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A Study about Effects of River Water Quality on Fish Living in Büyük Menderes Basin, Turkey

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Abstract

The measurements for the quality of the water were made at eight stations of Adıgüzel Dam, Yenice Regulator, Sarayköy Bridge, Feslek Regulator, Yenipazar Bridge, Aydın Bridge, Koçarlı Bridge, Söke Regulator located at the Buyuk Menderes River, Turkey. The study was conducted for the period between 2000-2013 for the months of February, April, June, August, October and December. The results received were analyzed for temperature, pH, EC, Cl^-, Na, Ca^{2+}, Mg^{2+}, K^+, SO_4^{2-}, TDS, TH and SS aquaculture. The results of the analyses revealed that although the water pollution in the river showed variations throughout the year, in fact the samples obtained at various locations displayed high levels of pollutants. The "Regulation on Turkish Water Pollution Control" was made use of in classifying the parameters of the water in this study. These parameters were compared with the WHO Guidelines and TS-266. Among the 8 Dams that were included in the study, the best quality of water was measured in the Adıgüzel Dam, which gave the lowest values; and the levels were measured to be higher in the Saraykoy Station than those of the other dams. There was a severe drought in Menderes Basin in 2007, and therefore the highest annual values were measured for the year 2007. In those years, the levels of the irrigation water decreased as low as 4255 m^3/ha. The SPSS 21 Statistical Analysis Program was made use of in analyzing the data of the study. The One-Way Anova and Tukey Multiple Comparison tests were also used for the analyses of the data as well. The $p < 0.05$ level was accepted as being significant in the analyses. The distribution of the data was performed by using the Box-plot Graphs. Furthermore, the effects on fish species and the pollution in Büyük Menderes River were also examined in the study.

Keywords

Büyük Menderes River, Water Quality, Fish, Pollution, Turkey

1. Introduction

Water pollution results from adverse changes in physical, chemical, bacteriological, radioactive and ecological features of water sources. Water pollution is a quality change which not only disturb economical stability and but also restrict usage as a result of anthropogenic impacts. FAO is defined as mixing some substances that is harmful and hazardous to living resources and human health, injuring water quality into the water [1] [2].

Water quality is a very significant issue of critical importance in various nations and especially Turkey there is cause for concern. Naturally, it is expected that freshwater supplies will dwindle in the near future and thus this requires careful examination and monitoring. By monitoring the water quality, it's possible to understand the effect of pollution and it will assist to manage aquatic resources and to protect aquatic fauna [3].

Urbanization, tourism, industry, agriculture and other similar human activities on Earth have great impacts on the basin of the Büyük Menderes River. There are also some obstacles that prevent the migration of the fish and also decrease the quality of water. In the past, the river was a precious source of water for drinking for the people living around, and for fishing. Nowadays, on the other hand, it is not possible to be used for irrigation due to the low quality and the influences of the abovementioned factors.

In Turkey, there are many regulations that are being constantly updated as related to water and the effects of pollution on this source. One of these principal regulations is the "Regulation for Control of Water Pollution" printed in official gazette of the Republic of Turkey on the date of 12/31/2004. This regulation is mainly concerned with the fundamental principles to prevent contamination of water resources and their safe usage. The water resources include both freshwater and groundwater resources. Furthermore, the Turkish Standard TS 266 regulates the water use for human consumption. The examined parameters have been compared with TS 266 and WHO guidelines.

Aim of this research focuses on analyzing the influences of the pollutant materials on water quality parameters as well as fish diversity in the Büyük Menderes River Basin. The key chemical parameters of temperature, pH, EC, Cl^-, Na, Ca^{2+}, Mg^{2+}, K^+, SO_4^{2-}, TDS, TH and SS were monitored in the Büyük Menderes River between 2000 and 2013. The fish populations in years 2003 and 2013 were compared (**Table 1**) [4] [5].

2. Materials and Method

2.1. Study Area

The Büyük Menderes River is located in the western Anatolia, southwest Turkey, between 37˚6' - 38˚55' North and 27˚36' - 30˚36' East. Borders of the basin which constitutes 3.2% of Turkey's land surface includes parts of Aydın, Uşak, Denizli, Muğla, Afyon, Isparta, Burdur and İzmir provinces. With 584 km, it is the longest river in the Aegean Region. Many lateral streams feed the river, with the main tributaries being the Çine, Banaz, Çürüksu and Akçay rivers. The majority of small tributaries dry out in summer. As an important river system, the Büyük Menderes includes wetlands such as

Table 1. The variety of fish types caught from past to present from the Büyük Menderes River [4] [5].

Fish Species	Before 2003	2003	2013
Silurus glanis	✓	X	✓
Anguilla anguilla	✓	✓	✓
Nemachilus angorae	✓	✓	X
Cyprinus carpio	✓	X	✓
Capoeta capoeta bergamae	✓	✓	✓
Barbus capito pectoralis	✓	✓	X
Barbus plebejus escherichi	✓	✓	X
Leuciscus cephalus	✓	✓	X
Chondrostoma holmwoodi Meandrensis	✓	✓	✓
Acanthobrama mirabilis	✓	✓	X
Aphanius anatoliae anatoliae	✓	✓	✓
Gambusia affinis	✓	✓	X
Cobitis turcica	X	✓	X
Hemigrammocapoeta kemali	X	✓	✓
Gobio gobio	X	✓	X
Barbus tauricus esherichi	X	✓	X
Esox lucius	X	✓	X
Carassius gibelio	✓	X	✓
Squalius fellowesii	X	X	✓
Squalius carinus	X	X	✓
Alburnoides cf. Smyrnae	X	X	✓
Alburnus cf.	X	X	✓
Ladigesocypris mermere	X	X	✓
Vimba mirabilis	X	X	✓
Barbus pergamonensis	X	X	✓
Luciobarbus kottelati	X	X	✓
Pseudorasbora parva	✓	X	✓
Rhodeus amarus	X	X	✓
Pseudophoxinus maeandricus	X	X	✓
Pseudophoxinus maeandri	X	X	✓
Tinca tinca	X	X	✓
Gobio maeandricus	X	X	✓
Esox lucius	X	X	✓
Aphanius fasciatus	X	X	✓
Cobitis cf simplicispina	X	X	✓
Gambusia holbrooki	X	X	✓
Atherina boyeri	X	X	✓
Knipowitschia caucasica	X	X	✓
Lepomis gibbosus	X	X	✓
Oxynoemacheilus cf. Cinicus	X	X	✓
Oxynoemacheilus germencicus	X	X	✓
Syngnathus abaster	X	X	✓
Liza ramada	X	X	✓
Ctenopharyngodon idella	✓	X	X

