ASSESSMENT OF THE SURFACE WATER QUALITY IN THE KUCUK MENDERES RIVER, TÜRKİYE

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Abstract. The Kucuk Menderes River is one of the important rivers of the Aegean Region in Türkiye. The river carries agricultural pollution and domestic and industrial wastewater to the Aegean Sea. Therefore, the aim of this study is to determine the parameters of pollution in the Kucuk Menderes River. The parameters of pH, temperature, dissolved oxygen, conductivity, salinity, turbidity, phosphate, ammonium nitrogen, nitrite, nitrate, boron, total coliform and fecal coliform were determined. The average values of these parameters were the followings: pH 9.27, temperature 19.5 °C, dissolved oxygen 4.92 mg/L, conductivity 2695 µs/cm, salinity 0.4‰, turbidity 177 mg/L, phosphate 0.17 mg/L, ammonium nitrogen 0.43 mg/L, nitrite nitrogen 0.09 mg/L, nitrate nitrogen 1.73 mg/L, boron 1 mg/L. The values were compared with the criteria values specified in the regulations and those in other studies.
Keywords: *physico-chemical parameters, phosphate, nitrogen, boron, pollution*

Introduction

If water is to be used for a specific purpose, the water must have quality properties suitable for that purpose. First of all, problems causing water pollution should be determined. Water quality should be monitored and evaluated in order to improve the polluted water resources for various reasons and to protect the natural resources in a way that prevents pollution problems (Dincer, 2014).

Water quality affects the productivity, abundance and physiological conditions of living species in the water source. Studies on deterioration of water quality for various reasons, nutrient element dynamics in rivers and water quality become more important every day (Tepe and Boyd, 2002).

Pollutant sources that affect water quality and arise with various activities have point or nonpoint character. Point pollutants can be prevented from posing a threat to the basin by being treated after their formation. In contrast, nonpoint/diffuse pollutants are difficult to control once formed. Therefore, it is necessary to take measures to reduce pollution at source for nonpoint pollutants. For this purpose, it is necessary to determine the nonpoint sources of pollution and loads for the sustainable use of water resources in the basins, and to make suggestions to reduce the pollution loads in the future (Anonymous, 2013).

Kucuk Menderes Basin is between Gediz and Büyük Menderes basins in the western part of Turkey. The basin area is approximately 702.931 hectares. The Kucuk Menderes River rises from Bozdağ and flows into the Aegean Sea. In the alluvial plain formed by

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the Kucuk Menderes River, there are Akgöl, Gebekirse Lake and large swamps. This river creates various wetland ecosystems in the alluvial plain it forms. This region, which is a wetland, is also one of the important bird sanctuary areas of our country (Anonymous, 2014).

There are many studies on the Kucuk Menderes River. In the studies conducted by Egemen et al. (2005), Gundogdu and Ozkan (2006), Balık et al. (2006), water quality classes in the river were determined. A study of water potential, water basins and water pollution in Turkey also found pollution levels of the Kucuk Menderes River (Akın and Akın, 2007). A study conducted by the Environment Institute of The Scientific and Technological Research Council of Turkey, Marmara Research Center identified the category of pollution of the Kucuk Menderes River (Anonymous, 2013). The water quality of the river was determined in the Kucuk Menderes Basin Water Quality Monitoring Report (Anonymous, 2014). In the study conducted by the Environmental Protection Commission of the Governorship of İzmir, it was stated that the pollution in the river was at a high level (Tomar, 2009). A study was conducted to investigate organic chlorinated heavy metals and pesticides in the surface water of the Kucuk Menderes River (Turgut, 2003). Studies were conducted to evaluate the water quality of the river according to macro invertebrates and investigate the distribution of benthic Diatom (Fitobentos) composition (Solak et al., 2018).

The Kucuk Menderes River carries the domestic and industrial wastewater discharged from the rapidly developing settlements to the Aegean Sea, as well as the agricultural pollution caused by pesticides and chemical fertilizers used incorrectly in intensive agricultural activities. Pollution threatens sustainable agriculture, environment and human health by negatively affecting the river ecosystem and basin productivity. In this study, therefore, it is aimed to determine the sources of pollution in the Kucuk Menderes River and to present solutions for taking necessary precautions.

Materials and methods

The river water samples were collected monthly from 5 stations between November 2017 and October 2018. The stations from which water samples taken are presented in *Figure 1* and *Table 1* includes the coordinates of the stations.

Table 1. *Coordinates of stations*

Station No	Station name	Coordinates	
1	Belevi	38°01’27.56”N	27°26’26.57”E
2	Zeytinkoy Bridge	37°58’36.07”N	27°21’10.95”E
3	Akgol & Kucuk Menderes junction	37°58’24.09”N	27°18’29.32”E
4	Selcuk-Ozdere Bridge	37°57’46.31”N	27°17’02.26”E
5	Pamucak	37°57’33.55”N	27°15’48.75”E

The parameters of pH, dissolved oxygen, temperature, conductivity, turbidity and salinity were measured at sampling stations by water quality checker [Water Quality Checker™ (DKK-TOA WQC 24)]. Phosphate, ammonium, nitrite, nitrate and boron parameters were determined by spectrophotometric methods in our research laboratory.

