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Research article/Araştırma makalesi

Application of water quality index method for assessing the surface water quality status of Mert Stream in Turkey

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Abstract

In this study, the water quality data obtained from 6 sampling stations between July 2011 and June 2012 monitoring period at Mert stream was evaluated. In order to assess the present water quality of Mert stream, different WQI approach (modified WQImin) was applied to a data set expressly collected for the present study. The mean WQI value of the stream is 81.9, which lies on the mid water classification region, so the water is considered at fair quality. The resulted WQI shows that 91.6, 92.5, 74.3, 91.6, 75.2 and 62.5 for sites St1, St2, St3, St4, St5 and St6 respectively. Among stations, there was significant variations in water quality index from poor quality to good quality that St5 and St6 in urban part and St3 in rural part of the stream are under the pressure of pollution. While the reason of the low water quality in 5th and 6th stations is based on domestic and industrial wastes, the reason of poorness in 3th station arises from poultry farm wastes poured intensely from chicken farms near the station into the stream in Kavak district. The most effective water quality parameters are pH, electrical conductivity (EC) and total suspended solids (TSS) on the determination of WQI for the present study.

Key words: water quality index, water pollution, Mert Stream, Samsun, Turkey

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Türkiye'deki Mert Irmağı'nın Yüzey Suyu Kalitesini Değerlendirmek için Su Kalite İndeksi Metodunun Uygulanması

Özet

Bu çalışmada, Mert Irmağı'ndaki 6 istasyondan Temmuz 2011 ve Haziran 2012 tarihleri arasında yapılan izleme çalışmasından elde edilen su kalitesi bilgileri değerlendirilmiştir. Bu çalışmada, Mert ırmağının mevcut su kalitesini değerlendirmek için toplanan verilere farklı bir WQI yöntemi (modifiye WQImin) uygulanmıştır. Hesaplanan ortalama WQI değeri 81.9 olup bu değer su sınıflandırma açısından orta-kaliteye karşılık gelmekte ve buda ırmak suyu için çokta kötü olmayan bir kalitede olduğunu göstermektedir. İst1, İst2, İst3, İst4, İst5 ve İst6 için ölçülen WQI değerleri sırasıyla 91.6, 92.5, 74.3, 91.6, 75.2 ve 62.5'dır. İstasyonlar arasındaki su kalite indeksi değerlerinde, düşük kaliteden iyi su kalitesine kadar çeşitlenme vardır. Buna göre ırmağın şehir bölümünde kalan 5. ve 6. istasyonları ile ırmağın kırsal kesiminde kalan 3. istasyonları kirlilik baskısı altındadır. 5. ve 6. istasyonlarda ırmak suyundaki düşük su kalitesinin nedeni evsel ve endüstriyel atıklar olmasına karşın 3. istasyondaki kalite düşüklüğünün nedeni, Kavak ilçesinde istasyonun yakınında bulunan tavuk çiftliklerinden ırmağa dökülen atıklardan kaynaklanmaktadır. Bu çalışmada su kalite indeksini (WQI) belirlemede en etkili su kalitesi parametreleri pH, elektriksel iletkenlik ve toplam askıda katı madde olmuştur.

Anahtar kelimeler: su kalite indeksi, su kirliliği, Mert Irmağı, Samsun, Türkiye

1. Introduction

Water quality is a major problem all over the world due to the general pollution caused by human activities. Water quality indices are an easy application for assessig water quality, controlling water pollution, restoring or improving

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water quality, and assessing the impacts of best management practices in the basin (Quilbe et al., 2006). Water quality index reflects the general water quality conditions in the aquatic ecosystem. For this reason, water quality index are a simple and understandable application for managers and decision makers on the quality and possible uses of wetlands (Bordalo et al., 2001).