Işıklı Lake, Bafa Lake, and the Büyük Menderes River Delta. It is also a very important river basin in terms of biodiversity, being subject to the effects of both the Mediterranean and continental climates. The locations of the eight stations selected for this study are shown in Figure 1. The stations were chosen deliberately to identify the degradation of the quality of the water as a result of the urban pollution observed in the area. Station 1 is the Adıgüzel Dam. In this dam, there is a certain problem detected in the form of mutations in the genetic structure of the fish and this problem results from the industrial residues which contain leather and textile as well as waste materials coming from Uşak. Station 2 is constituted by the Yenice Regulator. It is 32 km away from the Adıgüzel Dam where pollution stems from domestic waste and pesticides. Station 3 is the Sarayköy Bridge which is influenced by the wastes coming from the Denizli-Sarayköy sewage system, the geothermal plant nearby, and a textile factory. Station 4 is the Feslek Regulator. The Büyük Menderes River is polluted by domestic wastes and pesticide packages coming from the nearby residential and industrial areas. Station 5 is the Yenipazar Bridge which is polluted by the water coming from the Akçay tributary in the Yenipazar Bridge. Station 6 is the Aydın Bridge which is affected mainly by untreated wastewater coming from the industrial zones and municipal sewage treatment plants nearby. Station 7 is the Koçarlı Bridge which merges with the Menderes following the

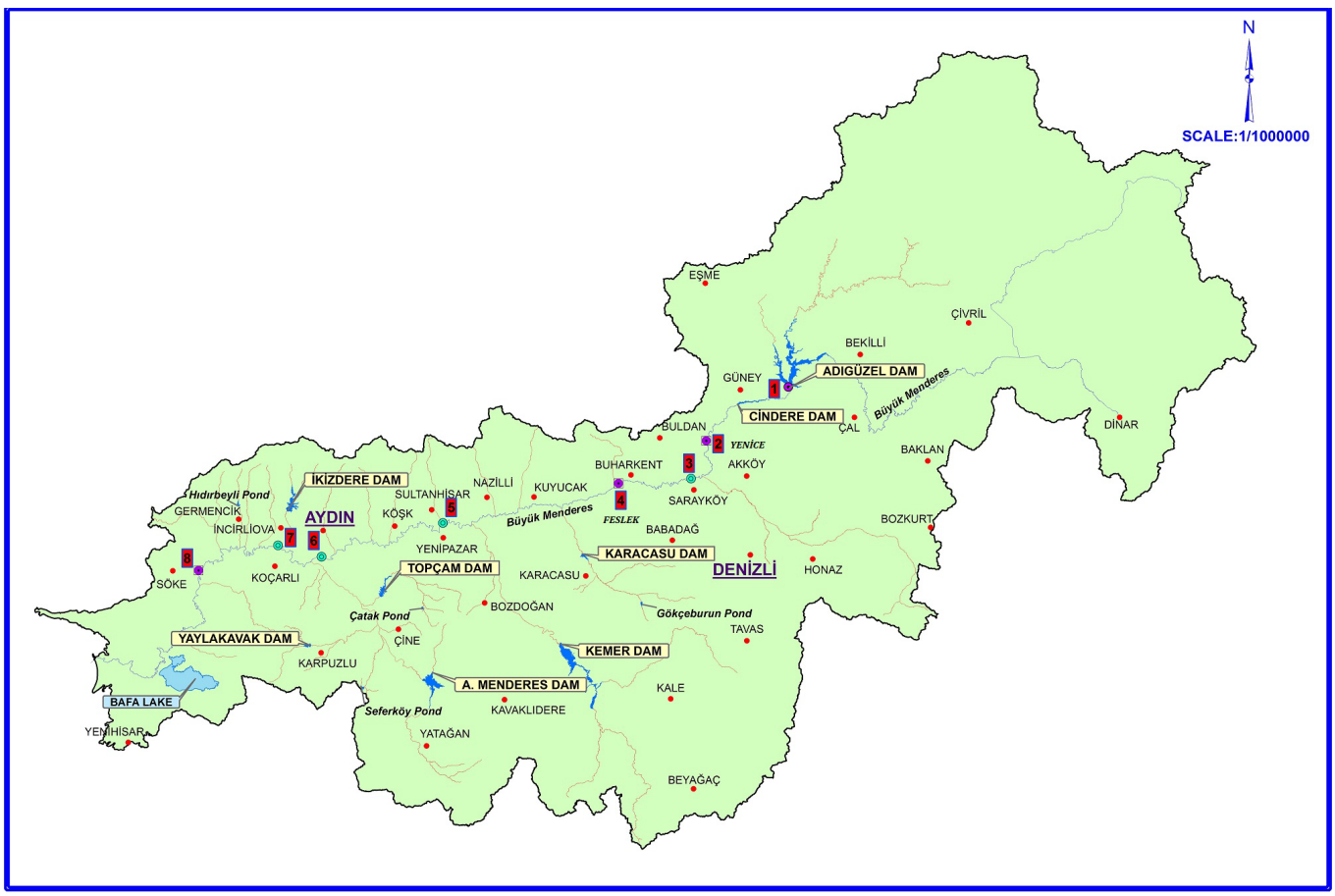

Figure 1. The stations taken sample from Büyük Menderes River.

Cine and İkizdere streams. Station 8 is the Söke Regulator, stations of which are polluted by the domestic wastes and pesticide packages coming from the nearby areas.

2.2. Data Analysis

The quality of the water was measured in 8 stations which are the Adıgüzel Dam, the Yenice Regulator, the Sarayköy Bridge, the Feslek Regulator, the Yenipazar Bridge, the Aydın Bridge, the Koçarlı Bridge, the Söke Regulator. The temperature, pH and conductivity values were measured in the stations. The samples to be used for the measurements were brought to the laboratories as soon as possible to start the analyses. A Mercury Thermometer with 0.1˚C sensitivity was used in the measurements. The Orion pH Meter (Model SA 720) was used to measure the pH. The Jenway conductometer was used to measure the electrical conductivity. The argentometric method was used to measure the chloride; flame photometry was used to measure the sodium and potassium; the Perkin Elmer automatic absorption Spectrophotometer equipment was used to measure the calcium and magnesium; the calorimetric method was used to measure the sulfate; Total dissolved solid (TDS) was measured by TDS meter (Model: HM Digital); Total water hardness (TH) as $CaCO_3$; Suspended Solids (SS) dried at 103˚C - 105˚C. In order to analyze the results, the international algorithmic processes were implemented [6]. Analysis of the water samples was conducted at government facilities of SHW Quality Control Laboratory. The measurements were made between the years 2000 and 2013, in the months of February, April, and then June, August, October as well as December. All of the water samples were analyzed for temperature, pH, EC, Cl^-, Na, Ca^{2+}, Mg^{2+}, K^+, SO_4^{2-}, TDS, TH and SS. The SPSS 21 Statistical Analysis Program was used for the data analyses. The One-Way Anova and the Tukey Multiple Comparison tests were applied to the data. The difference between the groups was $p < 0.05$. The distribution of the data was shown by using the Box-Plot Graphs.

