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Determination of Water Quality Parameters of Büyük Menderes River, Turkey

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In this study, seasonal averages of some chemical constituents at upper and lower six monitoring stations in Büyük Menderes river were investigated. These water quality parameters are electical conductivity (EC), sodium, chloride, chemical oxygen demand (COD), boron and sodium absorption rate (SAR). Laboratoary analyses for water samples were conducted at State Hydraulic Works of Turkey DSI's Quality Control and Laboratory Department in Aydin. In the result of the research, there have been differencies for chemical contents between sampling stations. However seasonal changes have also been worth taking into consideration. While pollution has been arising more and more in upstream (Sarayköy and Çubukdag bridges), there have been clear increases especially electrical conductivity boron, sodium chloride, chemical oxygen demand (COD) and sodium absorption rate (SAR). Especially, increasing level in COD and boron values at upstream stations suggest that water quality of Büyük Menderes river has been deteriorated in terms of organic and geothermal pollution from industries and residential areas. It is expected that the results of this study not only provide the information to the public with the recent change in water quality of Büyük Menderes river quantitatively but also help in establishing future management strategies.

Key Words: Water quality, Boron, Büyük Menderes river, Turkey.

INTRODUCTION

Büyük Menderes river, located in the western part of Turkey, is an important source of water especially for irrigation in Büyük Menderes Basin. Water resources are affected by pollution resulting from human activities such as irrigation and discharge of saline drainage water to Büyük Menderes river system. The growing industrial and urban development lead to pollution of rivers, as well as ground waters and the problem of water pollution due to industrial water discharge arose as one of the most important aspects of the environmental pollution. On the other hand, fertilizers and plant protection pesticides appear to be other important pollution sources for agricultural lands, as well as for ground or surface waters.

Büyük Menderes river is located in the western part of Turkey, with a length of 584 km, drains an area of about 24 873 km^2, parts of 5 provinces, namely Aydin, Mugla, Denizli, Usak and Afyon, which corresponds 3.2 % of Turkey. It raises near Dinar county of Afyon province and discharges into Agean Sea within the boundaries of Aydin province. Its major tributaries are Kufi, Banaz, Dokuzsele, Çürüksu, Dandalaz, Akçay and Çine streams. Major cities in the basin are Usak, Denizli, Sarayköy, Nazilli, Aydin and Söke.

Büyük Menderes river and its tributaries have long been considered as receiving water body for disposal of industrial and municipal wastewaters. Until recently this did not pose a serious problem. But, especially within last one or two decades, due to population increase and industrial development, the water quality of the river has been deteriorated. Major industries creating pollution in Büyük Menderes river, with their wastewaters either partially treated or untreated, are leather processing industries, sugar and textile mills. Geothermal sources in Kizildere and Saraykoy should also be counted. In addition to industrial and geothermal effluents, municipal wastewaters is the other source of pollution in surface waters in the basin. Especially in 1980s considerable investments had been made on construction of sewage systems in residential areas in the basin, as in other parts of Turkey[1]. Several studies have been done by many researchers in terms of water quality problems of rivers. In some countries as the main reasons for increased salinity level of the Rhine river in Eastern France are pointed out the mining and industrial activities[2]. Cunningham and Morton[3] studied the trend in salinity of the river Murray in South Australia by analyzing more than 500 mg/L monthly chloride concentration values over a period of 43 years. Results showed that chloride concentraions varied in the ranges of 20 to 365 mg/L. Colorado river has a salinity concentration of less than 30 mg/L at the beginning of the head waters in the mountain of Colorado. The salinity level progressively increases downstream as a result of addition of soluble salts to the river and increasing the salt concentration due to reduction in the volume of the river water as a concequence of evaporation and abstraction[4]. Valles *et al.*[5] observed the salinity of the Jaj-Rud river in Iran at nine stations and determined that the concentration of dissolved compounds increases and the water quality deteriorates from upstream to downstream. Fluctuations in electrical conductivity (EC) of the water in the ranges of 255-13640 µS/cm during the summer and 255-1980 µS/cm during the spring have been also found. Chemical composition of water and dissolved organic carbon (DOC) levels were investigated over three years, along two large rivers in NE Poland.

