Celal Bayar University Journal of Science

Determination of Surface Water Quality in Susurluk Stream (Balıkesir-Turkey)

Orkide Minareci[1]*

[1] Manisa Celal Bayar University, Faculty of Engineering and Natural Sciences, Biology Department, Manisa, Türkiye
* orkide.minareci@cbu.edu.tr
* Orcid No: 0000-0001-6746-6057

Received: March 27, 2025
Accepted: May 12, 2025
DOI: 10.18466/cbayarfbe.1666450

Abstract

The Susurluk Stream is under the threat of pollution due to population growth, industrialization and agricultural activities. Therefore, it was aimed to determine some water quality parameters of the stream (temperature, pH, dissolved oxygen, total dissolved substance, conductivity, anionic detergent, phosphate, boron, copper, chromium, nickel and lead). The average values were found as follows; temperature 17.5 °C, pH 7.9, dissolved oxygen 6.01 mg/L, total dissolved substance 395 mg/L, conductivity 788 µS/cm, anionic detergent 0.297 mg/L; phosphate 0.039 mg P/L; boron 0.921 mg/L; copper 1.954 µg/L; chromium 0.375 µg/L; nickel 2.230 µg/L; lead 0.175 µg/L. These values were compared with the criteria values specified in the relevant regulations and the quality of the water was determined.

Keywords: Anionic detergent, Boron, Heavy metal, Phosphate, Susurluk Stream, Water quality.

1. Introduction

The introduction of various pollutants into water bodies initiates biological, physical, and chemical processes, resulting in water pollution [1].

Detergent pollution is particularly significant due to its impact on biological activity in aquatic environments. The primary adverse effects of detergents in water include foam formation, oxygen depletion caused by biological degradation, negative impacts on aquatic organisms, the occurrence of eutrophication, and detrimental effects on drinking water quality. When surfactants from detergents are present in high concentrations in receiving waters, they lead to foam formation, which impedes aeration and oxygen exchange when the water surface is covered. Surfactants undergo biochemical reactions in water, resulting in the consumption of dissolved oxygen during their degradation, which can lead to oxygen deficiency [2].

The primary source of phosphorus in domestic wastewater is the detergents used. The phosphorus that reaches receiving water bodies is derived from domestic, industrial, and agricultural waste sources.

Eutrophication results in several negative outcomes, including rapid algal blooms, taste and odor issues caused by algal growth, the release of toxic substances by algae, aesthetic problems such as algae floating on the water surface, the accumulation of organic matter at the bottom of lakes, the death of aquatic organisms due to oxygen depletion, water discoloration, and difficulties in water filtration [3].

According to the limits established by the World Health Organization, the concentration of anionic detergents in drinking water should not exceed 0.2 mg/L. Contaminated water from detergents can transfer to humans through poorly rinsed vegetables and fruits, as well as utensils [1].

Sources of high concentrations of boron in water and soil include boron mines, irrigation waters, and various industries. Elevated boron levels adversely affect human health [4]. Therefore, it is essential to understand the negative impacts of boron on living organisms and to determine the concentrations of boron in water and soil.

Toxic elements such as copper, chromium, lead, zinc, nickel, cadmium, antimony, argon, arsenic, mercury, and selenium are introduced into air, water, and soil through anthropogenic activities [5]. Due to their diverse sources, persistence in the environment, and tendency to affect biological systems, these metals rank among the primary pollutants, accumulating in increasing concentrations within the food chain [6, 7].

Water courses, sewage, and waste from domestic, industrial, and agricultural sources become contaminated through the transport of pollutants by rainwater and surface runoff. The pollution of water courses disrupts the ecological balance, negatively impacting organisms.

The Susurluk Stream, the most significant river in the Susurluk Basin, originates in Kutahya and flows into the Sea of Marmara. Key environmental issues in the basin include the discharge of untreated domestic and industrial wastewater, mining activities, intensive agricultural and livestock practices, irregular waste storage, erosion, gravel and sand extraction from riverbeds, and pollution events resulting from the natural characteristics of the rivers and geothermal waters [8].