3. Results and Discussion

The water parameter measurement (the temperature, pH, EC, Cl^-, Na, Ca^{2+}, Mg^{2+}, K^+, SO_4^{2-}, TDS, TH and SS) between the years 2000 and 2013 are given. The results were given in Tables 2-4.

Table 2. Results of chemical analyses of water samples taken from Büyük Menderes River.

Stations	Temperature (˚C)	pH	EC (µs/cm)	Cl (mg/l)
Adıgüzel	18.46 ± 4.41^{a}	7.79 ± 0.18^{d}	785.80 ± 135.23^{d}	50.81 ± 16.45^{d}
Yenice	18.44 ± 4.70^{a}	7.82 ± 0.26^{cd}	1213.83 ± 536.30^{c}	57.99 ± 19.60^{d}
Sarayköy	19.67 ± 4.57^{a}	7.91 ± 0.29^{ab}	1892.27 ± 658.81^{a}	160.14 ± 60.24^{a}
Feslek	18.52 ± 4.68^{a}	7.86 ± 0.24^{bc}	1997.39 ± 676.72^{a}	145.88 ± 53.64^{a}
Yenipazar	19.51 ± 4.71^{a}	7.90 ± 0.24^{ab}	1559.16 ± 466.09^{b}	109.07 ± 39.10^{b}
Aydın	20.14 ± 5.52^{a}	7.97 ± 0.24^{a}	1425.76 ± 410.95^{bc}	102.02 ± 40.36^{bc}
Koçarlı	19.63 ± 5.18^{a}	7.95 ± 0.25^{ab}	1277.23 ± 426.28^{c}	88.86 ± 40.01^{c}
Söke	19.73 ± 5.51^{a}	7.99 ± 0.26^{a}	1296.77 ± 428.53^{c}	94.07 ± 43.03^{bc}

Values are mean ± SEM. The differences between the amount expressed with different exponential characters in the same column are statistically significant ($p < 0.05$).

Table 3. Results of chemical analyses of water samples taken from Büyük Menderes River.

Stations	Na (mg/)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	K^{+} (mg/l)
Adıgüzel	93.97 ± 61.83^{b}	75.90 ± 25.24^{e}	38.65 ± 9.59^{f}	6.20 ± 1.27^{c}
Yenice	75.26 ± 36.50^{b}	85.62 ± 27.79^{de}	59.44 ± 33.77^{e}	7.64 ± 2.18^{b}
Sarayköy	133.40 ± 68.85^{a}	149.02 ± 51.90^{a}	94.30 ± 41.86^{bc}	8.73 ± 3.67^{b}
Feslek	153.30 ± 73.76^{a}	145.05 ± 46.58^{a}	109.87 ± 45.58^{a}	10.85 ± 3.77^{a}
Yenipazar	91.57 ± 37.45^{b}	120.43 ± 42.76^{b}	99.51 ± 26.20^{ab}	8.59 ± 3.46^{b}
Aydın	96.46 ± 43.27^{b}	104.09 ± 33.95^{bc}	84.16 ± 26.09^{cd}	8.77 ± 3.38^{b}
Koçarlı	85.43 ± 43.04^{b}	96.46 ± 32.32^{cd}	71.21 ± 25.20^{de}	8.62 ± 3.62^{b}
Söke	90.24 ± 46.51^{b}	90.39 ± 29.67^{cd}	71.87 ± 25.47^{de}	8.30 ± 3.67^{b}

Values are mean ± SEM. The differences between the amount expressed with different exponential characters in the same column are statistically significant ($p < 0.05$).

Table 4. Results of chemical analyses of water samples taken from Büyük Menderes River.

Stations	SO_4^{2-} (mg/l)	TDS (mg/l)	TH (mg/l $CaCO_3$)	SS (mg/l)
Adıgüzel	116.27 ± 52.68^{e}	493.25 ± 105.04^{e}	337.56 ± 74.15^{d}	1.27 ± 1.22^{cd}
Yenice	108.38 ± 100.47^{e}	734.43 ± 275.62^{d}	359.90 ± 86.34^{d}	1.14 ± 0.56^{d}
Sarayköy	439.26 ± 203.08^{b}	1284.65 ± 483.99^{a}	785.87 ± 296.08^{ab}	2.51 ± 1.42^{a}
Feslek	520.81 ± 245.04^{a}	1379.86 ± 502.26^{a}	797.90 ± 274.25^{a}	2.50 ± 1.14^{a}
Yenipazar	318.21 ± 169.21^{c}	1056.31 ± 346.58^{b}	697.44 ± 198.63^{b}	2.07 ± 0.91^{b}
Aydın	304.68 ± 148.17^{cd}	957.75 ± 315.38^{cb}	595.80 ± 167.46^{c}	1.64 ± 0.79^{c}
Koçarlı	254.18 ± 137.04^{cd}	861.40 ± 307.53^{cd}	533.65 ± 170.075^{c}	1.47 ± 0.76^{cd}
Söke	241.50 ± 131.78^{d}	849.85 ± 314.48^{cd}	511.07 ± 178.28^{c}	1.54 ± 0.85^{c}

Values are mean ± SEM. The differences between the amount expressed with different exponential characters in the same column are statistically significant ($p < 0.05$).

3.1. Temperature

The temperature value was the lowest in the Yenice Regulator (18.44 ± 4.70^{a} mg/l) and the highest in the Aydın Bridge (20.14 ± 5.52^{a} mg/l), which is given in Table 2. No significant differences were observed in the annual temperature values of the 8 stations ($p > 0.05$). The temperature was the lowest (16.62 ± 4.48^{f} mg/l) in 2012 and the highest (22.07 ± 4.79^{a} mg/l) in 2007. The difference between the years for which the study was conducted was found to be statistically significant ($p < 0.05$) (Figure 2). In terms of water temperature, The Büyük Menderes water can be classified as "class I" according to the TWPCR.

3.2. pH

The pH value was measured as the lowest in the Adıgüzel Dam (7.79 ± 0.18^{d}) and as the highest in the Söke Regulator (7.99 ± 0.26^{a}), which is given in Table 2. In all of the 8 stations, significant differences were determined in the annual pH levels ($p < 0.05$). The pH was measured as the lowest (7.73 ± 0.24^{e}) in 2003, and measured as the highest (8.11 ± 0.33^{a}) in 2008. There were differences between all the years, and these differ-

ences were found to be statistically significant ($p < 0.05$) (see Figure 3). In terms of pH, the water of Büyük Menderes river can be classified as "class I" according to the TWPCR. Therefore, pH value in all the years is compatible with the values proposed by TS 266 and WHO guidelines.