As a result of this study, dissolved organic carbon (DOC) concentrations and chemical water parameters were highest in the upper part of the lowland river and lowest in the upper course of the lakeland river[6]. The Amu Darya river (Central Asia) water quality has been studied by Crosa *et al.*[7]. The examined data demonstrated a considerable downstream degradation of the Amu Darya waters, mainly releated to salinity, the major ions being sulphate, chloride, sodium and potassium. The high salinization levels of the waters are mainly due to the presence of sulphate and chloride. Kannel *et al.*[8] studied the assessment of variation of water qualities and detection of pollution sources along the Bagmati river and its tributaries in the Kathmandu valley of Nepal. The study revealed that the upstream river water qualities in the rural areas were increasingly affected from human sewage and chemical fertilizers. In downstream urban areas, the river was heavily polluted with untreated municipal sewage. Barzani *et al.*[9] investigated the water quality of seven feeder rivers of Tasik Chini, Pahang Malaysia. They have observed illegal logging, agricultural activities and other unsustainable developments have taken place in the areas surrounding the lake. The impact of these activities may have caused environmental degradation to Tasik Chini and its adjacent areas.

Quite similar is the situation with the rivers in Turkey. Ögretir[10] investigated the problems of pollution of the Karasu river in the middle Anotolian region and found out that the salt load increases dramatically from upstream to downstream. Also, much higher than normal levels of COD were determined. Dogan *et al.*[11] reported for high salinity and alkalinity levels, as well as high concentration of sodium, chloride, boron and other toxic ions in water of the Ankara stream in the middle Anatolian region. Büyük Menderes river, water resource of the basin was to be polluted by geothermal waste water and thermal springs including boron and chloride contents. Boron concentrations of thermal waters in Büyük Menderes river basin vary from 1 to 24 mg/L and the chloride contents of these waters have a range of 10-1.790 mg/L. Especially, Kizildere and Germencik geothermal fields, located in Büyük Menderes graben in south-west Turkey, have relatively high boron and chlorine contents. Currently, the wastewater, which includes up to 24 mg/L boron, is discharged into the river at a rate of 750-1500 tonnes per hour from the Kizildere and Germencik geothermal fields[12,13]. Koç[14] investigated the boron contents of the Büyük Menderes river at seven stations and found out that the concentration of boron decreases from upstream to downstream. Even though boron concentrations of river water is under 0.5 ppm limit value, boron element will store in basin soils, decrease in crop yields and occur problematic soils in basin. Ödemis *et al.*[15] researched to determine variations in chemical water quality parameters of the Turkish part of Orontes river, whose basin is shared by Lebanon, Syria and Turkey.

According to results organic pollutant parameters (TDS, BOD and COD) fluctuated at rainy, transitional and dry seasons. Between 1999 and 2001, TDS and COD values showed an increasing trend, while BOD levels showed a decreasing trend. Monthly measurements conducted at Göksu, Lamas, Efrenk, Tarsus and Seyhan rivers discharging into the Cilician Basin of the Eastern Mediterranean Sea. Among the sampled river, Tarsus river was beter in water quality, with the lowest electrical conductivity, alkalinity, total hardness and nutrient concentration values Özsoy *et al.*[16].

Since the status and deterioration in water quality of Büyük Menderes river has been an important public concern in the basin, the objective of this study was to quantify the seasonal changes of some water quality parameters in Büyük Menderes river.

EXPERIMENTAL

Water quality monitoring in the Buyuk Menderes river are carried out by the State Hydraulic Works of Turkey (DSI) and the monitoring stations whose data were used in this study. Six points (namely, Sarayköy, Çubukdag, Yenipazar, Aydin, Koçarli bridges and Söke regulator) were selected to research some water quality parameters of Büyük Menderes River between 2000 and 2006. The Sarayköy and Çubukdag bridges represent upstream, Yenipazar and Aydin bridges midstream; Koçarli bridge and Söke regulator downstream. Bridges and Söke regulator were constructed on Menderes river.