The sources of significant pollution in the Susurluk Stream include the Bigadic Borax facilities, poultry farms located in the Karsiyaka District of Erdek, leather factories, the Susurluk Sugar Factory, and industrial waste from the Bandirma region [9].

In the Susurluk Basin Water Quality Monitoring study [10]; In the Water Quality Monitoring study conducted in the basin in 2016 [11]; In the study conducted by Kalayci and Kahya (1998) in the rivers in the basin [12]; In the study conducted by Ozalp and Ertorun (2024) to reveal the water quality of the Susurluk, Capraz and Karadere streams [13]; In the study in which boron pollution of Simav Stream was determined [14]; In the study conducted regarding the Simav Stream water pollution problem [15], it was stated that the stream was polluted and its water quality classes were determined.

Due to these pollution events occurring in Susurluk Stream, this study aimed to determine the surface water quality of Susurluk Stream.

2. Materials and Methods

In our study area, the Susurluk Stream, sampling stations were established based on significant pollution discharge locations [16]. Water samples were collected from the surface using polyethylene bottles and transported to the laboratory using a cold chain. Sampling was conducted seasonally between November 2022 and June 2023. The stations are shown in Figure 1, and their coordinates are provided in Table 1.

Table 1. Coordinates of sampling stations

Stations	**Coordinates**	
1. Kepsut Bridge	39° 41’ 18.4" K	28° 08’ 17.9" D
2. Yıldız Bridge	39° 48’51.2" K	28° 10’ 44.7" D
3. Sultan Cayır	39° 51’ 38.2" K	28° 09’ 21.7" D
4. Susurluk Bridge	39° 55’ 03.2” K	28° 09’ 58.5“ D
5. Capraz Creek	39° 58’ 01.4" K	28° 10’ 20.7“ D
6. Yahya Village	39° 59’ 38.3” K	28° 10’ 43.5” D

Given these pollution events, this study aims to determine the surface water quality of the Susurluk Stream. Physicochemical parameters were measured at sampling sites using water quality parameter measurement devices. The reaction between anionic surfactants and methylene blue resulted in the formation of salts, which were dissolved in chloroform, allowing for the quantification of detergent concentration via spectrophotometry [17]. The concentration of ortho-phosphate phosphorus was determined by measuring the phosphomolybdic acid formed from the reaction of ammonium molybdate, ascorbic acid, and potassium antimonyl tartrate in an acidic medium [18]. The boron concentration was measured through the spectrophotometric analysis of the red compound formed with carmine [19]. Heavy metal analyses were conducted using ICP-MS equipment.

Graphpad Prism for Windows program was used for statistical analysis. Statistical tests were applied to determine whether anionic detergent, phosphate, boron and heavy metal concentrations showed significant differences between seasons and stations.

Celal Bayar University Journal of Science
Volume 21, Issue 3, 2025, p 65-71
Doi: 10.18466/cbayarfbe.1666450