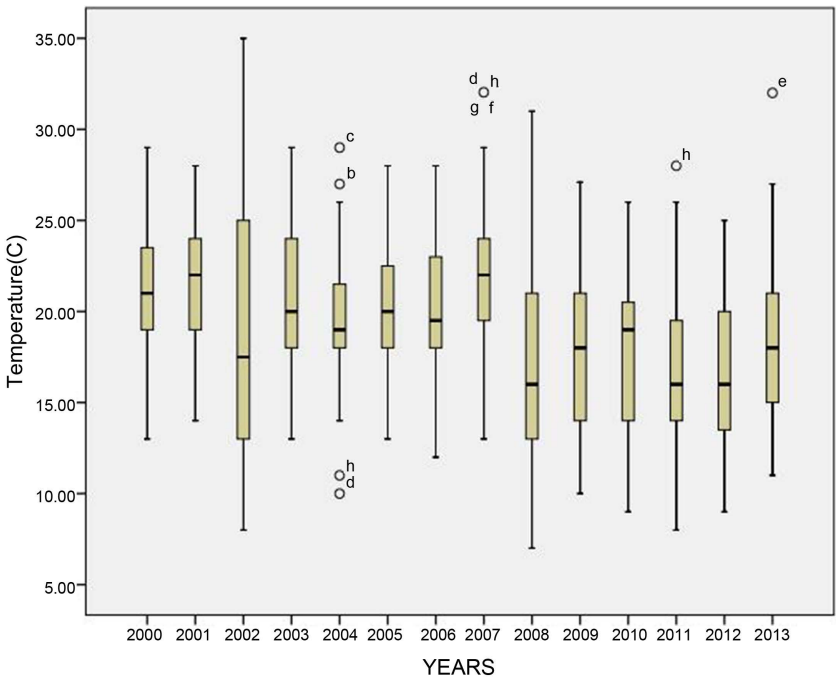

Figure 2. Change graphics of ˚C values in Büyük Menderes River during 2000-2013.

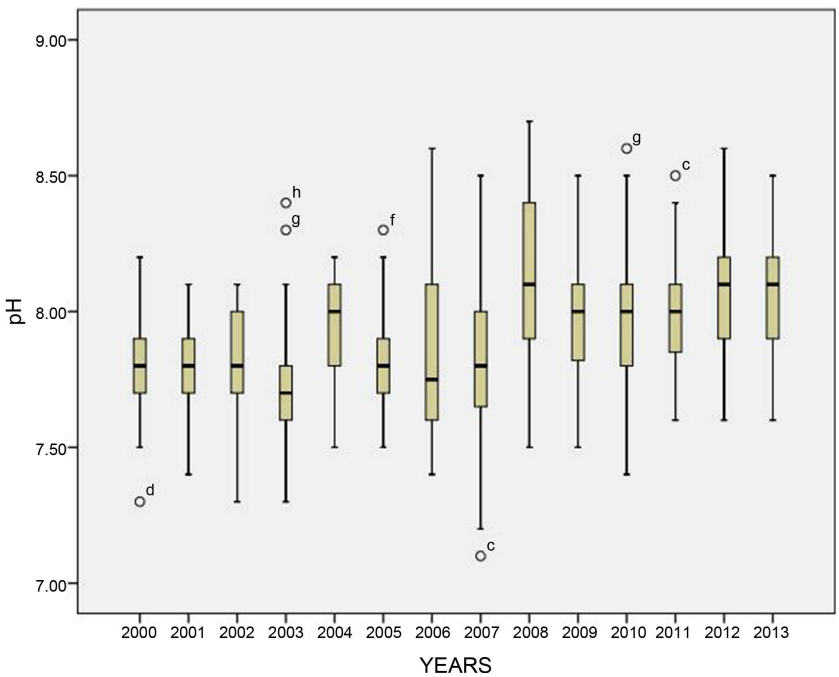

Figure 3. Change graphics of pH values in Büyük Menderes River during 2000-2013.

3.3. Electrical Conductivity (EC)

The EC value was measured as the lowest in the Adıgüzel Dam (785.80 ± 135.23[d] µs/cm) and measured as the highest in the Feslek Regulator (1997.39 ± 676.72[a] µs/cm), which is given in Table 2. In all of the 8 stations, significant differences were determined in the annual Electrical Conductivity (EC) levels ($p < 0.05$). The Electrical Conductivity (EC) level was measured as the lowest (1249.14 ± 508.22[c] µs/cm) in 2004, and it was measured as the highest (1718.66 ± 772.67[a] µs/cm) in 2007. The differences between all the years were statistically significant level ($p < 0.05$) (Figure 4). The electrical conductivity (EC) is usually used for indicating the total concentration of charged ionic species in water [7]. EC value in all the years is compatible with the value proposed by TS 266 and WHO guidelines.

3.4. Chloride (Cl^-)

The Chloride was measured as the lowest in the Adıgüzel Dam (50.81 ± 16.45[d] mg/l) and it was measured as the highest in the Sarayköy Bridge (160.14 ± 60.24[a] mg/l), which is given in Table 2. The differences were observed to be significant in all of the 8 stations ($p < 0.05$). The Chloride was measured as the lowest (72.85 ± 44.10[e] mg/l) in 2013 and it was measured as the highest (130.20 ± 66.44[a] mg/l) in 2007. The annual differences were found to be statistically significant ($p < 0.05$) (Figure 5). Water quality at Adıgüzel Dam was I. class in terms of COD values while Sarayköy Bridge was II. Class. Chloride value in all the years is compatible with the value proposed by TS 266 and WHO guidelines. For freshwater fish, however, the concentration of chloride should not exceed 860 mg/L [8]. All Cl^- values recorded in sampling stations in Büyük Menderes River were below the maximum permissible level for protection of aquatic life.

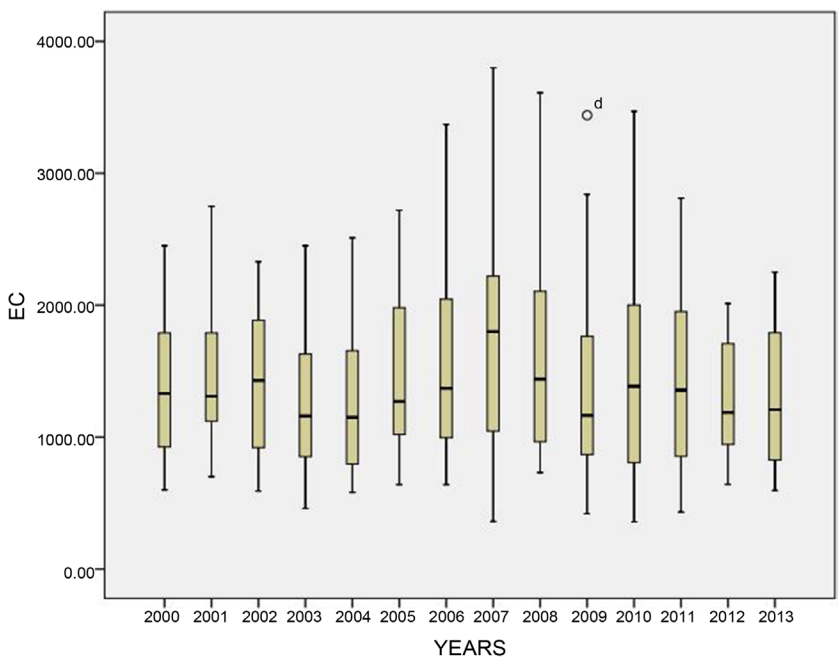

Figure 4. Change graphics of EC values in Büyük Menderes River during 2000-2013.