Water quality indices have been used in the United States and most European countries since the 1970s. In the literature there are many different water quality index models and comparative studies on best reflecting water quality. All of these indices consist of eight or more water quality parameters such as dissolved oxygen (DO), conductivity, temperature, pH, and total suspended solids. However, monitoring and testing of all 15 parameters used in water quality indices is not very practical and economical. Instead, water quality criteria can be obtained by selecting a few of the most dominant and easily measurable parameters. Therefore, temperature, pH, dissolved oxygen, total suspended solids, and electrical conductivity were selected among the previously mentioned 15 variables. These five variables used in WQImin are the water quality parameters commonly used in drinking water. The parameters except total suspended solids can be measured easily in the field using multiparameter water quality instruments (Akkoyunlu and Akiner, 2012).

Growing population, rapid urbanization, increased economic activity and industrialization have caused reduction and abuse of water resources.

The tributaries of rivers and streams passing through the cities carry pollutant loads in large amount released from industrial, domestic/sewage wastes in urban areas, while pesticides and fertilizers used in agricultural activities in rural areas are reach wetlands through washing with rain. This triggers the eutrophication in the wetlands, which makes freshwater resources unusable. This environmental problems stimulate the eutrophication in the wetlands, which makes freshwater resources unusable (Qadir et al., 2007). These pollutant effluents are discharged to the aquatic environment without purification, resulting in water pollution problems and these polluted waters are no longer used for drinking and agricultural activities (Fent, 2004). Therefore, it is important to monitor water quality levels in river basins to control water pollution (Simeonov et al., 2003) and to interpret changes in water quality (Dixon and Chiswell, 1996; Singh et al., 2004). Spatio-temporal monitoring of stream water quality has been used as one of the most important tools for water quality assessment (Singh et al., 2004; Shrestha and Kazama, 2007).

The objective of this research was to evaluate spatial and seasonal trends in water discharge, nutrients and also to compare data with water quality criteria and with certain quality indices such as water quality index (WQI), identifying the environmental pressures and assessing the impact of the loads to Mert basin. In accordance with this purpose, WQI values station-based for the water in the Mert Stream was created through easily measurable parameters. These results are of great importance to decision-makers and managers for water management who will have a general knowledge of the water quality in wetlands during a specific period of time, instead of attempting to understand complex water quality data. At the same time, this study will provide important information on how well the WQI index reflects the water quality in Mert stream.

2. Materials and methods

1.1. Description of the study area

Mert Stream is located within the border of Samsun Province in the Central Black Sea Region of Turkey (between 41°09'02"–41°17'04" N and 35°48'04"–36°21'50" E). The west of the stream is located by Kızılırmak River and Mert River Basins, the south by Yeşilırmak River Basin and the east by Abdal Creek Basin. Mert stream originates from Karadağ locality, known as Toptepe, located at 1150 m altitude in the Ladik district. In Kavak district, after the stream merges with Karataş Creek, 24 km from the sea and it's the largest tributary, it takes its name which is called the Mert. Supplying the utility water needs of some villages on the route, Mert stream is very important as it constitutes the irrigation resource of fertile lands of the region. Its maximum flow is 750 m^3/s. The width of the stream bed is 50 m. While the depth of the stream decreases to less than 50 cm in summer months, in winter the depth reaches again 4-5 m.

The locations of the stations in this study have been determined as follows in order to represent the whole stream (Figure 1). The features of the sites determined at six sampling areas on the stream are as follows:

1st station (41°09'50″ N, 36°05'59″ E) is located on Çamlıdere creek, which is the side branch of the stream located in Samsun-Kavak district Küçükçukur and Ahurlar Village. The altitude is 820 m and the distance to the Black Sea is 67 km. The coast of the site is covered with stones and pebbles.

2nd station (41°03'38″ N, 35°58'41″ E) is located at the point where the discharge waters of Güven Pond, which is located near the highway of Kavak-Ankara, are poured into the stream with Çamlıdere creek. The altitude is 780 m and the distance to the black sea is 65 km. The coast and ground of the site are covered with stone and mud.