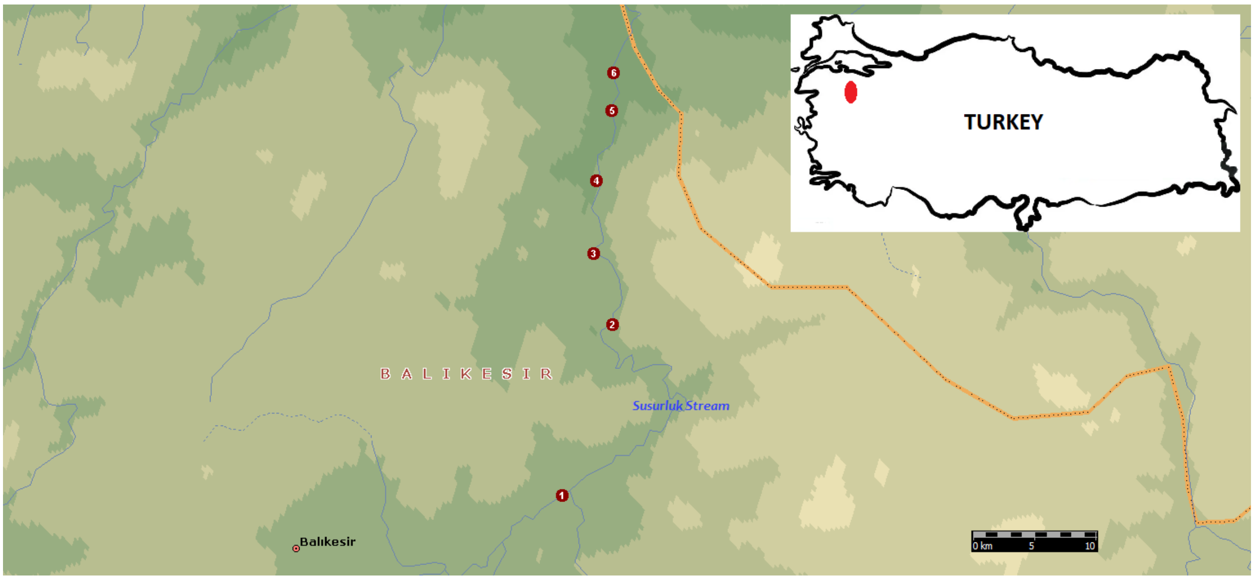

Figure 1. Sampling stations

2. Results and Discussion

The physicochemical parameters were measured as mean pH 7.9, temperature 17.5 °C, dissolved oxygen 6.01 mg/L, total dissolved substance 395 mg/L, conductivity 788 µS/cm. Anionic detergent 0.297 mg/L; phosphate 0.039 mg P/L; boron 0.921 mg/L; copper 1.958 µg/L; chromium 0.375 µg/L; nickel 2.230 µg/L; lead 0.175 µg/L were found.

Seasonal average concentrations of the identified parameters in surface water samples from the Susurluk Stream are presented in Table 2.

When compared with the "Quality Criteria for Continental Water Resources" outlined in the Water Pollution Control Regulation [20], the Susurluk Stream was classified as class III (polluted water) for anionic detergent parameters and class II (lightly polluted water) for dissolved oxygen and phosphorus parameters (Table 3). The criterion value for anionic detergents is set at ≤0.3 mg/L according to European Union water quality standards. The average value obtained in this study (0.297 mg/L) is close to this criterion.

When compared with the criteria from the Surface Water Quality Management Regulation [21], the Susurluk Stream was determined to be class II (lightly polluted water) water in terms of conductivity, dissolved oxygen, and total phosphorus parameters (Table 4). The average boron concentration also approaches the criterion values.

According to the Technical Procedures Notification of the Water Pollution Control Regulation (Official Gazette 1991) [22], the criterion range for boron in class II water is specified as 0.5-1.12 mg/L. Thus, the water quality regarding the boron parameter is classified as class II. Comparisons with allowable maximum heavy metal concentrations in irrigation waters indicated that the heavy metal concentrations in the water are low.

Due to the anionic detergent load, the water quality of the stream has been classified as class III (polluted water), while its phosphate concentration has been classified as class II (lightly polluted water). It is thought that the amount of anionic detergents increases near sampling stations located close to urban areas, linked to domestic waste load. Additionally, the phosphorus content in domestic wastewater largely stems from the phosphates present in detergents, suggesting a parallel increase in phosphate levels corresponding to detergent concentrations.

