



Research Paper

The use of water quality index method to determine the quality of surface water in the Mert Stream (Samsun, Turkey)

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ABSTRACT

In this study, the water quality data obtained from six (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 WQI_{min}) 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 the stations, there was significant variations in water quality index from poor quality to good quality indicating that St5 and St6 in urban part and St3 in rural part of the stream are under the pressure of pollution. The reason for the low water quality in 5th and 6th stations is based on domestic and industrial wastes; the reason for poorness in the 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.

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INTRODUCTION

Water quality is a major concern all around the world, as water uses are threatened by generalized contamination resulting from human activities. The use of water quality indices (WQI) is a simple practice for assessing the water quality status, studying the controlling processes of water pollution, defining and applying environmental objectives to restore or improve water quality, assessing the effects of best management practices in a watershed and calibrating hydraulically and water quality models (Quilbe et al., 2006).

A general water quality index (WQI) can be used to indicate the overall water quality conditions. It assigns a number to a body of water to indicate its quality. It consists of water quality variables, such as dissolved oxygen (DO), conductivity, turbidity, total phosphorus and fecal coliform, each of which has specific impacts to uses (Said et al., 2004). So, water quality indices are intended to provide a simple and understandable tool for managers and decision makers on the quality and possible uses of a given water

body. The first WQI was developed in the United States and applied in Europe since 1970s, initially in the United Kingdom. The WQI approach has many variations in the literature and comparative evaluations have been undertaken (Bordalo et al., 2001).

There are several water quality indices that have been developed to evaluate water quality in United States and in Canada. All of these indices have eight or more water quality variables. However, tracking and testing too many parameters is not very practical and economical. Quality criteria obtained by using a few of the most predominant or easily measurable parameters also can be reported. For this purpose, temperature, pH, dissolved oxygen, total suspended solids and electrical conductivity were selected among the previously mentioned 15 parameters and new WQI referred to as WQI_{min}. While selecting these five parameters to use in our developed WQI_{min}, common water quality parameters important in drinking water were

mainly concentrated. Practicality of measurement was the key factor behind our decision. Specified parameters for developing WQImin can be measured easily using multiparameter water quality sondes and compact handheld instruments. Several types of these equipments are accredited and widely used throughout the world and have reasonable prices for an institute. By using these equipments, the aforementioned five parameters of WQImin do not need any sampling, or transportation of samples from research field to the laboratory for an extra testing and using additional chemicals and equipments is not necessary.

Growing population, increased economic activity and industrialization have resulted in an increased water demand. In addition, rapid urbanization is changing the patterns of consumption. This has caused a severe misuse of water resources. Rivers, streams and their tributaries passing through the cities are receiving large amount of contaminants released from industrial, domestic/sewage and agricultural effluents, which has resulted in an increasing degradation of freshwater ecosystem mainly by eutrophication (Qadir et al., 2007). Indiscriminate discharge of these effluents (either from industrial, municipal, or agricultural activities) containing toxic substances into aquatic environment creates problems of water pollution rendering water no longer fit for drinking, agriculture and aquatic life (Fent, 2004; Qadir et al., 2007). Therefore, it is important to control water pollution, monitor water quality in stream basin (Simeonov et al., 2003) and interpret temporal and spatial variations in water quality (Dixon and Chiswell, 1996; Singh et al., 2004). Spatiotemporal 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 objectives of this research were 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. Human activity has an enormous influence on the global cycling of nutrients due to extensive use of inorganic fertilizers and this direct impact is reflected in Mert Stream water quality as well. As such, environmental quality indicators and indices are a powerful tool for processing, analyzing and conveying raw environmental information to decision-makers and managers.

MATERIALS AND METHODS

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" to 41°17'04" N and 35°48'04" to 36°21'50" E). The west of the stream is located by Kızılırmak River and Mert River Basins, the south by Yeşilirmak River Basin and the east by Abdal Çayı Basin. Mert stream originates from Karadağ locality, known as Toptepe, located at 1,150 m altitude in the Ladik district. In Kavak district, after the stream merges with Karataş Creek, 24 km from the sea and it is the largest tributary and 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 m³/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 4 to 5 m. The alluvium thickness of the Mert stream ranges between 10 to 40 m. The alluvium is usually composed of gravel, sandy coarse gravel, blocky gravel and clay layers (Bakan and Şenel, 2000).