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The absorbance of the samples was determined using Jasco UV – VIS 530 Spectrophotometer.

The amount of phosphate is determined by measuring the phosphomolybdic acid formed as a result of the reaction of ammonium molybdate, ascorbic acid and potassium antimony tartrate in spectrophotometer (Parsons et al., 1984).

The amounts of ammonium, nitrite and nitrate nitrogen were determined using the photometric method with spectrophotometer (Strickland and Parsons, 1972).

The amount of boron is found by measuring the colored compound formed by boron with carmine, a specific reagent, in a spectrophotometer (Hatcher and Wilcox, 1950; Anonymous, 2005).

For statistical analysis, Graphpad Prism for Windows Package statistical program was used. Significant differences between stations were determined by analysis of variance (One-Way ANOVA). Tukey test was used to determine between which stations there were significant differences.

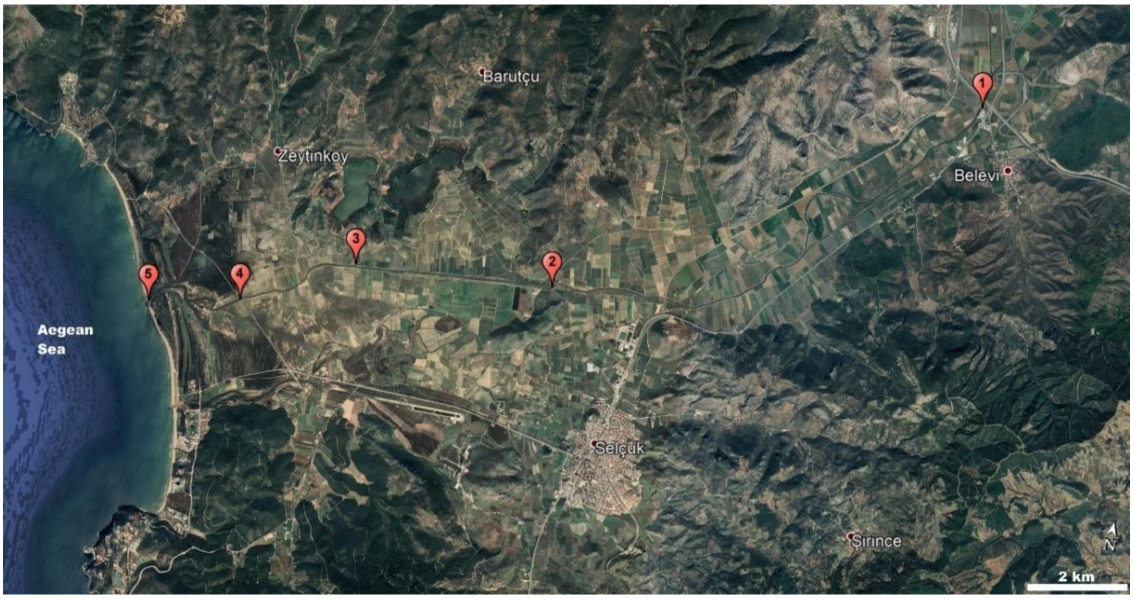

Figure 1. *The sample stations*

Results

The pH, temperature, dissolved oxygen, conductivity, salinity, turbidity, phosphate, ammonium nitrogen, nitrite nitrogen, nitrate nitrogen, boron values are shown on *Figures 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12.* The monthly average values of water quality parameters according to stations are clearly visible in the graphs.

Average pH 9.27, temperature 19.5°C, dissolved oxygen 4.92 mg/L, conductivity 2695 µs/cm, salinity ‰ 0.4, turbidity 177 mg/L, phosphate 0.17 mg/L, ammonium nitrogen 0.43 mg/L, nitrite nitrogen 0.09 mg/L, nitrate nitrogen 1.73 mg/L, boron 1 mg/L were found in river water samples (*Tables 2* and *3*).

The obtained parameters are compared with the Criteria for Water Pollution Control Regulation (Official Gazette, 2004). The river water, in terms of ammonium nitrogen parameter II. quality (less contaminated water), in terms of dissolved oxygen, phosphate and boron parameters III. quality (polluted water), in terms of pH and nitrite parameters IV. quality (highly contaminated water) in water class were detected (*Table 2*).