Table 2. Seasonal mean concentrations of parameters (±SD< 0.001)

Seasons	pH	Temperature (°C)	Dissolved oxygen (mg/L)	Total dissolved substance (mg/L)	Conductivity (µS)	Detergent (mg/L)	Phospate (mg/L)	Boron (mg/L)	Copper (µg/L)	Chromium (µg/L)	Nickel (µg/L)	Lead (µg/L)
Autumn	7.8	14.4	5.9	328	835	0.402	0.052	0.259	1.925	0.352	2.243	0.150
Winter	8.4	12.5	7.3	467	741	0.261	0.041	0.615	1.827	0.326	2.228	0.175
Spring	8.0	18.7	5.7	356	773	0.314	0.024	1.271	1.948	0.400	2.025	0.200
Summer	7.5	24.7	5.5	430	801	0.209	0.041	1.542	2.134	0.425	2.425	0.175
Mean	**7.9**	**17.5**	**6.1**	**395**	**788**	**0.297**	**0.039**	**0.921**	**1.958**	**0.375**	**2.230**	**0.175**

Table 3. Comparison with Quality Criteria of Intra-Continental Water Resources (Water Pollution Control Regulation) [20]

Water Quality Parameters	**Water Quality Classes**				
	1.	**2.**	**3.**	**4.**	**This Study**
Temperature (^{0}C)	25	25	30	>30	17.5
pH	6.5-8.5	6.5-8.5	6.0-9.0	6.0-9.0 except	7.9
Dissolved oxygen (mg/L)	8	6	3	< 3	**6.01**
Total dissolved substance (mg/L)	500	1500	5000	>5000	395
Anionic Detergent (mg/L)	0.05	0.2	1	>1.5	**0.297**
Boron (mg/L)	1	1	1	>1	0.921
Total Phosphorus (mg/L)	0.02	0.16	0.65	>0.65	**0.039**
Copper (µg/L)	20	50	200	>200	1.958
Chromium (µg/L)	20	50	200	>200	0.375
Nickel (µg/L)	20	50	200	>200	2.230
Lead (µg/L)	10	20	50	>50	0.175

Table 4. Comparison with Quality Criteria of Intra-Continental Surface Water Resources (Regulation on Amendment of Surface Water Quality Management Regulation) [21]

Water Quality Parameters	**Water Quality Classes**				
	1.	**2.**	**3.**	**4.**	**This Study**
pH	6 - 9	6 - 9	6 - 9	< 6.0 or > 9.0	7.9
Temperature (°C)	≤ 25	≤ 25	≤ 30	>30	17.5
Conductivity (µs/cm)	< 400	1000	3000	>3000	**788**
Dissolved oxygen (mg/L)	> 8	6	3	< 3	**6.01**
Total Phosphorus (mg P/L)	< 0.03	0.03-0.16	0.16-0.65	> 0.65	**0.039**
Boron (µg B/L)	≤ 1000	≤ 1000	≤ 1000	> 1000	0.921
Copper (µg Cu/L)	≤20	50	200	> 200	1.958
Chromium (µg Cr/L)	≤20	50	200	> 200	0.375
Nickel (µg Ni/L)	≤20	50	200	> 200	2.230
Lead (µg Pb/L)	≤10	20	50	> 50	0.175

Results from the one-way ANOVA test indicated a significant difference ($p < 0.05$) in detergent and boron concentrations across seasons, while differences between sampling stations were found to be insignificant ($p > 0.05$) (Table 5).

Table 5. One-Way ANOVA test results between seasons

One-way Anova Variance Analysis	Detergent	Boron
P value	0.0013	<0.0001
P significance	important	very important
Group number	4	4
F value	7.76	352.1
R^2 value	0.5379	0.9814

To identify which seasons exhibited significant differences, a Tukey test was applied; differences in the detergent parameter were significant in the autumn, while differences in the boron parameter were significant in the spring and summer.

The elevated boron levels observed in spring and summer can be attributed to the use of groundwater resources for agricultural irrigation during these months, leading to the influx of boron into the Susurluk Stream.

Similar pollution studies conducted on the Susurluk Stream have also concluded that the stream is polluted, consistent with our findings.