The locations of the stations in this study were determined as follows in order to represent the whole stream; 1st station (41°09'50" N, 36°05'59" E) is a location between Küçükçukur and Ahurlar villages which is 67 km from the Black Sea, 2nd station (41°03'38" N, 35°58'41" E) is at the point where Mert stream merges with Çamlıdere creek, 3rd station (41°03'23" N, 36°06'20" E) is in Germiyan village and 51 km distance to the sea, 4th station (41°07'13" N, 36°09'41" E) is in Mert village, while the 5th station (41°15'54" N, 36°20'35" E) is at the point where Mert stream merges with Yılanlı creek in Canik district (2.3 km from the Black Sea) and 6th station (41°16'43" N, 36°21'06" E) is in the stream mouth part where the Mert stream flows into the Black Sea (Figure 1).

Sampling and sample analysis

Water samples were taken monthly from six sites starting from July, 2011 to June, 2012. Figure 1 shows the sampling stations. The sampling stations were selected according to the point and non-point pollution load possibilities of the basin mainly from agricultural and minor industrial activities. Samples were collected at 30 cm depth from the surface. All measurements were carried out in triplicate and the results expressed as averages. The measurement at sampling site, dissolved oxygen (DO), electrical conductivity (EC), 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, while TSS was analyzed according to Standard Methods for the Examination of Water and Wastewater (Anonymous, 1995).

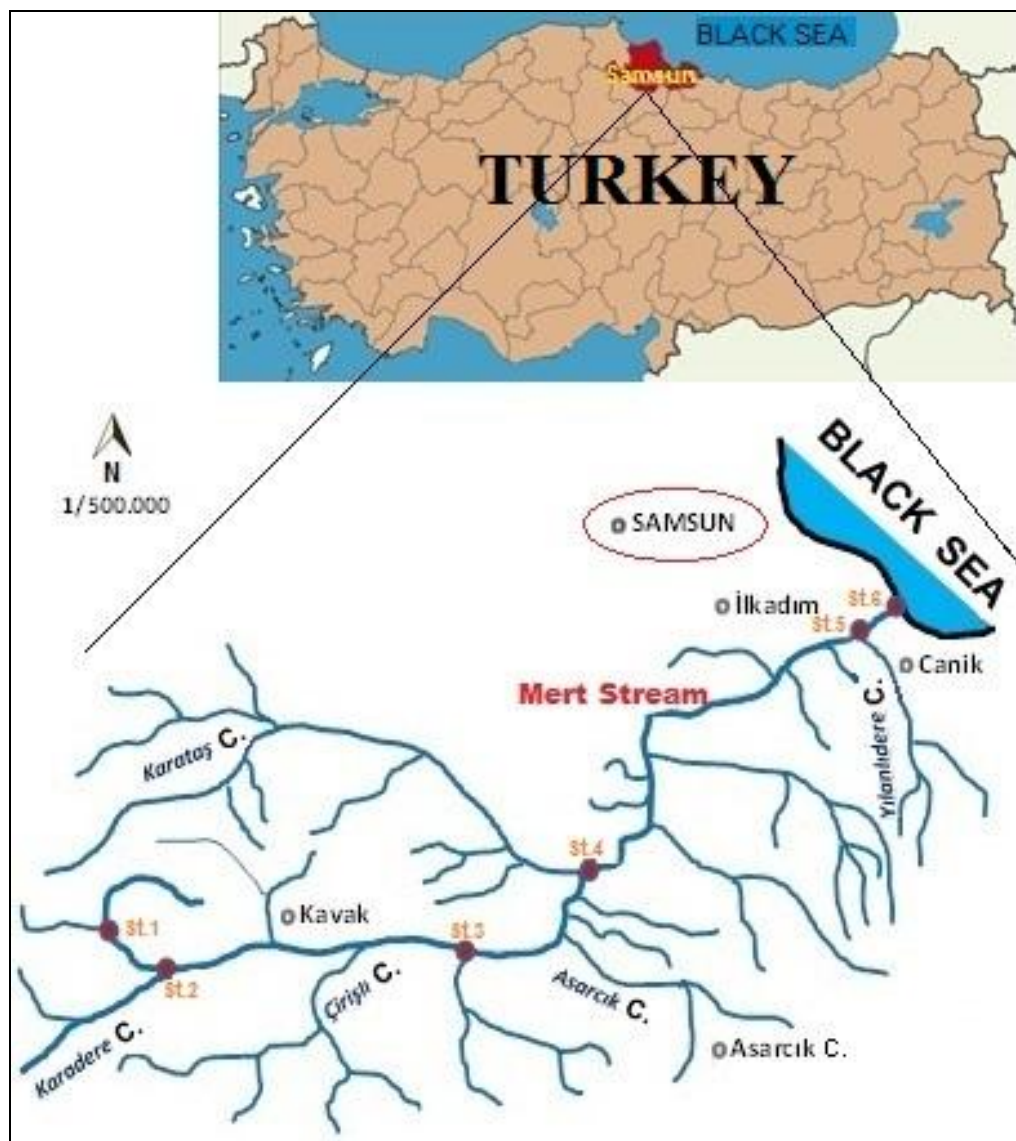


Figure 1: Location and sampling stations of Mert Stream.