During the experimental period, water samples from six monitoring stations were taken and analyzed at bimonthly intervals. Therefore, water samples were collected primarily bimonthly, namely in February, April, June, August, October and December. Laboratoary analyses for water samples were conducted at DSI's Quality Control and Laboratory Department in Aydin. Twelve water quality parameters used in this study are pH, electrical conductivity, sodium, potasium, calcium, magnesium, carbonate, bicarbonate, chloride, sulphate, chemical oxygen demand and boron. Analytical methods are given in DSI's Quality Control and Laboratory Manual[17]. pH was measured using a glass electrode pH-meter(Hanna® Instruments pH 211). Ec-meter (Hanna® Instruments EC 214) was used to measure electirical conductivity. Sodium and potasium were analyzed by flame photometer, calcium and magnesium by Versenat titration. Carbonate and bicarbonate were analyzed by sulfuric acid titration, chloride by silver nitrate titration. Sulphate was calculated by subtracting the total amount of anions such as bicarbonate, carbonate and chloride from total amount of cations. Boron was analyzed using Carmen solution and method of colorimeter. Finally, chemical oxygen demand (COD), were determined by Merck® spectrophotometer. Sodium per cent and sodium absorption rate (SAR) were calculated using the following equations[18]:

$$\% Na = [Na/(Na + K + Ca + Mg)] \times 100$$
$$SAR = Na/[(Ca + Mg)/2]^{1/2}$$

where; Na, K, Ca, Mg in me/L.

RESULTS AND DISCUSSION

Seasonal averages of chemical analysis were computed for February, April, July, August, October and December between 2000 and 2006 in the basin. Average data of water samples taken from Sarayköy, Çubukdag, Yenipazar, Aydin, Koçarli bridges and Söke regulator were summarized in Table-1.

Electrical conductivity (EC): Results concerning the seasonal averages of Büyük Menderes river salinity are plotted on Fig. 1. As it can be seen from the figure fluctuations in EC values exist from station to station, as well as from season to season. EC concentrations in the basin decreased from upstream to downstream. EC concentrations of Sarayköy and Çubukdag bridges were higher than other stations. On the other hand, EC concentration of river decreased in the irrigation season (June-August), owing to irrigation water released from Dams. Due to addition of industrial and domestic wastes containing high amounts of soluble salts to the river system the salt load dramatically increased after the irrigation season (October-December). As a result salinity reached up to 2.37-2.44 ds/m at the most polluted section (Çubukdag and Sarayköy bridges) of the river. Owing to the gathering waters from the non-polluted branches, the salt load of the river decreases to 1.57-1.81 ds/m at Yenipazar, Aydin, Koçarli bridges and Söke regulator. Therefore, water quality generally improves downstream as higher quality tributary flows dilute salt concentrations. Similar fluctuations in the water salinity of the Menderes river are reported by Yesilirmak and Anaç[1]. They found out decreasing trends in EC were observed at Çubukdag, Feslek, Nazilli, Yenipazar, Aydin and Koçarli stations. Ögretir[10] determined the salinity of the Karasu River in the Middle Anatolian Region increases progressively from upstream to downstream.