According to water quality results from the winter period of 2014, under the Surface Water Quality Management Regulation, the Susurluk Stream was generally classified as Class IV water quality in terms of parameters including pH, dissolved oxygen, nitrite nitrogen, ammonium nitrogen, total Kjeldahl nitrogen, total phosphorus, COD, and BOD [10].

The 2016 Water Quality Monitoring Final Report also indicated that the seasonal water quality results for the Susurluk Stream classified it overall as Class IV (very polluted water) water quality [11].

In the study by Kalayci and Kahya (1998), non-parametric tests revealed a decreasing trend in discharge and sediment concentration, while an increasing trend was observed for water temperature, electrical conductivity, potassium, sodium, calcium + magnesium, bicarbonate, and chlorite concentrations. No trends were identified for pH, sulfate, carbonate, boron, and organic matter concentrations [12].

To assess the water quality of the Susurluk, Çapraz, and Karadere streams, various biotic indices including BMWP Original, BMWP Turkish, BMWP Spanish, and ASPT were utilized, resulting in five distinct water quality classes: Very Poor, Poor, Moderate, Good, and Very Good [13].

Borax facilities are located along the Susurluk Stream, also known as the Simav Stream. It is believed that these facilities contribute to boron pollution in the stream. In a study assessing the boron pollution in the Simav Stream, the annual average boron concentration was found to be 0.28 mg/L at the Bigadic Bridge and 7.19 mg/L at the ore site exit [14].

Gündüz et al. (2012) noted that the uncontrolled discharge of geothermal fluids into surface waters causes water pollution due to high temperatures and element concentrations. It was concluded that the high levels of toxic elements such as arsenic and boron in the surface waters of the Simav Plain are related to the discharge of geothermal fluids [23].

In a study addressing the issue of water pollution in the Simav Stream, it was reported that the concentrations of boron ranged from 60 to 90 ppm due to the surface runoff of solid waste from boron mining operations during rainfall. Other contributing pollution factors include industrial facilities, the inadequacy or absence of treatment plants, and insufficient environmental awareness [15].

Comparisons were made between the concentrations of anionic detergents, phosphates, and boron found in various rivers and streams with those measured in the Susurluk Stream.

The average concentration of anionic detergents in the Susurluk Stream was found to be 0.297 mg/L, which is lower than the concentrations reported for other streams: Ankara Stream (3.37 mg/L), Melez Stream (5 mg/L), Arap Stream (4.8 mg/L), Nif Stream (2.155 mg/L), Gediz River (0.703 mg/L), and Melez Stream (0 – 6.93 mg/L) [24]; Kucuk Menderes River (0 – 0.93 mg/L), Karacay (0.071 – 1.122 mg/L), Gediz River (0.951 mg/L) [25]; and Kucuk Menderes River (0.043 - 0.845 mg/L) [26].

The average phosphate concentration in the Susurluk Stream was found to be 0.039 mg/L, which is higher than the concentrations in the Meriç River (0.0001 – 0.02 mg/L), Bakırcay River (0.0018 – 0.0229 mg/L), and Büyük Menderes River (0.0181 mg/L) [25]; and the Yuvarlak Stream (0.02 mg/L) [24]. However, it is lower than concentrations found in Yuvarlak Stream (0.08 mg/L), Dalaman Stream (0.213 mg/L), and Ankara Stream (3.81 mg/L) [24]; Gediz River (0.02 – 7.41 mg/L), Gediz River (0.016 – 4.054 mg/L), Asi River (0.002 – 2.44 mg/L), Bakırcay (0 – 0.7 mg/L), Karacay (Kahramanmaras) (0.22– 6.82 mg/L), Kucuk Menderes River (0 – 1.88 mg/L), Karacay (Manisa)

(0.002–0.225 mg/L), Gediz River (0.0044 – 0.248 mg/L [25]; and Kucuk Menderes River (0.17 mg/L) [27].