3rd station (41°03'23″ N, 36°06'20″ E) is next to the Germiyan1 highway bridge located in Germiyan Village on the Kavak-Asarcık highway. The altitude is 650 m and the distance to the black sea is 51 km. The water in this section of the stream is extremely turbid due to the fact that the chicken and egg farms located near 300 m discharge their wastes from this section to the stream.

4th station (41°07'13″ N, 36°09'41″ E) was selected from the point where Karataş Creek, which is the largest of the stream, carries the water of the Divanbaşı Pond in Mert Village at Kavak Boğaziçi District to the stream and merges with the Mert Stream. The altitude is 410 m and the distance to the black sea is 35.4 km.

5th station (41° 15'54″ N, 36°20'35″ E) is at the point where Mert stream merges with Yılanlı creek where the pollution is intense due to the landfill area of Samsun province for a while. The altitude is 20 m and the distance to the black sea is 2.3 km.

6th station (41°16'43″ N, 36°21'06″ E) is at the stream mouth part in Canik district where the Mert stream flows into the Black Sea. This site is also located on the Samsun-Ordu highway next to the shopping center of Piazza.

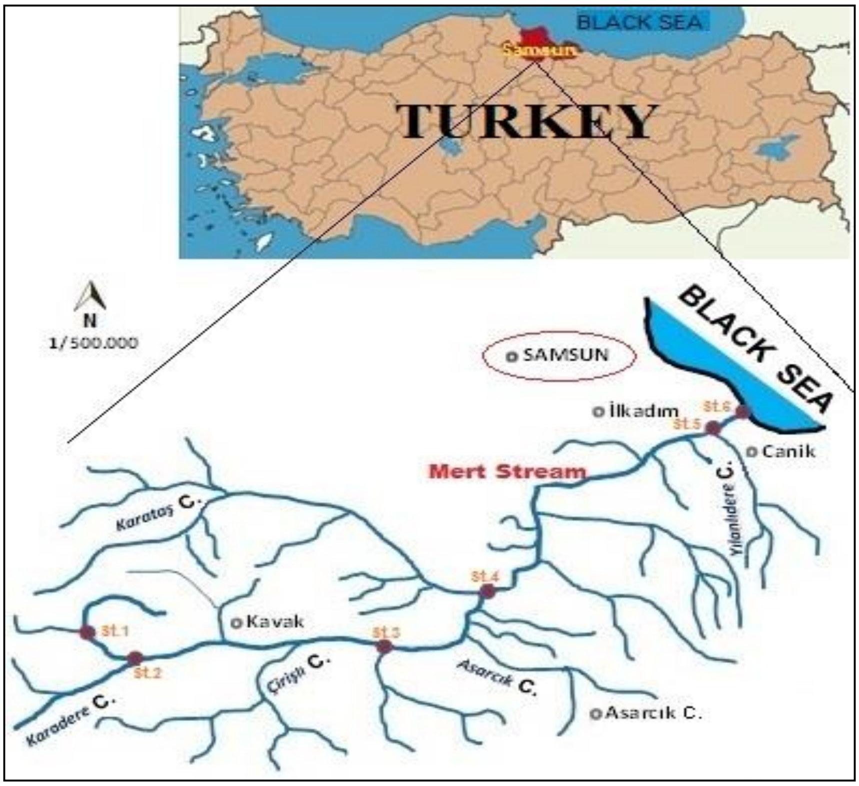

Figure 1. Location and sampling stations of Mert Stream

1.2. Sampling and sample analysis

Water samples were taken seasonally from six sites starting in July 2011 until June 2012. The sampling stations were given in Figure 1. The sampling stations were selected according to the point and non-point pollution load possibilities of the basin mainly from agricultural and minor industrialactivates. Samples were collected at 30 cm depth from the surface. All measurements were carried out in triplicate, and the results were expressed as averages. The measurement at sampling site, Dissolved oxygen, Electric conductivity, pH and water temperature were recorded. The water samples were held in ice boxes and immediately transported to laboratory of Ondokuz Mayıs University for water analysis following common protocols. Electrical conductivity (EC), pH, temperature (T) and dissolved oxygen (DO) were measured locally by field instruments (WTW 340i Multi-Parameter). Gravimetric method was used to determine the total suspended solids in the water. TSS was analyzed according to Standard Methods for the Examination of Water and Wastewater (APHA, 1995).