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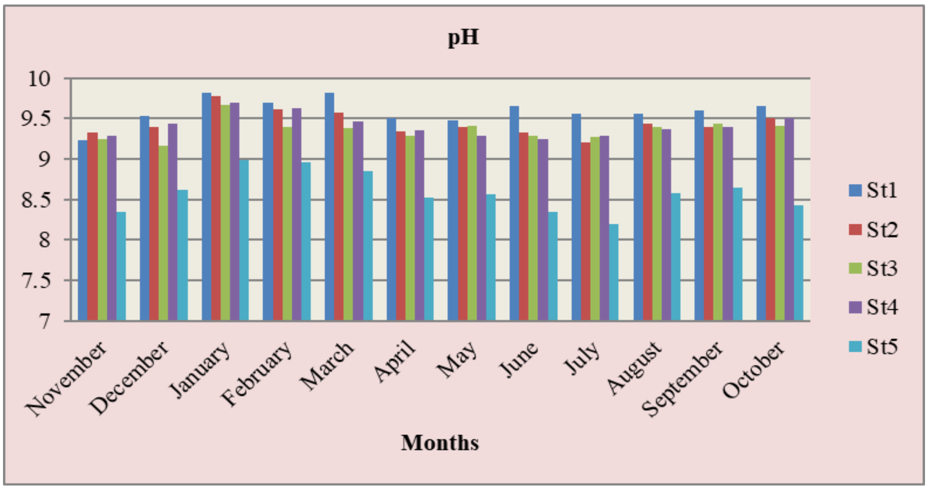