Water quality index (WQI_{min})

WQI is the modified index that uses 15 chemistry parameters and WQI_{min} is another modified index that is developed considering the 5 most predominant and easily measurable parameters. Linear relation was observed between WQI and WQI_{min}. To get the WQI, it is sufficient to calculate WQI_{min} value. To get the WQI_{min}, the Q-value should be determined for each variable and weighting and normalization factors assigned to each variable (Table 1). The WQI values are calculated separately for each variable obtained through the arithmetic weighted sum of the WQI_{min} values. Following calculating the WQI_{min} value, the value of the lake or stream's WQI is obtained practically by placing these value in the aforementioned Equation 1. Equation 1 shows nothing but the correlation between WQI

and WQI_{min}. 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). Table 1 shows the water quality status (WQS) according to WQI.

$$\text{WQI} = 1.0011 (\text{WQI}_{\min}) + 0.5179 \quad (R^2 = 0.8358, p < 0.000) \quad (1)$$

RESULTS

The physicochemical variables of water quality

Table 2 shows the seasonal average of physicochemical

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

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

field measurements of the stream water (2011 to 2012). Seasonal averages for all parameters in the surface water of Mert Stream were observed.

The temperature values of Mert stream varied between months, seasons, and among measurement stations. The mean water temperature value during one year of monthly

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

measurement is 14.3°C. The lowest value was measured in November, 2011 as 1.5°C in 4th station, while the highest value was observed in the 6th station in July, 2011 as 27.6°C. In addition, the seasonal mean temperature values between July, 2011 and June, 2012 are: 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 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 the 6th station, while the highest value has been observed in November, 2011 in the 4th 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 were observed as: 12.2, 9.5, 7.9 and 10.1 mg/L, respectively (Table 2).

The electrical conductivity (EC) values of Mert stream varied between months, seasons and among 6 stations. The mean electrical conductivity value of 6 stations where the study was conducted was found to be 1087 µs/cm. The electrical conductivity values, in parallel with saltiness and temperature values decreased in winter months and increased in months where the water temperature was high. The value in December, 2011 in the 2nd station was 550 µs/cm while it reached to its highest point in July, 2012 in the 6th station as 3,420 µs/cm. Also during one year of measurements between July, 2011 and June, 2012, the seasonal mean electrical conductivity values were 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 was observed in the 3rd station in December, 2011 as 9.2, while the lowest value was observed in August, 2011 in the 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 Tersakan stream varied between months, seasons and among four stations. During the one year of measurement, the lowest value was observed at St1 in Mert 2012 as 0.3 mg/L, while the highest value was observed at St6 in July, 2011 as 164

mg/L and the mean suspended solid matter (TSS) amount 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 were 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.

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, hence, the stream water is considered at fair quality in terms of average values. Figure 2 shows water pollution map of Mert Stream according to WQI values.

DISCUSSION

Looking for a way to evaluate the changes in water quality due to the combined effect of many parameters, we decided to calculate WQI. Since the analytical cost involved could be a limiting factor for water quality assessments in developing countries with scarce budgets for environmental studies, it should be necessary to use a WQI which allows the evaluation of spatial and temporal variations measuring 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 the 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

