO3
42	Anadolu	21.57	8.20	3.19	27.41	10.0	30.0	10.0	7.61	0.44	10.90	<0.01	<0.01	207.4	0.23	Mg-Ca-HCO3
43	Modernevler	21.34	8.38	3.13	26.97	5.0	15.0	6.0	7.47	0.40	10.90	<0.01	<0.01	225.7	0.21	Mg-Ca-HCO3
44	Sanayi	22.01	8.75	4.70	28.20	6.0	69.0	8.0	10.09	0.40	11.01	<0.01	<0.01	225.7	0.36	Mg-Ca-HCO3
45	Milas spring	45.68	9.47	4.70	2.82	<1.0	15.0	7.0	2.61	4.24	25.53	<0.01	<0.01	158.6	1.70	Ca-HCO3
46	Gölcük Lake	29.69	11.31	7.32	3.14	1.0	1.0	6.0	3.86	<0.01	20.16	<0.01	<0.01	109.8	2.10	Ca-HCO3
47	Andık*	15.60	13.90	8.01	2.80	-	-	-	11.50	-	18.70	-	-	79.4	4.10	Ca-Na-HCO3
48	Eğirdir Lake**	41.60	11.50	2.98	22.80	-	-	-	10.60	-	17.30	-	-	195.0	0.20	Ca-Mg-HCO3

* Davraz et. al. (2008), ** DSİ (1999–2006)

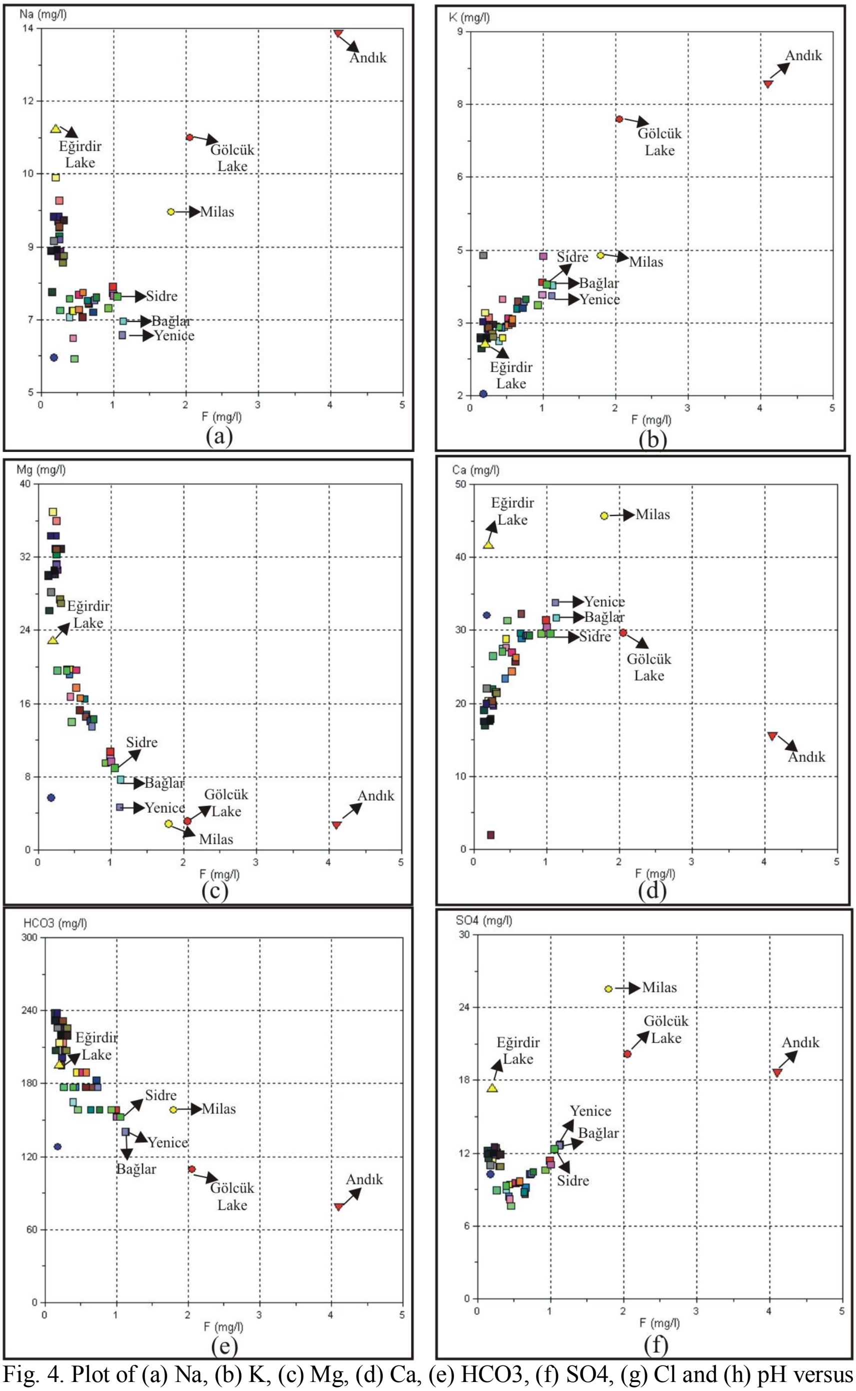

Fig. 4. Plot of (a) Na, (b) K, (c) Mg, (d) Ca, (e) HCO3, (f) SO4, (g) Cl and (h) pH versus F

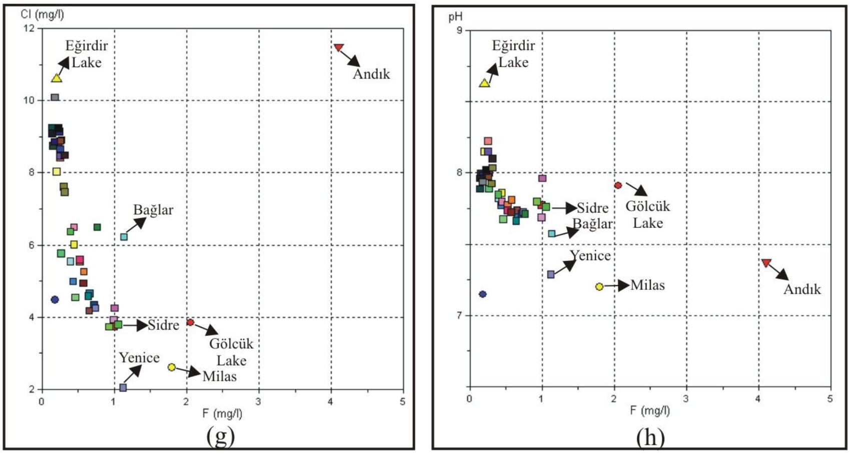

Fig. 4. (continued)

4. Conclusion

In this study, the distribution of water in drinking water system of Isparta has been described. The Eğirdir Lake water is dominated in drinking water system of Isparta. The results of hydrogechemical analyses show that the waters are comparable with national (Turkish Standards Institution – TS 266, 2005) and international (World Health Organisation – WHO, 2006; United States-Environmental Protection Agency – US EPA, 2002 and European Union – EU, 1998) drinking water standards. The high fluorine contents in drinking waters from Isparta and environs are reduced by mixing process with the waters of Eğirdir Lake. After this process it is observed that the drinking waters have standard fluoride values in some locations, but may lie below standard fluorine values (<0.5 mg/l) at some locations. F^- contents in waters below the standard value (<0.5 mg/l) may give rise to dental and medicine problems. Therefore, mixing operations for the drinking waters used in Isparta must be carried out very carefully.

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