Figure 2. *Monthly average graph of pH values by stations*

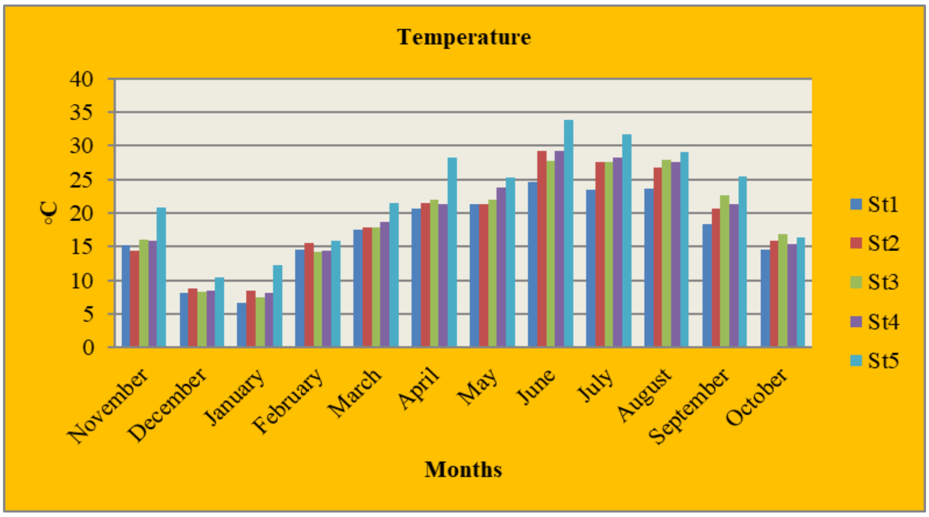

Figure 3. *Monthly average graph of temperature values by stations*

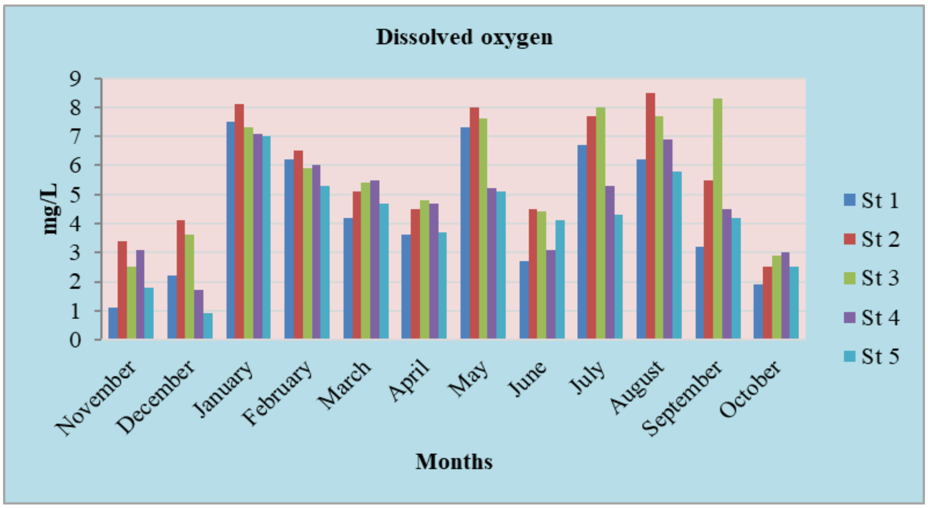

Figure 4. *Monthly average graph of dissolved oxygen values by stations*

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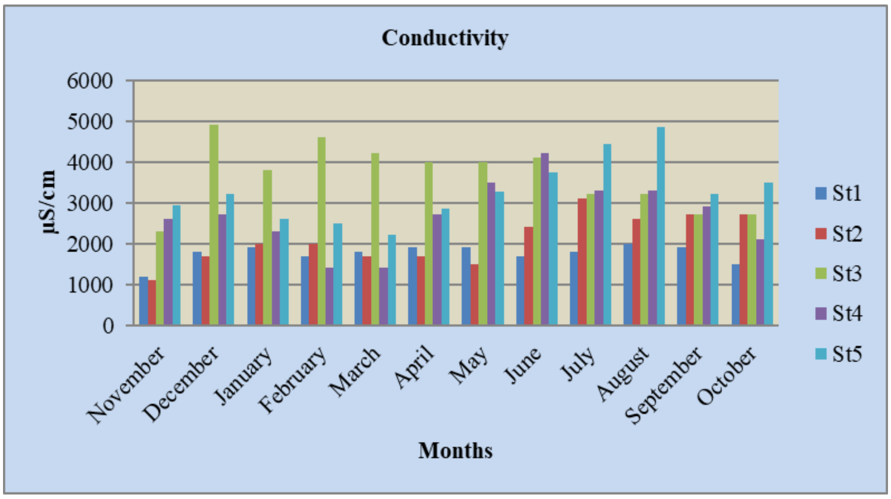