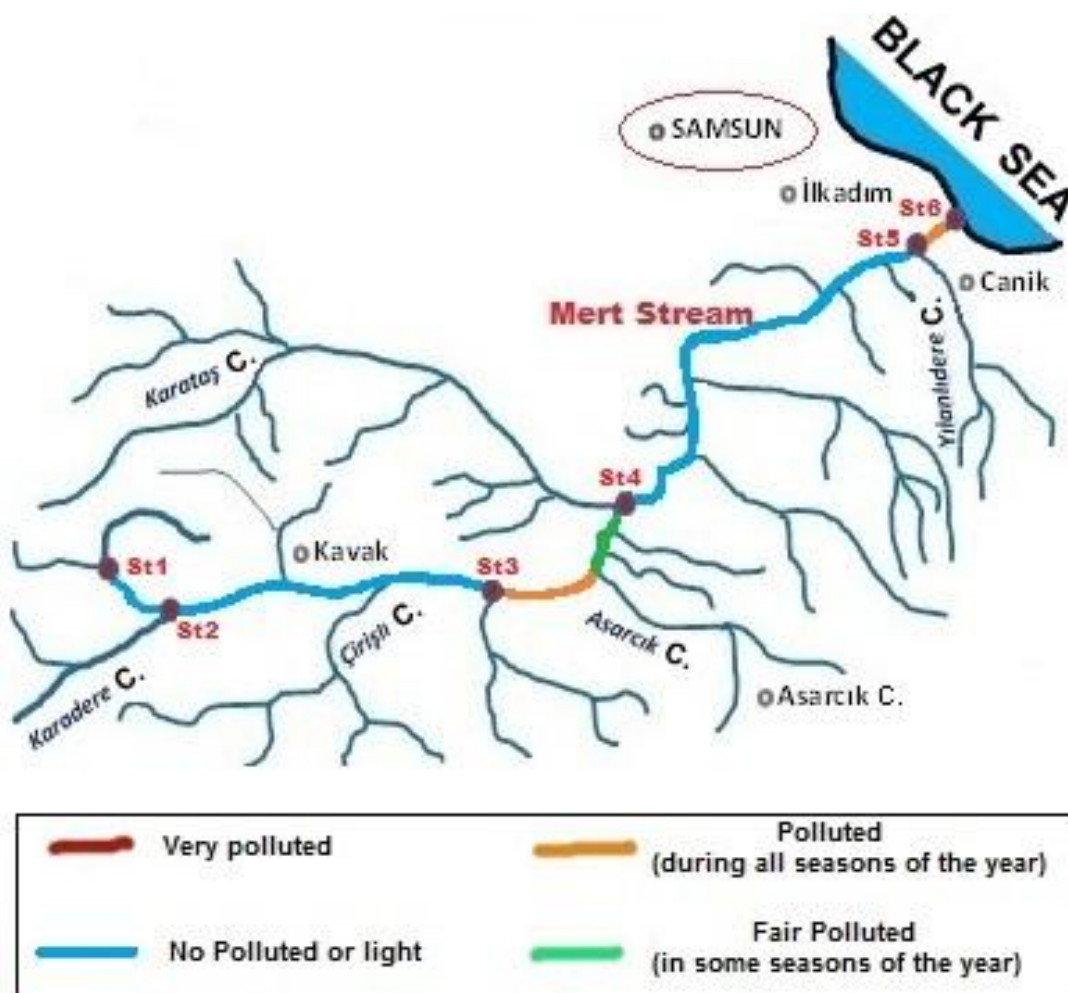


Figure 2: Water Pollution Map of Mert Stream according to WQI values.

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 on 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 causes a decrease in the amount of dissolved oxygen thereby resulting in eutrophication. 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 a useful tool in obtaining the right decision and evaluating water quality. This technique seems to be more systematic and offers 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 and St6) were categorized as poor water quality for human use (92, 93, 74, 92, 75 and 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 the edge of the part of the stream is unaffected by direct run-off from the waste dump. In

contrast, St5 and St6 are located at the urban part of the stream that receives direct run-off from the waste fill. Especially, the WQI value of the 6th station (62.5) had the lowest water quality, indicating 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 the 3rd station has low water quality despite situating at the upper part of the stream which is far from city impact. But after observing that there were chicken farms near to 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 low of dissolved oxygen became effective at the 6th station which had the lowest water quality of the stream.

During the study, which was conducted to evaluate 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 the stations were evaluated with regards to water quality and aquaculture using WQI method. As a result of this study, it was seen that there is not any important problem regarding water pollution in the upstream except the 3rd 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. Hence, the regulations about the protection of rivers should be carefully implemented and the ecological disruption 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.

CONCLUSION

The following suggestions can be made in order to increase the surface water quality in Mert stream:

- (1) Point and non-point source pollution arising from chicken farms at 3rd 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;
- (2) In order to enhance the water quality of the stream at St5 and St6, the wastewater and seepage water that arrived the stream from the settlements and industrial facilities in İlkadım and Canik districts should be prevented.

As a result, this study has shown that WQImin is a powerful, yet, a simple tool that can be used to accurately determine the impact of urban and industrial waste on the immediate surface water. 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 the evaluation of waters in the future.

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