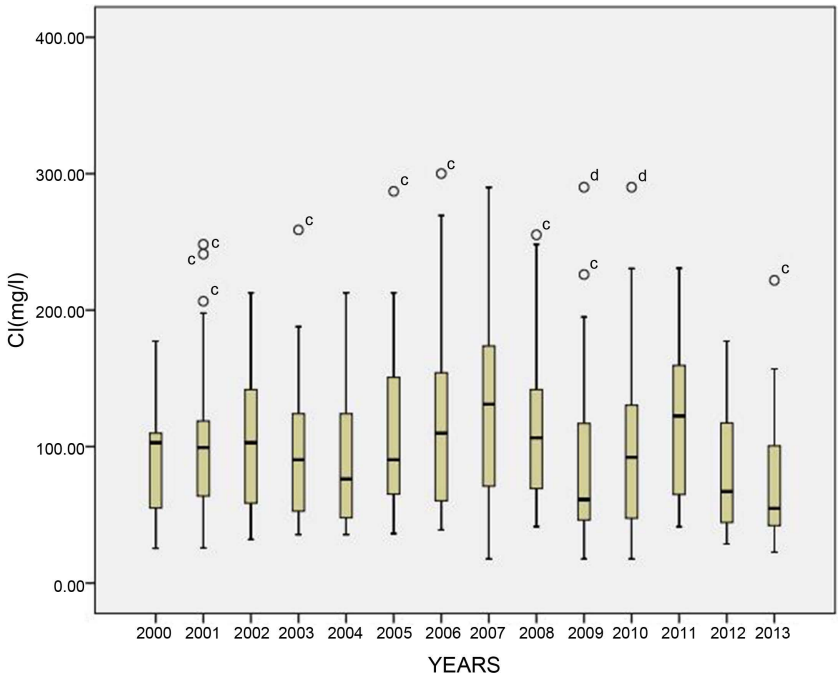

Figure 5. Change graphics of Cl^- values in Büyük Menderes River during 2000-2013.

3.5. Minerals (Sodium, Calcium, Magnesium, and Potassium)

The Sodium was measured as the lowest in the Yenice regulator (75.26 ± 36.50^b mg/l) and it was measured as the highest in the Feslek Regulator (153.30 ± 73.76^a mg/l), which is given in Table 3. In all of the 8 stations, significant differences were determined in the annual pH levels ($p < 0.05$). The Sodium was measured as the lowest (83.08 ± 36.44^d mg/l) in 2001 and it was measured as the highest (139.85 ± 87.51^a mg/l) in 2007. The annual differences were found to be statistically significant ($p < 0.05$) (Figure 6). In terms of sodium, the water of Büyük Menderes river can be classified as "class I" according to the TWPCR. Sodium value in all the years is compatible with the value proposed by TS 266 and WHO guidelines. The natural range of sodium ions in water and soil is so low, their existence can show river pollution caused by human activities [9].

In total hardness Ca and Mg are the most important two elements. They are important for skeleton structure of both aquatic and terrestrial organisms. Also, Mg has an important function in the blood of the human and animals. Water hardness is very important quality criteria for fisheries and drinking [10].

The Calcium levels were measured as the lowest at Adıgüzel Dam (75.90 ± 25.24^e mg/l) and they were measured as the highest at Sarayköy Bridge (149.02 ± 51.90^a mg/l), which is given in Table 3. In all of the 8 stations, significant differences were determined in the annual pH levels ($p < 0.05$). The Calcium was measured as the lowest (96.81 ± 37.68^a mg/l) in 2012 and it was measured as the highest (119.42 ± 49.50^a mg/l) in 2007. The differences between the values for the study years were not statistically significant ($p > 0.05$) (Figure 7).

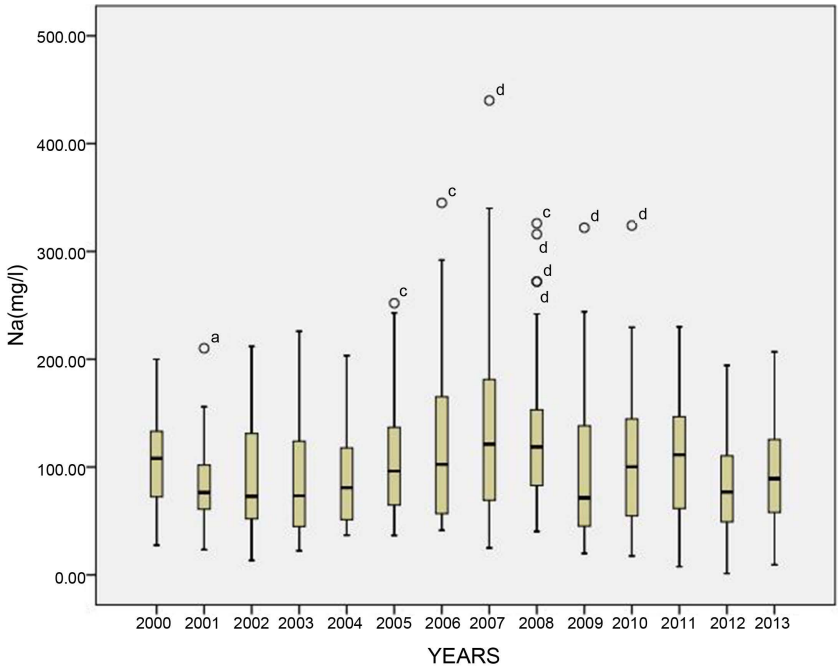

Figure 6. Change graphics of Na values in Büyük Menderes River during 2000-2013.