Sodium: Fig. 2 shows the average bimonthly values of sodium. The average sodium values at all stations do not exceed the ranges of 3.3-5.8 me/L during the February-August. The concentration of mentioned parameter increases in October and reaches as high levels as 7.35-8.70 me/L at Sarayköy and Çubukdag bridges. After the mentioned stations, sodium amount slightly decreases to 6.07-6.56 me/L at Sarayköy and Çubukdag bridges and to 4.77-5.10 me/L at other stations. Yesilirmak and Anaç[1] determined that for sodium concentrations, increasing trends were observed at the stations Sarayköy and Nazilli, on the other hand, decreasing trends were detected at Çubukdag, Feslek, Yenipazar, Aydin, Koçarli and Söke stations. Increases of the sodium represent deterioration in water quality,

TABLE-1
SEASONAL AVERAGES OF CHEMICAL CONSTITUENTS AT UPPER AND LOWER MONITORING STATIONS IN BÜYÜK MENDERES RIVER (AVERAGE FOR 2000-2006)

Station	Month	pH	EC (ds/m)	Cations (me/L)					Anions (me/L)					COD (mg/L)	Boron (mg/L)	Sodium (%)	SAR
				Na	K	Ca	Mg	Total	CO_3	HCO_3	Cl	SO_4	Total				
Sarayköy Bridge	Feb.	7.8	2.05	5.20	0.18	8.67	9.98	24.03	0	8.29	4.50	11.21	24.00	62	0.25	21.63	1.70
	Apr.	7.8	1.90	5.30	0.21	7.91	7.78	21.20	0	8.12	4.88	7.95	20.95	88	0.25	25.00	1.89
	June.	7.8	1.36	4.40	0.22	5.86	4.60	15.08	0	6.80	3.43	4.72	14.95	83	0.14	29.17	1.92
	Aug.	7.7	1.09	3.30	0.20	4.49	4.26	12.28	0	6.17	2.77	3.16	12.10	44	0.20	27.11	1.59
	Oct.	7.7	2.44	8.70	0.50	8.80	8.98	26.98	0	8.53	6.73	11.72	26.98	140	0.20	32.24	2.91
	Dec.	7.7	2.14	6.00	0.19	8.89	8.20	23.35	0	7.55	4.99	10.80	23.34	106	0.22	25.99	2.07
Çubukdag Bridge	Feb.	7.7	2.15	5.84	0.25	8.20	9.28	23.57	0	7.64	3.89	12.00	23.53	62	0.68	24.77	1.97
	Apr.	7.7	1.79	4.38	0.21	6.97	7.49	19.05	0	6.68	3.24	9.12	19.04	36	0.56	22.99	1.62
	June.	7.8	1.51	5.46	0.25	5.14	4.76	15.61	0	6.12	3.29	6.12	15.53	51	0.50	34.97	2.45
	Aug.	7.9	1.22	3.83	0.20	4.59	4.95	13.57	0	5.36	2.88	5.30	13.54	39	0.33	28.22	1.75
	Oct.	7.6	2.37	7.35	0.26	8.71	9.60	25.92	0	8.98	4.99	11.99	25.96	79	0.58	28.35	2.52
	Dec	7.7	2.37	6.56	0.23	6.40	7.14	20.33	0	7.41	4.57	8.32	20.30	78	0.76	32.26	2.42