The average boron concentration in the Susurluk Stream was found to be 0.921 mg/L, which is higher than that reported for the Büyük Menderes River (0.8352 mg/L) [25] and the Simav Stream (0-0.5 mg/L) [28]. However, it is lower than concentrations in Büyük Menderes River (0.33–6.41 mg/L), Büyük Menderes River (1.1 mg/L), Gediz River (0.19–2.25 mg/L), Seydisuyu (0.03-10.1 mg/L), and Karacay (Manisa) (0.134–3.937 mg/L) (Cakir 2013) [29]; Gediz River (0.125 - 4.548 mg/L) [30]; and Kucuk Menderes River (1 mg/L) [27].

The establishment of a database for the regular monitoring of pollution in natural water environments is an essential requirement. Therefore, pollution studies should be conducted on a regular basis [31].

3. Conclusion

As a result of comparing the water quality parameters with the criteria values in the regulations, the river water is found to be polluted water and slightly polluted water quality, so it will not be suitable for use as irrigation water in agricultural areas. Immediate measures must be taken to eliminate the sources of pollution in the Susurluk Stream. Wastewater from residential areas and industrial zones should be treated in treatment facilities before being discharged into the stream. The number of wastewater treatment facilities should be increased, and these facilities must operate at full capacity. Detergent pollution can be mitigated by using surfactants with high biological degradability, and alternative substances that do not contribute to pollution should be utilized instead of phosphates.

Author's Contributions

Orkide Minareci: Drafted and wrote the manuscript, performed the experiment and result analysis.

Ethics

There are no ethical issues after the publication of this manuscript.

References

[1]. Anonymous. Environmental Management - Water Pollution. Manisa Provincial Directorate of Environment and Forestry, Manisa, 2007.

[2]. Egemen, O. Water Quality. 7th Edition, Ege University Faculty of Fisheries, Publication No:14, Bornova – İzmir, 2011, 150 p.

[3]. Egemen, O. Environmental and Water Pollution. 3rd Edition, Ege University Faculty of Fisheries, Publication No: 42, Bornova – İzmir, 2006, 120 p.

[4]. Greenwood, NN, Earnshaw, A. Chemistry of the Elements. Butterworth-Heinemann Publish Second Edition, Oxford, 2001.

[5]. Samsunlu, A. Environmental Engineering Chemistry. Sam-Environmental Technologies Center Publication, Istanbul, 1999.

[6]. Saglam, N, Cihangir, N. 1995. Studies on biosorption of heavy metals by biological processes. *Hacettepe University Journal of Education*; 11: 157- 161.

[7]. Sivaslıgil, A. Particulate matter pollution in Gebze-Dilovası; Inventory of polluting sources and analysis of particulate matter carcinogenic PAHs. Master's Thesis. Gebze Institute of Technology, Istanbul, 2007.

[8]. Anonymous. Susurluk Basin Protection Action Plan. The Republic of Turkey Ministry of Forestry and Water Affairs and TUBITAK, Ankara, 2013.

[9]. Gurkan, U, Tekin Ozan, S. 2012. Helminth fauna of Chub (Squalius cephalus L.) in Susurluk Creek (Bursa-Balıkesir). *Suleyman Demirel University Journal of Science*; 7(2): 77-85.

[10]. Anonymous. Susurluk Basin Water Quality Monitoring Report Winter Period. The Republic of Turkey Ministry of Environment and Urbanization, General Directorate of Environmental Impact Assessment Permit and Inspection, Department of Laboratory Measurement and Monitoring, Ankara, 2014.

[11]. Anonymous. Ergene, Gediz, Northern Aegean (Bakırcay), Kucuk Menderes, Susurluk and Sakarya Basins 2016 Water Quality Monitoring Final Report. The Republic of Turkey Ministry of Environment and Urbanization, General Directorate of Environmental Impact Assessment Permit and Inspection, Department of Laboratory Measurement and Monitoring, Ankara, 2017.

[12]. Kalayci, S, Kahya, E. 1998. Detection of water quality trends in the rivers of the Susurluk Basin. *Turkish Journal of Engineering and Environmental Sciences;* 6(22): 503 – 514.