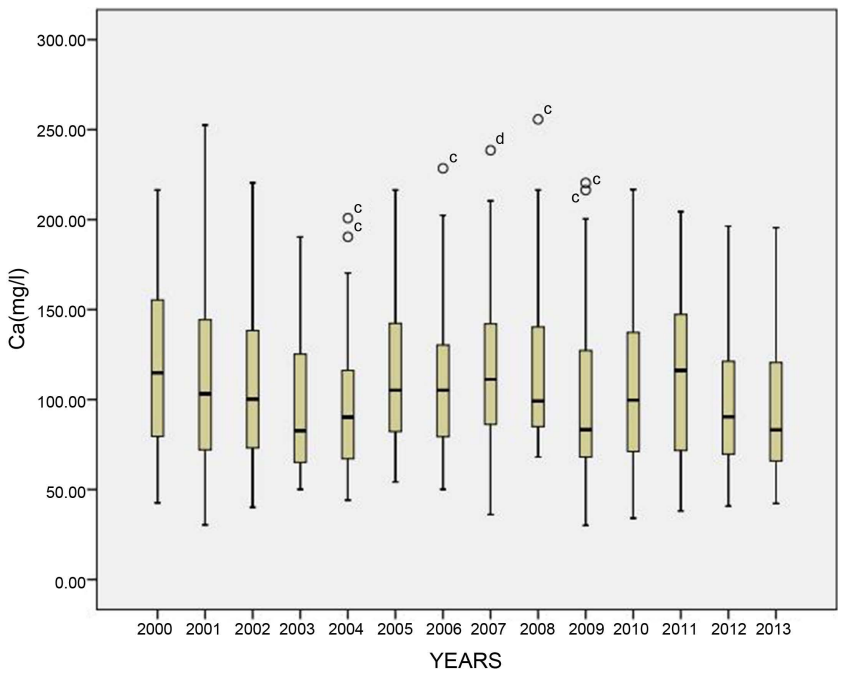

Figure 7. Change graphics of Ca^{2+} values in Büyük Menderes River during 2000-2013.

In fisheries, 400 mg/L calcium values are accepted as suitable [11]. Calcium value in all the years is compatible with the value proposed by TS 266 and WHO guidelines. The higher value of calcium registered during the study period may be due to the influx of industrial waste and sewage to the river water.

The Magnesium was measured as the lowest at Adıguzel dam (38.65 ± 9.59^{f} mg/l)

and it was measured as the highest in the Feslek regulator (109.87 ± 45.58[a] mg/l), which is given in Table 3. In all of the 8 stations, significant differences were determined in the annual pH levels ($p < 0.05$). The Magnesium was measured as the lowest (65.58 ± 27.38[d] mg/l) in 2012 and it was measured as the highest (92.74 ± 41.32[a] mg/l) in the year 2007. The difference per annum was found to be statistically significant ($p < 0.05$) (Figure 8). Furthermore, it was highlighted that the amount of magnesium which is found in 95% of water with 14 mg/l magnesium. In addition, it is probable that 100 mg/l - 400 mg/l of poisoned magnesium was found in fresh water. In retrospect, fresh water fish which are found in 1000 mg/l magnesium can also be found salty water which includes sodium and calcium [12].

Büyük Menderes River is poor in potassium and plankton growth is so low. The Potassium levels were measured as the lowest in the Adıguzel Dam (6.20 ± 1.27[c] mg/l) and they were measured as the highest in the Feslek Regulator (10.85 ± 3.77[a] mg/l), which is given in Table 3. In all of the 8 stations, significant differences were determined in the annual pH levels ($p < 0.05$). The Potassium was measured as the lowest (6.31 ± 1.51[e] mg/l) in 2001 and it was measured as the highest (11.48 ± 4.09[a] mg/l) in 2007. The annual differences were found to be statistically significant ($p < 0.05$) (Figure 9). In terms of potassium, the water of Buyuk Menderes river can be categorized as "class I" as per the regulations in TWPCR.

3.6. Sulphate (SO_4^{2-})

The Sulphate (SO_4^{2-}) values (Table 4) were measured as the lowest in the Yenice Regulator (108.38 ± 100.47[e] mg/l) and they were measured as the highest in the Feslek Regulator (520.81 ± 245.04[a] mg/l). In all of the 8 stations, significant differences were determined

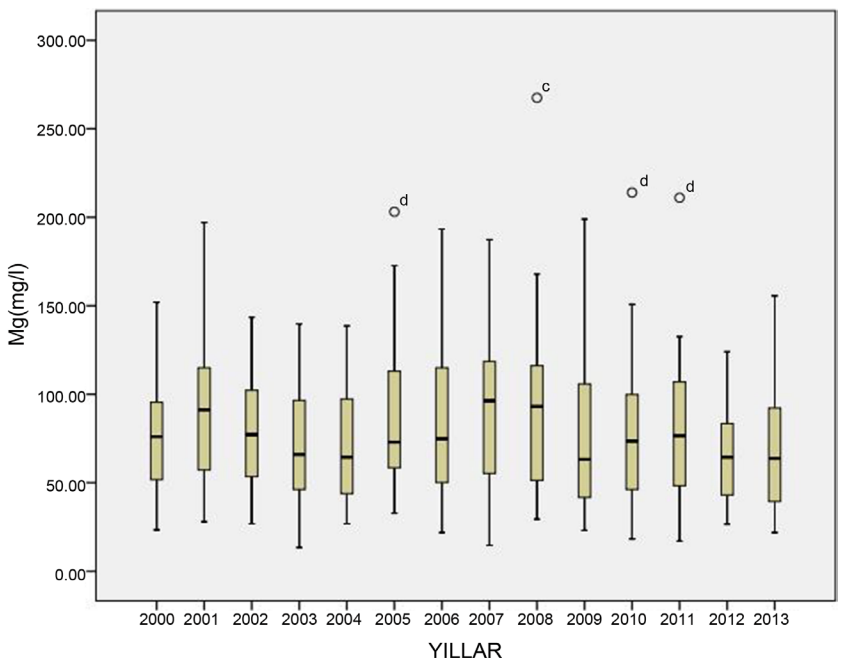

Figure 8. Change graphics of Mg^{2+} values in Büyük Menderes River during 2000-2013.

in the annual Sulphate (SO_4^{2-}) levels ($p < 0.05$). The Sulphate (SO_4^{2-}) values were measured as the lowest (166.07 ± 143.77^{d} mg/l) in 2003 and they were measured as the highest (378.21 ± 265.45^{a} mg/l) in 2007. The differences for all the study years were found to be statistically significant ($p < 0.05$) (Figure 10). Sulphur is present in natural

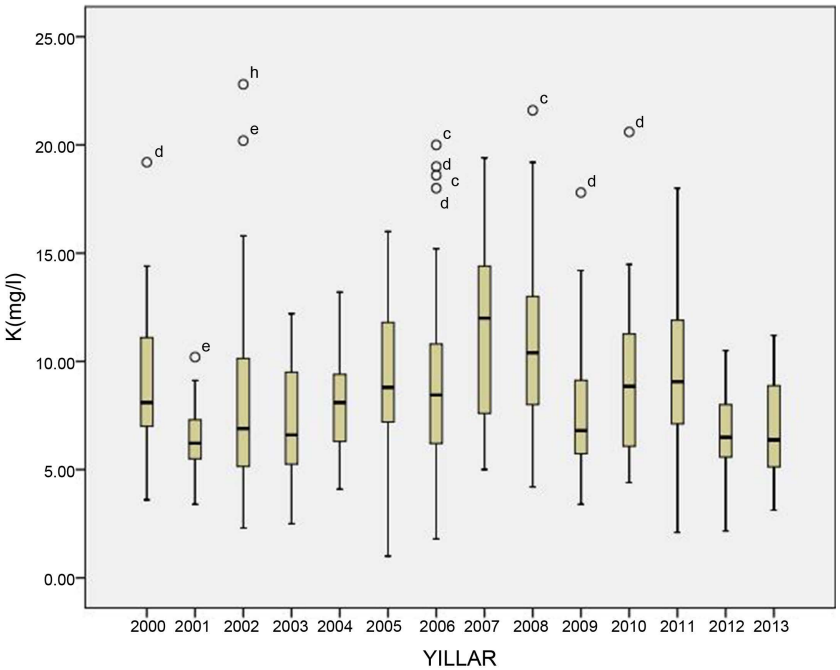

Figure 9. Change graphics of K^+ values in Büyük Menderes River during 2000-2013.