Yenipazar Bridge	Feb.	7.8	1.51	5.60	0.21	4.60	5.05	15.46	0	6.12	2.21	7.15	15.48	46	0.25	36.22	1.30
	Apr.	7.8	1.47	3.40	0.18	5.40	6.59	15.57	0	6.01	2.71	6.87	15.59	32	0.36	21.83	1.38
	June.	7.8	1.31	4.03	0.22	4.43	5.08	13.76	0	5.89	2.79	5.02	13.70	27	0.25	29.28	1.84
	Aug.	8.0	0.97	2.34	0.14	3.62	4.29	10.39	0	5.54	1.82	3.05	10.41	26	0.15	22.52	1.17
	Oct.	7.8	1.85	5.14	0.27	6.69	8.51	20.61	0	8.05	3.75	8.77	20.57	32	0.26	24.93	1.86
	Dec	7.7	1.81	4.77	0.23	6.51	7.94	19.45	0	7.41	3.69	8.32	19.42	33	0.33	24.52	1.77
Aydin Bridge	Feb.	7.8	1.45	3.42	0.21	5.63	5.78	15.04	0	5.98	2.50	6.58	15.06	43	0.17	22.73	1.43
	Apr.	7.8	1.39	3.57	0.19	4.72	6.02	14.50	0	5.48	3.23	5.83	14.54	32	0.25	24.62	1.54
	June.	7.9	1.24	4.19	0.26	3.71	4.60	12.76	0	5.97	2.79	3.96	12.72	33	0.14	32.83	2.05
	Aug.	7.9	0.97	2.27	0.14	3.62	4.38	10.41	0	5.25	1.74	3.40	10.39	28	0.21	21.80	1.13
	Oct.	7.9	1.74	4.99	0.29	6.12	7.24	18.64	0	7.46	3.77	7.43	18.66	37	0.24	26.77	1.93
	Dec	7.7	1.70	4.92	0.25	6.49	5.95	17.61	0	6.86	3.27	7.53	17.66	38	0.28	27.93	1.97
Koçarli Bridge	Feb.	7.7	1.21	2.99	0.19	4.66	4.64	12.48	0	5.28	2.11	5.03	12.42	46	0.11	23.95	1.38
	Apr.	7.8	1.14	2.78	0.15	4.12	4.80	11.85	0	4.85	2.13	4.90	11.88	28	0.15	23.45	1.31
	June.	7.8	1.18	3.07	0.28	4.45	4.25	12.05	0	5.62	2.50	3.88	12.00	28	0.07	25.47	1.47
	Aug.	8.0	0.92	2.12	0.15	3.49	4.43	10.19	0	4.99	1.67	3.34	10.00	32	0.08	20.80	1.06
	Oct.	7.9	1.74	7.53	0.29	4.21	5.69	17.72	0	7.39	3.60	6.69	17.68	29	0.18	42.49	1.86
	Dec	7.8	1.57	5.10	0.24	5.63	6.17	17.14	0	6.51	3.24	7.36	17.11	37	0.17	29.75	2.09
Söke Regulator	Feb.	7.8	1.18	2.95	0.18	4.31	4.51	11.95	0	5.24	2.11	4.62	11.97	46	0.11	24.68	1.40
	Apr.	7.8	1.12	2.87	0.15	4.09	4.18	11.29	0	5.07	2.14	4.05	11.26	33	0.07	25.42	1.41
	June.	7.8	1.25	4.04	0.22	3.72	4.47	12.45	0	5.84	3.14	3.45	12.43	34	0.01	32.44	1.99
	Aug.	8.0	0.99	2.38	0.12	3.45	4.90	10.85	0	5.39	1.80	3.69	10.88	30	0.10	21.93	1.16
	Oct.	7.9	1.70	5.16	0.29	5.48	6.80	17.73	0	7.18	3.74	6.85	17.77	38	0.15	29.10	2.08
	Dec	7.9	1.57	5.04	0.24	5.33	6.19	16.80	0	6.43	3.29	7.03	16.75	46	0.18	30.00	2.10