Figure 5. *Monthly average graph of conductivity values by stations*

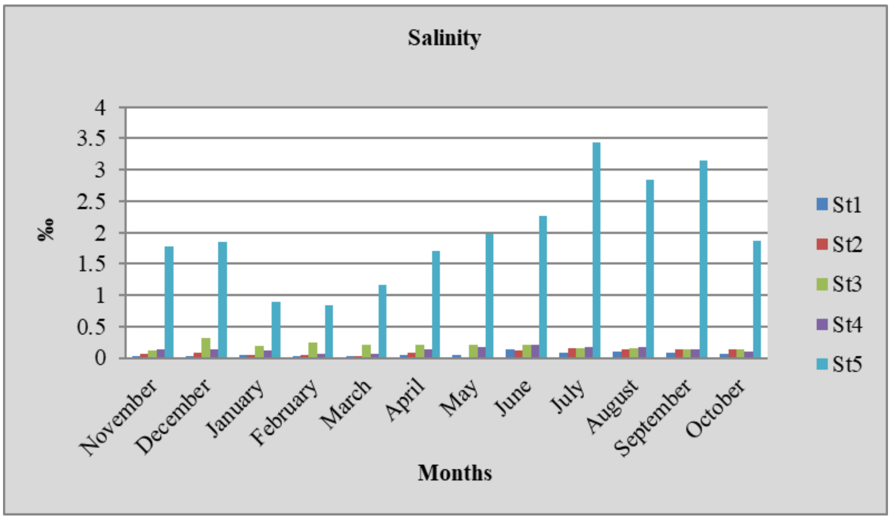

Figure 6. *Monthly average graph of salinity values by stations*

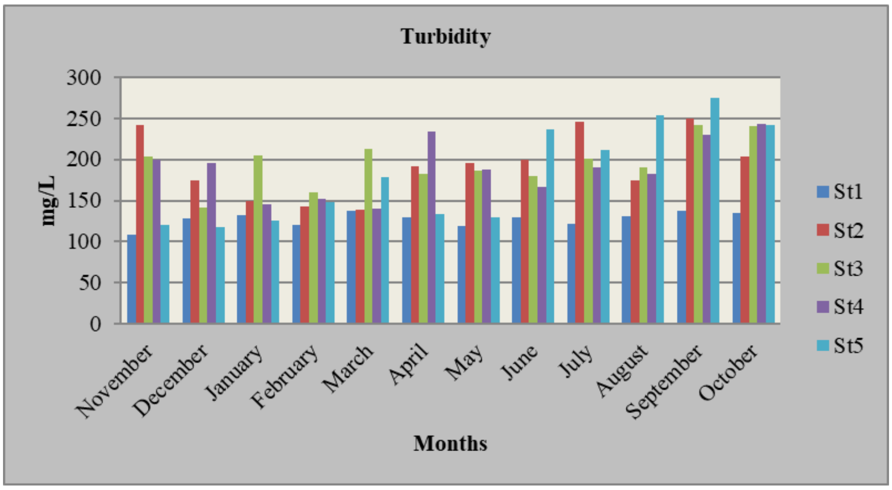

Figure 7. *Monthly average graph of turbidity values by stations*

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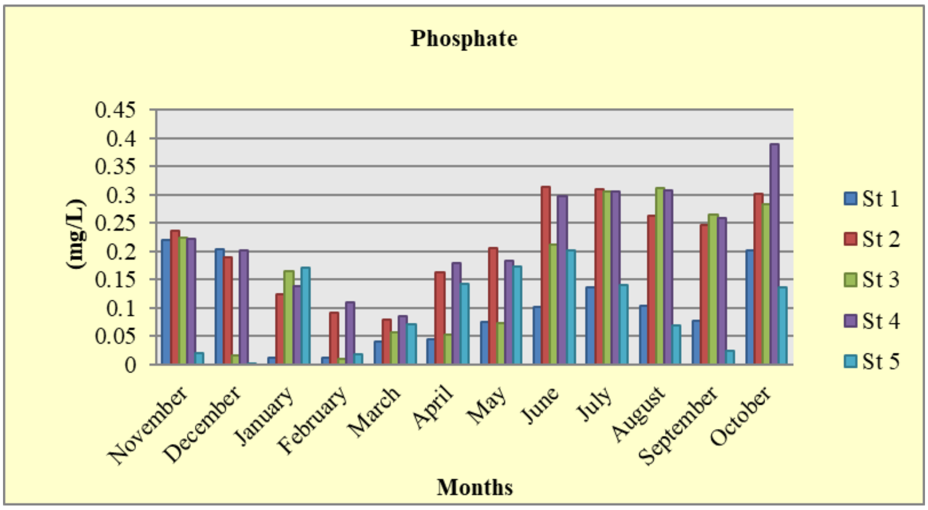

Figure 8. *Monthly average graph of phosphate concentrations by stations*

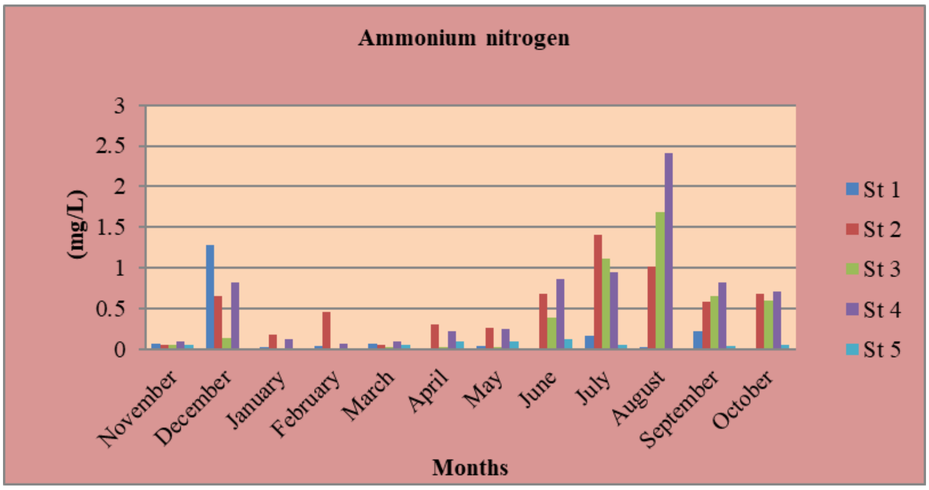

Figure 9. *Monthly average graph of ammonium nitrogen concentrations by stations*

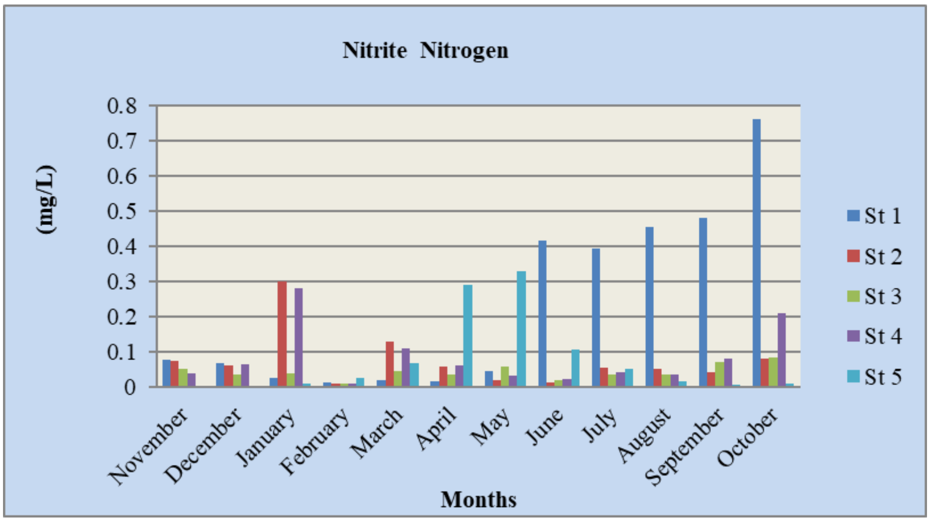

Figure 10. *Monthly average graph of nitrite nitrogen concentrations by stations*