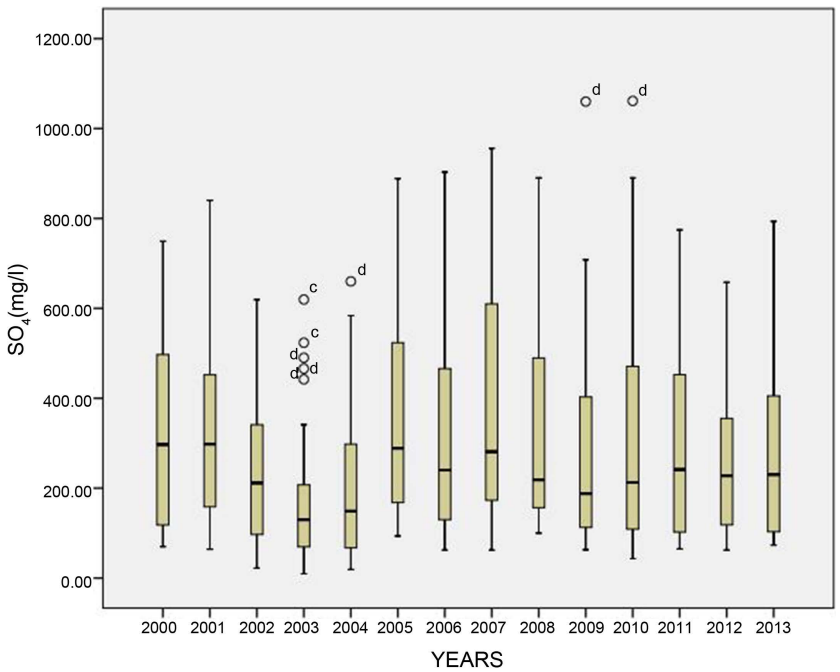

Figure 10. Change graphics of SO_4^{2-} values in Büyük Menderes River during 2000-2013.

waters as sulphate. Water quality at Yenice Regulator was I. class in terms of sulphate values while Feslek Regulator was IV. Class. In this region, increase in sulphate originates from land with gypsum.

3.7. Total Suspended Solids (TDS)

TDS was measured as the lowest in the Adıgüzel Dam (493.25 ± 105.07^{e} mg/l) and it was measured as the highest in the Feslek Regulator (1379.86 ± 502.267^{a} mg/l), which is given in Table 4. In all of the 8 stations, significant differences were determined in the annual pH levels ($p < 0.05$). TDS was measured as the lowest (797.50 ± 323.745^{d} mg/l) in 2004 and it was measured as the highest (1239.58 ± 584.13^{a} mg/l) in 2007. The annual differences were found to be statistically significant ($p < 0.05$) (Figure 11). Water quality at Adıgüzel Dam was I. class in terms of TDS values while Feslek Regulator was II. class. Klein (1992) has reported that the excess amount of TDS in water disturbed ecological balance and cause suffocation of aquatic life.

3.8. Total Hardness (TH)

TH was measured as the lowest in the Adıgüzel Dam (337.56 ± 74.15^{d} mg/l) and it was measured as the highest in the Feslek Regulator (797.90 ± 274.25^{a} mg/l), which is given in Table 4. In all of the 8 stations, significant differences were determined in the annual pH levels ($p < 0.05$). TH was measured as the lowest (490.69 ± 234.90^{e} mg/l) in 2013 and it was measured as the highest (655.52 ± 280.59^{a} mg/l) in 2008. The yearly difference was found to be statistically significant ($p < 0.05$) (Figure 12). Water quality was found to be Class I grade at the Adıgüzel Dam for the case of TDS values while Feslek

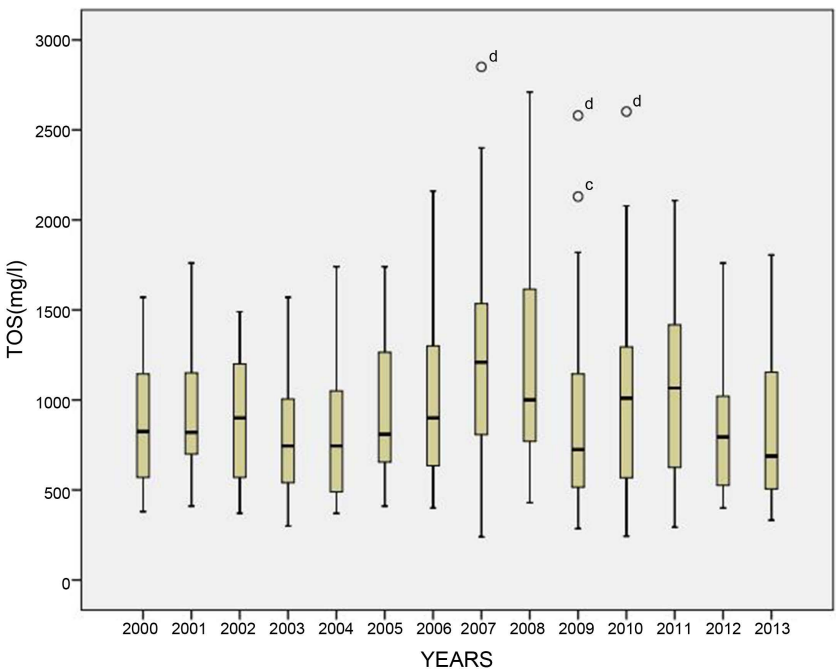

Figure 11. Change graphics of TDS values in Büyük Menderes River during 2000-2013.