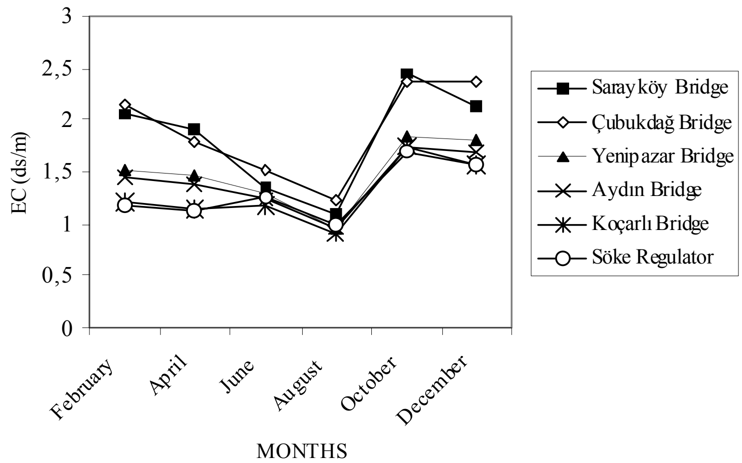

Fig. 1. Seasonal variation of electrical conductivity (EC) at Büyük Menderes river (average for 2000-2006)

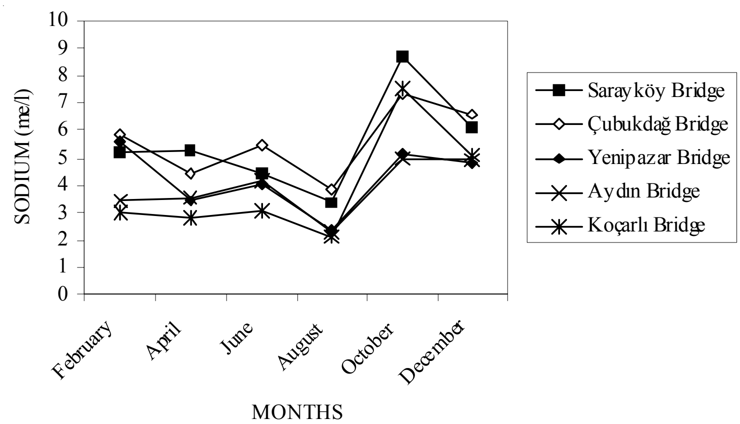

Fig. 2. Seasonal variation of sodium at Büyük Menderes river (average for 2000-2006)

whereas decreases represent improvement in water quality. All natural waters contain some sodium since sodium salts are highly water soluble and it is one of the most abundant elements on earth. Increased concentrations in surface waters may arise from sewage and industrial effluents and from the use of salts on roads to control snow and ice[19].

Chloride: Quite similar results have been recorded from the point of view of main anion that of chloride (Fig. 3). As it is evident from Fig. 3, the highest concentrations of chloride are determined in water samples taken from Sarayköy followed by Çubukdag bridges. High chloride amounts 6.73-4.99 me/L are recorded for the pointed out stations. Chloride concentration of river decreased in the irrigation season (August), owing to irrigation water released from dams. Increasing trends in chloride concentrations were detected after the irrigation season (October) at all stations. Chloride may be increased with atmospheric deposition of oceanic aerosols, with the weathering of some sedimentary rocks and from industrial and municipal effluents and agricultural and road run-off. Ögretir[10] found out that as high concentrations of chloride as 37.5 me/L estimated in waters of Kocadere, a tributary of the Karasu river. High amounts of chloride, 398.9 and 1095.2 mg/L have been estimated in Balgat and Çubuk streams, tributaries of the Ankara stream[11]. A short review of the literature shows, that chloride pollution is a problem, that does not concern only rivers in Turkey.

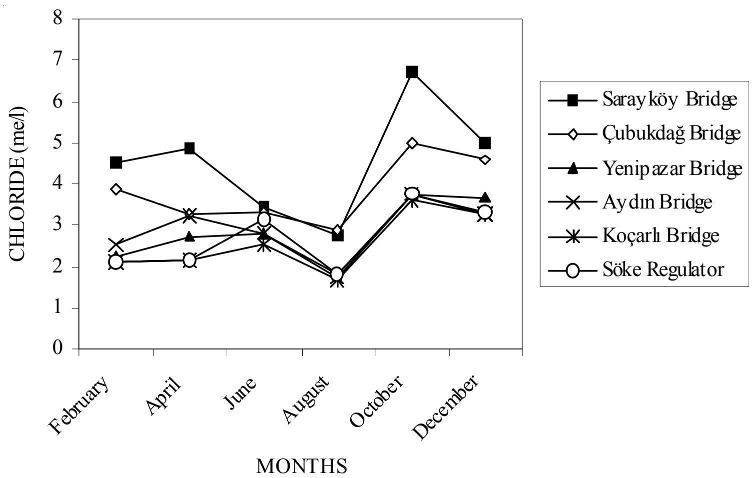

Fig. 3. Seasonal variation of chloride at Büyük Menderes river (average for 2000-2006)