[13]. Ozalp, B, Ertorun, N. 2024. Determination of biological water quality of Susurluk, Capraz and Karadere Streams using macroinvertebrates and biotic indices. *Acta Aquatica Turcica*; 20(3): 242-255. (https://doi.org/10.22392/actaquatr.1433735)

[14]. Balki, N. 1982. Investigation of Simav Stream in terms of boron pollution and research of methods of purifying wastewater that causes pollution by adsorption. Doctoral Thesis. Uludag University, The Graduate School of Social Sciences, Bursa, 1982.

[15]. Gulum, K, Akgun A. 2011. Water pollution and suggestions of solution in the lower part of Simav River (between out of Caygoren Dam and Kepsut Pass). *e-Journal of New World Sciences Academy*; 6(2): 31-42.

[16]. Sharp, WE. 1970. Stream order as a measure of sample source uncertainity. *Water Resources Research*; 6(3): 919-926.

[17]. Anonymous. Standard methods for the examination of water and wastewater. 19th Edition, APHA, AWWA, WPCF, Washington, 1995.

[18]. Parsons, TR, Maita, Y, Lalli, CM. A manual of chemical and biological methods for seawater analysis. Pergamon Pres, New York, 1984, 173 p.

[19]. Anonymous. Standard methods for the examination of water and wastewater. 21st Edition, APHA, AWWA, WEF, Washington, 2005.

[20]. Official Gazette. Water Pollution Control Regulation. No: 25687, 2004.

[21]. Official Gazette. Regulation on Amendment of Surface Water Quality Management Regulation. No: 29327, 2015.

[22]. Official Gazette. Water Pollution Control Regulation Technical Procedures Circular. No: 20748, 1991.

[23]. Gunduz, O, Mutlu, M, Elci, A, Simsek, C, Baba, A. 2012. Effect of geothermal fluid discharge on surface water quality: Example field Simav Plain (Kutahya). *Environmental Science and Technology*; 3(4): 231-246.

[24]. Minareci, O. Investigation of detergent pollution in Gediz River. Doctoral Thesis. Celal Bayar University, The Institute of Natural and Applied Sciences, Manisa, 2007.

[25]. Minareci, O, Cakir, M, Minareci, E. 2018. The study of surface water quality in Buyuk Menderes River (Turkey): determination of anionic detergent, phosphate, boron and some heavy metal contents. *Applied Ecology and Environmental Research;* 16(4): 5287-5298. (http://dx.doi.org/10.15666/aeer/1604_52875298)

[26]. Minareci, O, Bazer, M. 2019. Investigation of anionic detergent pollution in surface water of Kucuk Menderes River. *Afyon Kocatepe University Journal of Science and Engineering;* 19(021002): 267-274. (https://doi.org/10.35414/akufemubid.554586)

[27]. Minareci, O, Bazer, M. 2024. Assessment of the surface water quality in the Kucuk Menderes River, Türkiye. *Applied Ecology and Environmental Research;* 22(2): 1563-1575. (http://dx.doi.org/10.15666/aeer/2202_15631575)

[28]. Okay, O., Guclu, H., Soner, E., Balkas, T. 1985. Boron pollution in the Simav River, Turkey and various methods of boron removal. *Water Research;* 7: 857-862.

[29]. Cakir, M. Investigation of detergent and boron pollution in Buyuk Menderes river. Master's Thesis. Celal Bayar University, The Institute of Natural and Applied Sciences, Manisa, 2013.

[30]. Minareci, O. 2014. Investigation of boron pollution in the Gediz River. *Ekoloji;* 23(91): 91-97. (https://doi.org/10.5053/ekoloji.2014.9111)

[31]. Balcioglu, EB. 2014. A preliminary research on anionic detergent pollution of coastal surface water from various regions of Marmara Sea. *Afyon Kocatepe University Journal of Science and Engineering;* 14 (021005): 39-44. (https://doi.org/10.5578/fmbd.7917)