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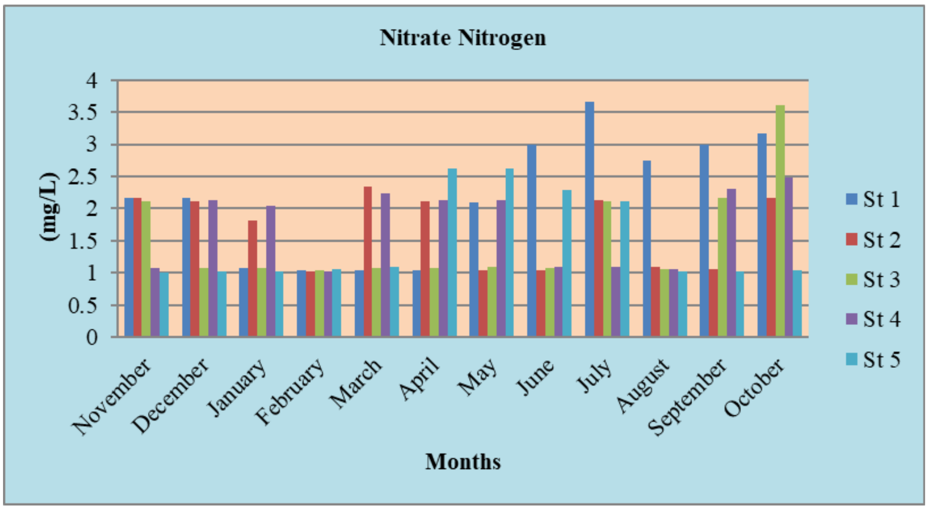

Figure 11. *Monthly average graph of nitrate nitrogen concentrations by stations*

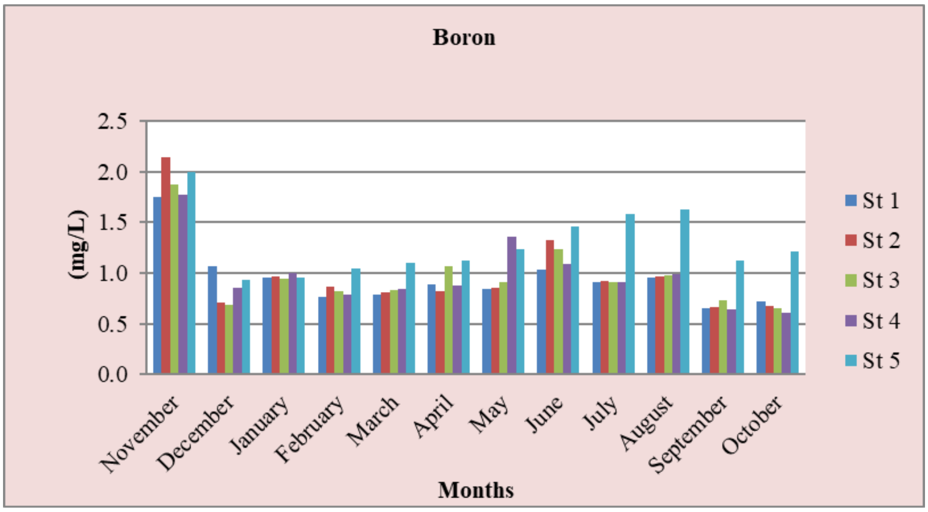

Figure 12. *Monthly average graph of boron concentrations by stations*

Table 2. *Comparison with quality criteria (Water Pollution Control Regulation) (Official Gazette, 2004)*

Parameters of water quality	**Water quality classes**				**This study**
	I	**II**	**III**	**IV**	
Temperature (°C)	25	25	30	> 30	19.5
pH	6.5-8.5	6.5-8.5	6.0-9.0	6.0-9.0 except	**9.27**
Dissolved oxygen (mg/L)	8	6	3	< 3	**4.92**
Total dissolved substance (mg/L)	500	1500	5000	> 5000	177
Total phosphorus (mg P/L)	0.02	0.16	0.65	> 0.65	**0.17**
Boron (mg B/L)	1	1	1	> 1	**1**
Ammonium nitrogen (mg/L)	0.2	1	2	> 2	**0.43**
Nitrite (mg/L)	0.002	0.01	0.05	> 0.05	**0.09**
Nitrate (mg/L)	5	10	20	> 20	1.73

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The obtained values are compared with Criteria for Above Ground Water Quality Regulation (Official Gazette, 2015). The river water, in terms of ammonium nitrogen parameter II. quality (less contaminated water), in terms of dissolved oxygen, phosphate, conductivity parameters III. quality (polluted water), in terms of pH parameter IV. quality (highly contaminated water) in water class were detected (*Table 3*).