Chemical oxygen demand (COD): COD is a pollution parameter indicating the level of organically pollution. The highest seasonal average rates of the mentioned parameter 140 mg/L (Fig. 4) is determined in samples from the most polluted section of the river (Sarayköy bridge). Relatively high level of pollution was observed in waters of the second station (Çubukdag bridge). On the other hand, COD values of water samples from other stations are almost the same levels during the whole year (Fig. 4). Also, according to data, COD decreased in the dry season (June-August) and increased in the rainy season. The increases at these stations represent deterioration in water quality. Chemical oxygen demand test allows mesurement of a waste in terms of the total quantity of oxygen required for oxidation to carbon dioxide and water[20]. In this context, COD analysis in surface waters can give the indication of the degree of pollution from municipal or industrial wastewaters. Increasing trends in COD at most of the stations indicate that more wastewaters, treated, untreated or partially terated, have been discharged to Büyük Menderes river or its tributaries due to population increase and industrial development in the basin. High rates of COD have been recorded in result of the investigations done on pollution of other Turkish rivers. Ögretir[10] reported that in some sections of the Karasu river as Kocadere, the values of this parameter exceed the level of 900 mg/L.

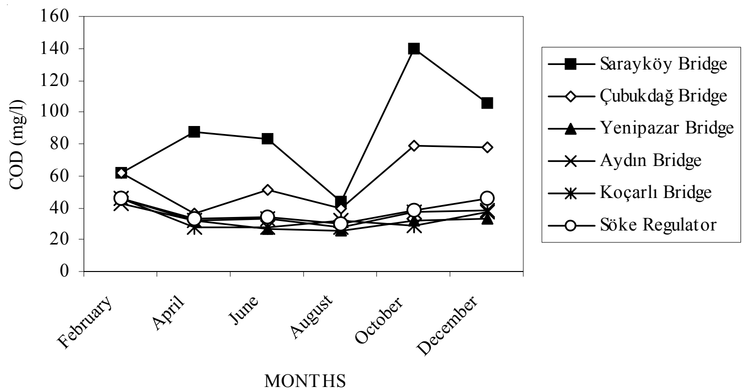

Fig. 4. Seasonal variation of chemical oxygen demand (COD) at Büyük Menderes river (average for 2000-2006)

Boron: Increasing level in boron concentrations was observed at the station Çubukdag bridge as 0.68-0.76 mg/L (Fig. 5). On the other hand, decreasing levels were detected at other stations, namely Sarayköy, Yenipazar, Aydin, Koçarli and Söke. Boron concentrations in the river decreased from upstream to down stream. Boron concentration of Çubukdag bridge were higher than stations. Thermal wastewaters were to flow into the Büyük Menderes river, therefore boron concentrations of water samples taken from Çubukdag bridge were too high. On the other hand, boron concentration of river decreased in the irrigation season (June-August), owing to irrigation water released from Adigüzel Dam. Therefore, boron concentrations fluctuate through year, higher some monts and lower in some months (Fig. 5). Boron is necessary for plant growth and is toxic for plants when it is higher than 0.50 mg/L[21]. A small quantity of boron is necessary for growth of the plants, but larger amount of boron became toxic. Surface water rarely contain enough boron to be toxic but well water and springs occasionally contain toxic amounts, especially near geothermal areas and earthquake faults. Boron problems originating from the water are probably more frequent than those originating in the soil[18]. High rates of boron have been recorded in result of the investigations done on pollution of Büyük Menderes river[14].