1.3. Water Quality Index (WQImin)

While WQI is an index using 15 water quality parameters, WQImin developed by Akkoyunlu and Akiner (2012) is a modified index that uses 5 most predominant and easily measurable parameters. A linear relation was observed between WQI and WQImin with R^2 value of 0.84 as seen in the following equation 1. To get the WQI, it is sufficient to calculate WQImin value. To get the WQImin, the Q-value should be determined for each variable and also weighting and normalization factors are assigned to each variable (Table 1). The WQI values that are calculated separately for each variable obtain through the arithmetic weighted sum of the WQImin values. Following calculating the WQImin value, the value of the lake or stream's WQI obtains practically by placing these value in aforecited Eq. (1). Eq. (1) shows nothing but the correlation between WQI and WQImin. Regression fits well since the determination coefficient is sufficiently close to one. Water quality can be ranked as very poor (0–60), poor (61–80), fair (81–90), good (91–95), excellent (96–100), according to the "Modified WQI" scale (Akkoyunlu and Akiner, 2012). The water quality status (WQS) according to WQI is shown in Table 1.

$$WQI = 1.0011\ (WQImin) + 0.5179 \quad (R^2 = 0.8358,\ p<0.000) \quad (Eq.1)$$

Table 1. WQI range, status and possible usage of the water sample (Akkoyunlu and Akiner, 2012)

WQI	Water quality status (WQS)	Possible usage
0–60	Very poor	Proper treatment required before use
61–80	Poor	Irrigation
81–90	Fair	Irrigation and industrial
91–95	Good	Drinking, irrigation and industrial
96–100	Excellent	Drinking, irrigation and industrial

3. Results

1.1. The physicochemical variables of water quality

Seasonal average of physicochemical field measurements of the stream water (2011-2012) was given at Table 2. It was observed that seasonal averages for all parameters in the surface water of Mert Stream.

Table 2. Some physicochemical analysis results of the Mert Stream (2011-2012)

	Parameters	Summer	Autumn	Winter	Spring	*Average*
Station 1	*Temperature (°C)*	18.4	10.8	3.9	13.7	*11.7*
	Dissolved Oxygen (mg/L)	9.4	11.2	13.1	10.4	*11*
	pH (pH unit)	7.9	7.6	8	7.2	*7.7*
	Electrical Conductivity (µs/cm)	1087	923	807	860	*919*
	Total suspended solid (mg/L)	1.6	4.5	1	0.4	*1.9*
Station 2	*Temperature (°C)*	24.9	14.2	4.2	16.5	*15*
	Dissolved Oxygen (mg/L)	8	10.4	13.3	9.9	*10.4*
	pH (pH unit)	7.4	7.8	7.7	7.1	*7.5*
	Electrical Conductivity (µs/cm)	873	743	603	720	*735*
	Total suspended solid (mg/L)	1.6	4.5	1	0.4	*1.9*
Station 3	*Temperature (°C)*	23.3	12.2	5.4	16.3	*14.3*
	Dissolved Oxygen (mg/L)	8.6	11.1	12.6	9.9	*10.6*
	pH (pH unit)	7.4	7.5	8.4	7.5	*7.7*
	Electrical Conductivity (µs/cm)	1270	1130	900	897	*1049*
	Total suspended solid (mg/L)	103.7	81	63.3	71.3	*79.8*
Station 4	*Temperature (°C)*	21.8	10.8	4.2	15.5	*13.1*
	Dissolved Oxygen (mg/L)	8.7	11.3	13	9.9	*10.7*
	pH (pH unit)	7.3	7.9	7.9	7.5	*7.7*
	Electrical Conductivity (µs/cm)	1173	940	763	907	*946*
	Total suspended solid (mg/L)	34.7	18.3	9.7	6.3	*17.2*
Station 5	*Temperature (°C)*	25.4	15	6.1	15.8	*15.6*
	Dissolved Oxygen (mg/L)	8.2	10.3	12.4	9.9	*10.2*
	pH (pH unit)	7.1	7.6	7.4	7.8	*7.5*
	Electrical Conductivity (µs/cm)	1410	1020	723	920	*1018*
	Total suspended solid (mg/L)	123.7	95.3	58.3	73.7	*87.8*
Station 6	*Temperature (°C)*	26	16.5	6.5	15.3	*16.1*
	Dissolved Oxygen (mg/L)	4.4	6.2	8.8	6.8	*6.6*
	pH (pH unit)	6.8	7.5	8	7.5	*7.5*
	Electrical Conductivity (µs/cm)	3067	1867	940	1543	*1854*
	Total suspended solid (mg/L)	153.7	134.3	91.3	88	*116.8*