Table 3. *Comparison with quality criteria (Above Ground Water Quality Regulation) (Official Gazette, 2015)*

Parameters of water quality	**Water quality classes**				**This study**
	I	**II**	**III**	**IV**	
pH	09-Jun	09-Jun	09-Jun	09-Jun	**9.27**
Dissolved oxygen (mg/L)	> 8	6	3	< 3	**4.92**
Conductivity (µs/cm)	< 400	1000	3000	> 3000	**2695**
Ortho-phosphate phosphorus (mg/L)	< 0.05	0.16	0.65	> 0.65	**0.17**
Ammonium nitrogen (mg/L)	< 0.2	1	2	> 2	**0.43**
Nitrate (mg/L)	< 3	10	20	> 20	1.73

One-way ANOVA variance analysis was carried out to determine whether the amounts of pH, temperature, dissolved oxygen, conductivity, salinity, turbidity, phosphate, ammonium nitrogen, nitrite nitrogen, nitrate nitrogen and boron showed significant difference among stations. As a result of the “One-way ANOVA” test, the difference in pH, salinity and phosphate amounts among the stations was significant ($p < 0.05$) and the difference of the other parameters among the stations was not significant ($p > 0.05$) (*Table 4*).

Table 4. *One-way ANOVA test results among the stations*

One-way analysis of variance	**pH**	**Salinity**	**Phosphate**
P value	**< 0.0001**	**< 0.0001**	**0.0011**
P value summary	********	********	******
Are means signif. different? ($P < 0.05$)	**Yes**	**Yes**	**Yes**
Number of groups	5	5	5
F	64.15	59.53	5.277
R squared	0.8235	0.8124	0.2773

Pamucak (station 5th) is the station where the Kucuk Menderes River flows into the Aegean Sea. The Tukey test was used to determine significant differences among stations. In this station, as a result of this test, the pH and phosphate amounts were found to be lower than the other stations, and the salinity was found to be higher than the other stations, due to the effect of the sea. As a result of the Tukey test, the phosphate amounts at stations 2, 3 and 4, which have significant differences, can be considered to be higher than other stations due to the domestic waste load of Zeytinkoy, Akgol and Selçuk-Ozdere settlements.

The One-way ANOVA test was used again to find if there was a statistically significant difference among the months. Differences were not found for all parameters ($p > 0.05$).

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Discussion

The obtained parameters are compared with the Criteria for Water Pollution Control Regulation and Criteria for Above Ground Water Quality Regulation (Official Gazette, 2004; Official Gazette, 2015). It has been determined that the river water has polluted water and very polluted water quality. It is considered that it is not appropriate to use this water for irrigation in agricultural areas.

Pollution is mainly caused by domestic waste water, especially textile, metal, mine, olive oil, dairy products industrial facilities and agricultural activities. It can be said that the phosphate load of the river increases due to the domestic waste load and phosphate fertilizers used in agricultural activities. It can be thought that the concentration of boron increases with the discharge of industrial wastewater into the river. High total phosphorus, nitrite and ammonium values are indicative of eutrophication in the river. This situation can be explained by the intensive agricultural activities and unconscious excessive use of fertilizers in the basin. The seasonal olive oil facilities and dairy businesses, which are densely located in the region, also significantly increase organic pollution. In addition, large factories and marble enterprises around Torbalı Fetrek Stream have a serious pollution load for the river.

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In addition, similar results have found in other pollution studies conducted in the Kucuk Menderes River. It is observed that the pollution events have increased in recent years in the river.

As a result of a study carried out in 2005, it was determined that the water quality of the Kucuk Menderes River is 3rd and 4th class water quality according to the classification of inland water resources. It has been stated that this quality of water is not suitable for use in any field, including agricultural use (Egemen et al., 2005).

In the study carried out by Gundogdu and Ozkan, it was was found that the water quality of the Kucuk Menderes River is 4th class water quality in terms of nitrite nitrogen, total phosphorus, BOD, cadmium, lead, copper, COD, total chromium and sulfur values; 3rd class water quality in terms of iron value; 2nd class water quality in terms of nitrate nitrogen and zinc values (Gundogdu and Ozkan, 2006).

In another study conducted in the Kucuk Menderes River, water quality was determined by using benthic invertebrates. As a result of chemical and biological determinations, the water quality level of the Kucuk Menderes River is in the "Highly Polluted Waters" group (Balik et al., 2006).

In a study on water basins and water pollution, it has been reported that the Kucuk Menderes River is at the 4th class pollution level in terms of organic matter, nitrogen and heavy metals arising from agricultural activities and industrial and domestic wastes (Akın and Akın, 2007).

In the study conducted by The Scientific and Technological Research Council of Turkey, Marmara Research Center, Environment Institute, it was determined that Kucuk

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Menderes River is in the 4th class, namely very polluted water category, in terms of COD, BOD, dissolved oxygen, color, boron and ammonium nitrogen parameters. COD 174 mg/L, BOD 88 mg/L and ammonium nitrogen 8.2 mg/L were found (Anonymous, 2013).

Organically chlorinated pesticides and heavy metals were investigated in Kucuk Menderes River surface water. Organochlorine pesticides, especially DDT, were found in the surface water of the river. Heavy metal concentrations were found to be low except for Ni, Cu and Zn (Turgut, 2003).