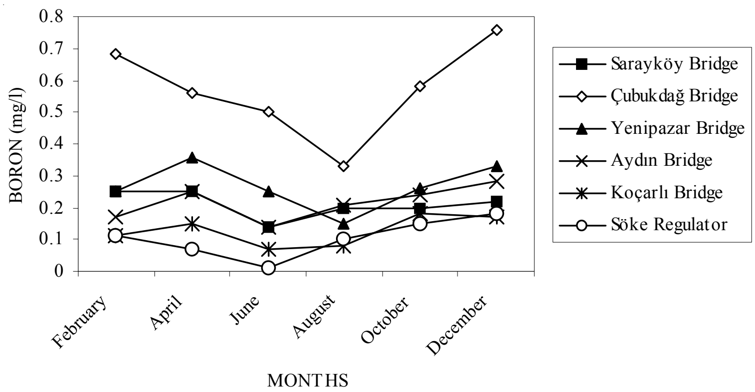

Fig. 5. Seasonal variation of Boron at Büyük Menderes river (average for 2000-2006)

Sodium absorption rate (SAR): Fig. 6 shows results concerning the sodium absorption rate (SAR) of the water, which is closely related to water alkalinity. SAR is also very important parameter for the quality of water used in agricultural aplications[18]. As it can be seen from the figure, data obtained for SAR are quite similar to those pointed out for parameters discussed above, particularly those for sodium. Excessively high levels of the SAR are determined in the samples taken from the most polluted section of the river (Sarayköy and Çubukdag bridge). After being increased up to 2.91-2.52 at the mentioned station, owing to gathering of non sodic waters from tributaries, SAR values decrease again to the limits of 1.5-2.0 at all the stations (Fig. 6). Therefore, water quality generally improves downstream as higher quality tributary flows dilute SAR concentration. Dogan *et al.*[11] reported for low SAR levels in the Ankara Stream, except for Balgat

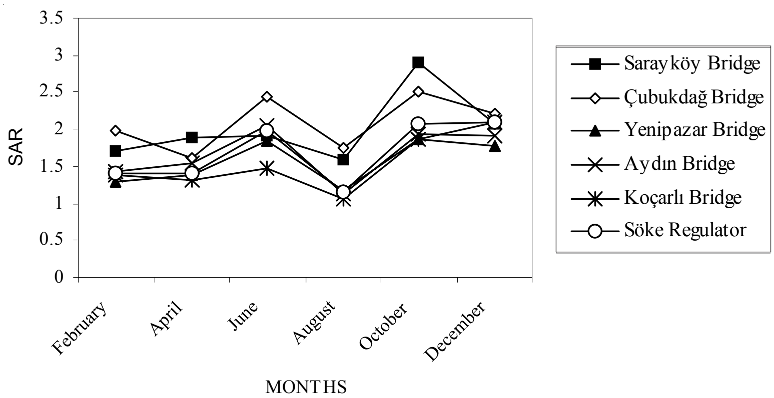

Fig. 6. Seasonal variation of sodium absorption rate (SAR) at Büyük Menderes river (average for 2000-2006)

and Cubuk tributaries, having SAR rates more than 30 and 14, respectively. SAR values determined in the Yesilirmak River water are very low and do not exceed level of 1.1[22].

Conclusion

As a result of this study, it was estimated that there exist obvious fluctuations in the Buyuk Menderes river water quality and pollution. These fluctuations are evident not only from station to station, but also from season to season. As a whole, it was determined that the concentrations of dissolved compounds increase and the water quality deteriorates at Sarayköy and Çubukdag stations. Despite the differences in some water quality parameters of water samples taken from different section of the river, it may be concluded that Çubukdag and Sarayköy stations are the most polluted stations. Excessively high rates of boron, sodium, chloride, electrical conductance, chemical oxygen demand (COD) and sodium absorption rate (SAR) exist in water of the mentioned stations. Especially, increasing level in COD and boron values at upstream stations suggest that water quality of Buyuk Menderes river has been deteriorated in terms of organic and geothermal pollution from industries and from residential areas in the period during which data were obtained. On the other hand, water quality generally improves downstream as higher quality tributary flows dilute salt and boron concentrations. The results of this study will be expected not only to provide information to the public with the recent changes quantitatively in water quality of Buyuk Menderes river, but also to help establish future surface water quality management strategies in the basin.

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