The temperature values of Mert stream varied between months, seasons, and among measurement stations. The mean water temperature value during one year of monthly measurement is 14.3°C. The lowest value was measured in November 2011 as 1.5°C in 4st station, while the highest value has been observed in 6th station in July 2011 as 27.6°C. Also the seasonal mean temperature values between July 2011 and June 2012 are as follows, respectively; winter 5.1°C, spring 15.5°C, summer 23.3°C, and autumn 13.3°C (Table 2).

The dissolved oxygen amount in Mert stream has varied monthly and seasonally during the study period. The mean value observed during one-year period is 9.9 mg/L, the lowest value is 3.5 mg/L in July 2011 at 6th station, while the highest value has been observed in November 2011 in 4st station as 14 mg/L. As a result of a study conducted for one year in 4 seasons, the mean dissolved oxygen values in winter, spring, summer and autumn seasons have been observed as follows, respectively; 12.2 mg/L, 9.5 mg/L, 7.9 mg/L and 10.1 mg/L (Table 2).

The electrical conductivity (EC) values of Mert stream have varied between months, seasons and among 6 stations. The mean electrical conductivity value of 6 stations where the study has been conducted was found to be 1087 µs/cm. The electrical conductivity values, in parallel with saltiness and temperature values, have decreased in winter months and increased in months where the water temperature has been high. The value in December 2011 in 2st station was 550 µs/cm while it reached to its highest point in July 2012 in 6th station as 3420 µs/cm. Also during one year of measurements between between July 2011 and June 2012, the seasonal mean electrical conductivity values have been found to be 789 µs/cm for winter, 974 µs/cm for spring, 1480 µs/cm for summer and 1104 µs/cm for autumn (Table 2).

The monthly mean pH value of six stations one year-round is 7.6. The highest pH value has been observed in 3th station in December 2011 as 9.2, while the lowest value has been observed in August 2011 in 6st station as 6.4. The mean values in winter, spring, summer and autumn of Mert stream following one-year sampling period are 7.9, 7.4, 7.3 and 7.7, respectively (Table 2).

The total suspended solid (TSS) values of the stream have varied between months, seasons and among four stations. During the one year of measurement, the lowest value has been observed at St1 in Mart 2012 as 0.3 mg/L, while the highest value has been observed at St6 in July 2011 as 164 mg/L and the mean suspended solid matter (TSS) amount has been found to be 50.9 mg/L for six stations in Mert stream. Also the seasonal mean suspended solid matter values during measurements between 2011 and 2012 have been found to be 37.4 mg/L for winter, 40 mg/L for spring, 56.3 mg/L for autumn and 69.8 mg/L for summer.

1.2. The water quality index calculations

In order to assess the present water quality and possible eutrophication risk level of Mert stream, different WQI approaches (modified WQImin) were applied to a data set expressly collected for the present study. Table 3 shows results and evaluations of WQI types for Mert stream. WQI values of the six stations are not in good agreement. While St1, St2 and St4 indicate good environmental conditions in terms of water quality, St3, St5 and St6 infer low water quality. The average WQI value of the stream is 82, which lies on the mid water classification region, so the stream water is considered at fair quality in terms of average values. According to WQI values, Water Pollution Map of Mert Stream is also given in the Figure 2.