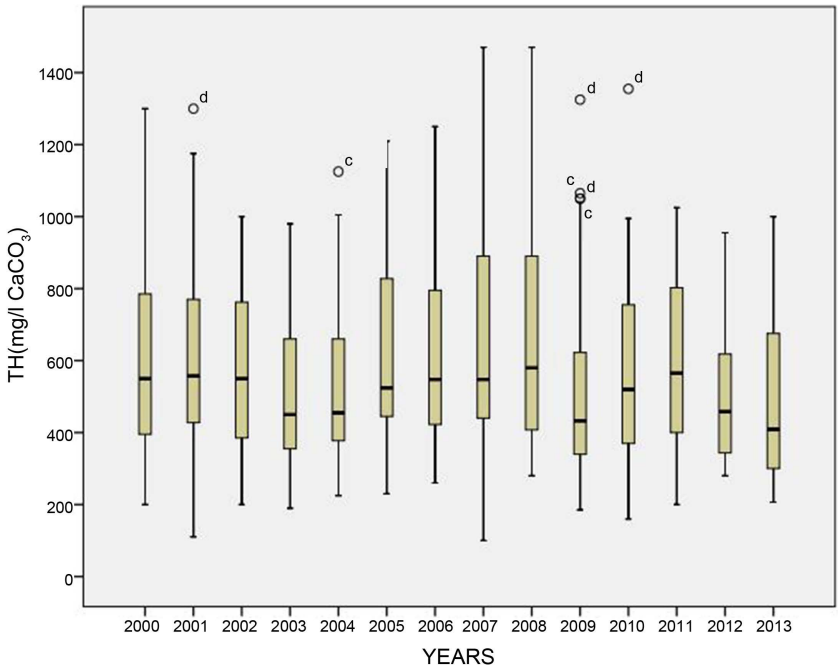

Figure 12. Change graphics of TH values in Büyük Menderes River during 2000-2013.

Regulator was found to be Class II grade.

3.9. SS (Suspended Solids)

Sophisticated concentrations of suspended solids can assist as carriers of toxics, which readily cling to suspended elements [13]. SS was measured as the lowest in the Yenice Regulator (1.14 ± 0.56^{d} mg/l) and it was measured as the highest in the Feslek Regulator (2.51 ± 1.42^{a} mg/l), which is given in **Table 4**. In all of the 8 stations, significant differences were determined in the annual pH levels ($p < 0.05$). SS was measured as the lowest (1.17 ± 0.89^{e} mg/l) in 2009 and it was measured as the highest (2.62 ± 1.10^{a} mg/l) in 2000. The annual differences were found to be statistically significant ($p < 0.05$) (**Figure 13**). Therefore, SS value in all the years is compatible with the values proposed by TS 266 and WHO guidelines.

Inland waters can be categorized in 4 classes as per the TWPCR. Class I is defined as the high quality grade water which is usable with quality of drinking water which can be used after disinfection, and also as water for activities that are recreational in nature (such as swimming which requires body to be in contact with water), as well as breeding of trout and other relevant farming activities. Class II is water which is partially polluted and it can be utilized as a drinking water as long as it is treated with advanced methods, and which can also be used for recreational purposes, fish breeding (excluding trout). It is also possible to use Class II water as an irrigation water as long as it can be maintained so that it has the required quality. Class III is actually polluted which can be used for industrial purposes after extensive treatment. However, industries such as food industry or textile related industries are not good candidates due to their need for very high quality water. Class IV is extremely polluted water with far more poor water

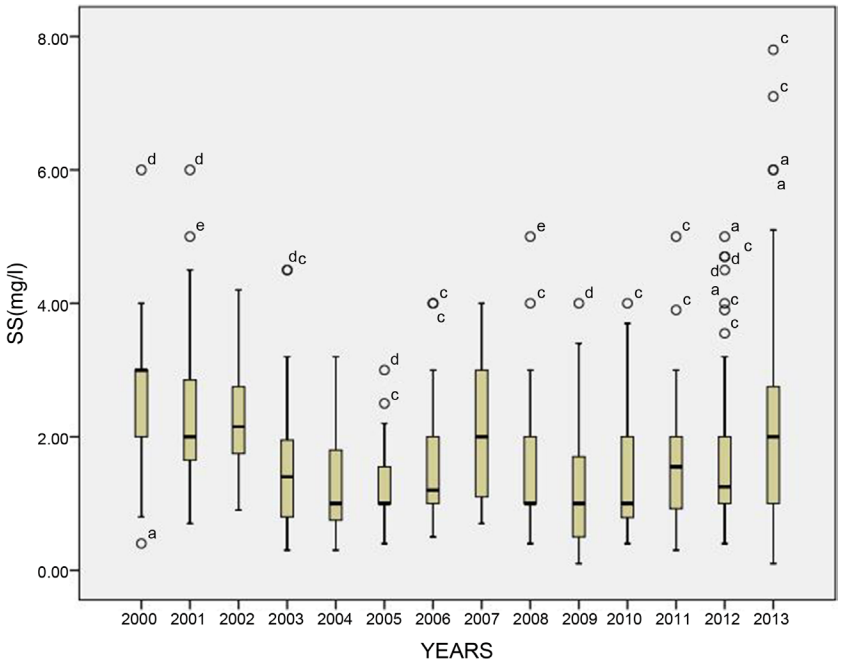

Figure 13. Change graphics of SS values in Büyük Menderes River during 2000-2013.

quality as compared to class III and thus it shouldn't be utilized in any circumstance. The studied parameters are also compared with TS 266 and WHO guidelines [14] [15].

3.10. Effect of Pollution on Fish

Knipowitschiacaucasica, *Hemigrammocapoetakemali*, *Pseudophoxinusmaeandri*, *Gobiomaeandricus*, *Esoxlucius*, *Gambusiaholbrooki*, *Tincatinca*, *Oxynoemacheilusgermencicus*, *Oxynoemacheilus cf. Cinicus*, *Cobitiscfsimplicispina*, *Chondrostomameandrense*, *Luciobarbuskottelati*, *Capoetacapoetabergamae*, *Ladigesocyprismermere* and *Alburnoides cf. Smyrnae*are endemic species and have little tolerance to pollution in water. The Buyuk Menderes River does not have many of these species. *Carassiusgibelio*, *Pseudorasboraparva* and *Lepomisgibbosus*, which are endangered species, may tolerate pollution more than the abovementioned species. In this context, *Carassiusgibelio* is found plenty in this particular river (**Table 1**).

4. Conclusion

One of the issues in the river site is to improve quality of water by controlling the sources of pollution that affect the basin. This is a significant challenge as it will require controlling point pollution source as well as diffusing source to achieve. Another challenge is the increase of the population at the basin of the river. The increase in the population also causes an increase in the load of the structures in the region. Furthermore, population increase also causes a higher amount of waste from domestic sources and there will also be crucial deterioration of the quality of water which will be caused by these domestic waste increases. One way to mitigate this problem will be to construct a special sewage management system with appropriate refining and filtering facilities.

Furthermore, all activities in the basin must be organized and coordinated so that there is no overlap and also to create efficiency. Naturally, the pollution sources will need to be contained and an efficient control process will need to be implemented to ensure that this containment takes place in a proper manner. The parameters of water quality as well as biological indicators may be analyzed to identify the quality of the water in the river. The microscopic algae, zooplanktons, macro-invertebrates, and the macrophytes may be analyzed for this purpose. Only then can we obtain long-term results and prevent the negative influences of the pollution in water.

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