In the Kucuk Menderes Basin Water Quality Monitoring Report, the river was found to be in 4th class water quality in terms of ammonium nitrogen, total phosphorus, COD, BOD, nitrite nitrogen parameters. The dirtiest point in the basin is the Tire/İzmir point on the Ödemiş Tire road. This point is the point after the Fetrek Stream joins the Kucuk Menderes River, where channel connection permission is given to the industries by the municipality. It is thought that the waste water of industrial facilities is given to Fetrek Stream without treatment. In this study carried out between 2012 and 2014, the river was generally identified at 4th class water quality every year (Anonymous, 2014).

In the analysis of water samples taken from various points of the Kucuk Menderes River by the Environmental Protection Board of the Governorship of Izmir, it was determined that the pollution was at a high level. It is stated that oxygen is low enough to cause the death of living creatures, heavy metals such as lead, nickel and zinc are at the highest level, water has acidic properties and the sulfur content is very high. It is stated that if measures are taken in the basin where domestic and industrial wastes are concentrated and the pollution continues in this way, it will not be possible to use water in any way, including for agricultural purposes. In particular, industrial wastes need to be treated in the basin (Tomar, 2009).

One of the most important problems in terms of water quality in the streams in the Kucuk Menderes Basin is that the Kucuk Menderes River is in the category of highly polluted water in terms of many parameters such as organic matter, nitrogen, color, dissolved oxygen and salinity values. Fetrek Stream, one of the branches of the Kucuk Menderes River, is also in the category of highly polluted water in terms of many parameters such as organic matter, nitrogen, color, dissolved oxygen, salinity, fluoride, manganese and boron, and is the most problematic stream of the basin (Anonymous, 2013).

In a study investigating the distribution of Benthic Diatom (Fitobentos) composition in the Kucuk Menderes Basin, it was stated that the most common taxa were taxa indicating contaminated waters. In the study evaluating the water quality according to macro invertebrates in the Kucuk Menderes River, it was reported that the high dominance of the species with the highest frequency rate indicates basin pollution (Solak et al., 2018).

In Kucuk Menderes River, anionic detergent concentrations ranged from 0.043 to 0.845 mg/L and the average concentration of anionic detergent was found 0.36 mg/L. In comparison with the quality criteria of the inland water resources, it was found that the river water was in the contaminated water class in terms of anionic detergent parameter (Minareci and Bazer, 2019).

In the study evaluating the water quality in Kucuk Menderes River according to macro invertebrates, the presence, high prevalence and frequency of positive indicator species for water quality indicates pollution in the Kucuk Menderes basin (Arslan et al., 2016).

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In another study conducted on the shores of Kucuk Menderes, macro invertebrate communities and environmental variables were evaluated in the Kucuk Menderes coastal wet-land. The results of this study showed that aquatic systems can regenerate in the absence of anthropogenic impacts such as wastewater discharge and agricultural activities (Yildiz et al., 2010).

Gediz and Büyük Menderes rivers are also rivers flowing into the Aegean Sea. In the study carried out in the Gediz River, water quality measurements were compared with the Regulation of Water Pollution Control. The river water was found in the II. Water Quality Class. In addition, the amounts of heavy metals were compared with inorganic pollution limit values and it was seen that the amounts of chromium and lead were high and reached levels that would threaten public health (Minareci et al., 2009a). In another study carried out in the Gediz River, total phosphate and anionic surfactant concentration guideline limits for surface water (Official Gazette, 2004) were compared with mean concentrations of phosphate and anionic detergent in water samples. The waters from the third (Manisa Municipality Wastewater Treatment Plant) and fourth (Manisa Industrial Wastewater Treatment Plant) stations were classified as 'highly polluted water' (Minareci et al., 2009b). In the study carried out in the Buyuk Menderes River, phosphate, anionic detergent, heavy metal and boron concentrations mean values were compared with the Water Pollution Control Regulation. Buyuk Menderes River was classified 'less polluted water' in terms of nickel and anionic surfactant (Minareci et al., 2018).

Conclusions and recommendations

The obtained water quality parameters were compared with the criterion values in the regulations. It has been determined that the river water has polluted water and very polluted water quality. It is considered that it is not appropriate to use this water for irrigation in agricultural areas.

Pollution detection studies must be carried out continuously, at certain periods, in all rivers.

Chemical fertilizers and pesticides used in agriculture should be kept under control by authorized institutions and farmers should be trained on this issue.

It should be ensured that the waste water of settlements and industrial zones in the river basins is treated in the treatment facilities and then fed to the rivers, and the necessary measures for this should be taken.

The number of treatment facilities where domestic and industrial wastewater is treated must be increased, their capacities must be increased and they must operate regularly.

It can be concluded that water pollution can be reduced if precautions are taken, such as developing awareness of environmental protection and fulfilling our duties in order to offer a healthy life and a clean environment to future generations.

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