Table 3. Results and Evaluations of Water Quality Index for Mert Stream

Water quality index			
Sampling stations	WQImin	WQI	*Station-based evaluation*
1	91	92	*good*
2	92	93	*good*
3	74	74	*poor*
4	91	92	*good*
5	75	75	*poor*
6	62	63	*poor*
Average	*81*	*82*	*fair*

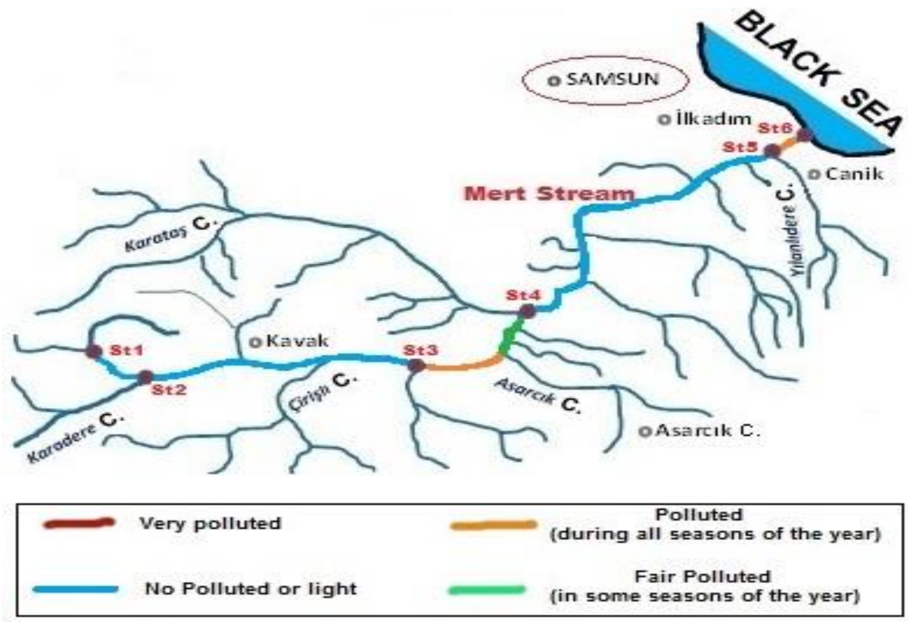

Figure 2. According to WQI values, Water Pollution Map of Mert Stream

4. Conclusions and discussion

In this study, a modified water quality index model (WQImin) was applied, allowing spatial and temporal variations to be assessed through only a few simple parameters. Temperature, pH, dissolved oxygen, conductivity and total suspended solids are the most important water quality indicators among all 15 parameters. WQImin is modified index which is developed considering aforementioned five important water quality parameters. Dissolved oxygen is a key factor for aquatic life. Temperature is also an important parameter from the aspect of aquatic life as it alters the viscosity and density of water and affects the speed of biochemical reactions and solubility of gases. The pH showing the balance between acid and bases in water is a basic parameter which should be assessed in any study about water chemistry and pollution. Conductivity should indicate the presence of salts, mineral acids, or similar contaminants discharged to the stream. TSS (total suspended solids) is associated with suspended material and also with bacteriological contamination. It should also be noted that total suspended solids (TSS) gives a measure of the turbidity of the water and eutrophication is apparent as increased turbidity. Considering the high concentrations of TSS, it was decided to assign relatively high weight for it. The aggregation of suspended solid matters leads the amount of dissolved oxygen to decrease and eutrophication to occur. Furthermore, these five parameters can be easily evaluated. So far, WQImin gives reasonable results for trend analysis at a lower cost. WQImin value is also 81 indicating fair quality (Table 3).

The current study was conducted to measure water quality of the stream which is the main irrigation water source of the Kavak district. According to the results we can state that Water Quality Index (WQImin) was useful tool to obtain the accurate decision and assessing water quality. In addition, this index model also provided a comparative assessment of the water quality for different sampling sites and different temporal samplings. During the study the average values of WQI for six stations (St1, St2, St3, St4, St5, St6) were categorized as poor water quality for the human use (92, 93, 74, 92, 75, 63 respectively) from 2011 to 2012. Generally, there was significant temporal variations in water quality index among poor quality to good quality. The computed average WQI (91.9) for stream points St1, St2 and St4 indicate fairly good quality of water while the average WQI (70.6) for the stream points St3, St5 and St6 indicate poor quality of water due to domestic and industrial discharges at St5, St6 and poultry farm wastes poured intensely from chicken farms near the 3rd station into the stream. This is not surprising as St1, St2 and St4 are upstream, and at the edge of the part of the stream that is unaffected by direct runoff from the waste dump. In contrast, St5 and St6 are located at the urban part of the stream that receives direct runoff from the waste fill. Especially the WQI value of 6th station (62.5) to be too close which is the lowest water quality means that the water in the urban part of the stream can be used after a serious treatment. Initially, it has been a surprise for us that 3th station has low water quality despite situating at the upper part of the stream which is far from city impact. But after seeing that there were chicken farms near the station, it was not surprising that the water quality in the third station was low. The index results coincided with water pollution map of Mert stream in Figure 2. The higher TSS values were noticed in St6 station, that may be mainly related to the domestic and industrial wastes discharged from industrial facilities and residential area in İlkadım and Canik district. pH, EC and TSS were being the most effective parameters in the low water quality index values at the 3rd, 5th and 6th stations, and also low of dissolved oxygen became effective at 6th station which had the lowest water quality of the stream.

During the study which has been conducted about the monthly and seasonal changes of Mert stream's water quality characteristics between July 2011 and June 2012 in 6 stations, the water samples obtained from stations were evaluated with regard to water quality and aquaculture through WQI method. As a result of this study, it was seen that there is not any important problem from the aspect of water pollution in the upstream except 3th station. If the agricultural activities and animal breeding facilities in the fields near the stream in Kavak district increase widely, the leakage water from fields through surface waters and wastes from animal breeding facilities near Mert stream may pollute in time the upper part of the stream. Therefore, it must be obligatory to built recycling facilities for wastes in the chicken and bovine farms established in the region and the use of organic fertilizers in agricultural activities should be encouraged especially in villages where the stream passes through. Even if it seems that there is no problem in terms of the average values of WQI, the urban part of the stream is under the pressure of pollution. It is the best evidence that massive fish deaths due to lack of oxygen and leakage water have been observed at times. So, the regulations about the protection of rivers should be carefully implemented, and the ecological disruption should be prevented. Also in order to protect Mert stream from pollution, to improve the water quality, to protect the natural fish stocks, to sustain the natural ecological balance of other aquatic organisms, and because of its importance from the aspect of irrigation of near agricultural fields in upstream, the stream should be periodically monitored.

The following suggestions can be made in order to increase the surface water quality in the Mert stream. (A) Point and nonpoint source pollution arising from chicken farms at 3th station in Kavak district should be prevented and solid and liquid wastes from the farms should be either disposed or utilized as fertilizer or biogas. (B) In order to enhance the water quality of the stream at St5 and St6, the wastewater and seepage water arrived to the stream from the settlements and industrial facilities in İlkadım and Canik districts should be prevent.

As a results, this study has shown that WQImin based on five parameters is a simple, yet a understandable tool, that can be used to provide a preliminary information about the level of pollution in surface water caused by urban and industrial wastes in wetlands. Çiçek et al. (2017) said that the overall assessment of an aquatic ecosystem is possible only by revealing all of the physical, chemical and biological data of that ecosystem. The fact that the results of index support the pollution detection study using algal organisms made earlier by Bektaş (2016) in the Mert stream indicate that WQI model can be used together with algal organisms in rapid evaluation of water quality in wetlands..

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