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THE WATER QUALITY OF STREAMS FLOWING INTO SOUTH EASTERN BLACK SEA COASTS IN TERMS OF PHYSICO-CHEMICAL PROPERTIES

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ABSTRACT

The purpose of this study is to determine the physico-chemical properties (temperature, pH, dissolved oxygen, electrical conductivity, suspended solid, nitrite nitrogen, nitrate nitrogen, orthophosphate and sulphate) within the water quality of 8 different streams flowing into the South eastern Black Sea coast. The water samples were collected monthly from April 2016 to March 2017 at a specified point at which the Melet, Aksu, Değirmendere, İyidere, Salarha, Büyükdere, Fırtına and Hopa streams flow into the sea. The physical parameters of the water samples were measured using a portable multi water quality meter (HQ40D), and analysed the chemical parameters using a spectrophotometer (HACH-LANGE-DR3900). The Gravimetric method was used to obtain suspended solids matter (SPM). The analysis results were compared with national and international quality standards and regulations for drinking as well as non-drinkable water.

The annual means of parameters for all streams featured in this study were 14.22±0.525 (4-26.1) °C in terms of temperature, 7.62±0.059 (6.1-9.1) in terms of pH, 158.63±8.837 (40-420) µS/cm in terms of electrical conductivity, and 10.38±0.132 (7.29-14.63) mg/L in terms of dissolved oxygen. On the other hand, the amount of suspended solid matter (SPM) was 68.36 ± 8.791 (0.3-604.1) mg/L, nitrite nitrogen was 0.016±0.005 (0.001-0.53) mg NO_2-N/L, nitrate nitrogen was 0.340 ± 0.026 (0-1.5) mg NO_3-N/L, orthophosphate phosphorus levels were 0.388±0.064 (0.02-4.29) mg o-PO_4-P/L, and the level of sulphate concentration was 10.458±0.949 (0-48) mg SO_4/L.

When the findings are evaluated according to national and international standards, all of the streams have a Class I water quality standard according to other parameters with the exception of orthophosphate phosphorus. For orthophosphate phosphorus levels, the Değirmendere and İyidere streams were determined to be Class IV, whilst the remaining streams were determined to be Class II in terms of water quality.

KEYWORDS:
Water quality, South Eastern Black Sea, Stream, Water Pollution

INTRODUCTION

The primary water arteries feeding into the seas are surface and groundwater sources. It is inevitable that these sources are affected by atmospheric and terrestrial surface cover, as well as anthropogenic activities stretching from high elevation to sea level. Each water basin has its own characteristic geochemical features. On the other hand, each water basin has different land use, forest cover, rural and urban settlements, and industrial activities. Therefore, the water quality of streams especially surface waters that change more rapidly than underground waters should be monitored periodically.

The quality of water that we can express as physical, chemical, and biological properties of water shows the health of the water ecosystem and water suitability for human consumption (drinking, irrigation, and industrial use) [1]. In this context, water pollution remains an important problem for human health and the environment [2].

Natural processes such as climate change and erosion, urbanization, chemical leaks, industrial and agricultural waste, and the degradation of water quality due to dam construction lead to the pollution of underground and surface water resources, the destruction of ecosystem balance, and other forms of pollution [3]. It is known that water quality is an important influence of human intervention [4]. Worldwide water quality deterioration is due to the many anthropogenic activities that release pollutants into the environment, thus negatively affecting ecosystems in the water [5].

Although streams are the most important freshwater source for humans, they are contaminated by the multitude of human activities that affect their physico-chemical characteristics and microbiological quality [6].

The Eastern Black Sea region in the north east of Turkey has two water basins. These include the water basin of Eastern Black Sea and Çoruh. The Eastern Black Sea, with an annual average of 14.90

km^3 worth of surface water potential basin meets 8% of Turkey's potential [7]. The Çoruh basin flows from the country of Georgia into the Black Sea, and has a water potential of 6.50 billion m^3 [8].

The Black Sea is dominated by hydrological precipitation and freshwater inflow, and its surface waters are special in that their seawater is less dense than the bottom waters, meaning that it is influenced by both the saltier Mediterranean waters as well as the surrounding water basins [9]. The saltier waters of the Mediterranean enter the straits and affect the deep waters of the Black Sea, while the continental shelf and coastal mixing regions dominate the waters of the stream basins [10].

The purpose of this study is to examine the water samples taken from 8 different streams flowing into the south eastern Black Sea coasts for 12 months, to determine the physico-chemical properties of these streams, to investigate their monthly and seasonal changes and to classify the water quality status according to national and international water quality criteria. Furthermore, we have examined the appropriateness of these stream resources on water quality both in being used as drinking water, as well as for aquaculture purposes.

MATERIALS AND METHODS

Study Area. This study was carried out to determine the physico-chemical properties of water samples collected from April 2016 to March 2017 from 8 different streams (Melet, Aksu, Değirmendere, İyidere, Salarha, Büyükdere, Fırtına, Hopa) flowing to the south eastern Black Sea from sampling points where there no sea water enters into stream/stream mouths (Figure 1). The coordinate information of the stations is given in Table 1.

FIGURE 1
Working area and station points (Google Earth)

TABLE 1
Location information of selected stations in the study

Station Number	Station Name	Station Location	Station Code	Latitude	Longitude
Station 1	Melet	Ordu	MOM	40.982672	37.932918
Station 2	Aksu	Giresun	AGM	40.912851	38.440208
Station 3	Değirmendere	Trabzon	DTM	41.001817	39.756872
Station 4	İyidere	Rize-İyidere	IRI	40.987386	40.329482
Station 5	Salarha	Rize	SRM	41.044023	40.573910
Station 6	Büyükdere	Rize-Çayeli	BRC	41.083591	40.711025
Station 7	Fırtına	Rize-Ardeşen	FRA	41.188648	40.962518
Station 8	Hopa	Artvin-Hopa	HAH	41.392478	41.417136

Sample Collection. International standardized methods have been used for sampling and analysis, with the Communique on Methods of Sampling and Analysis of Water Pollution Control Regulation being taken into consideration [11, 12]. For physico-chemical analysis, 324 samples were collected into 1 L sunlight-proof polypropylene bottles for over 12 months from the stream aforementioned sampling points 30 cm below the water surface. Physical parameters were analysed in situ, and chemical parameters were analysed at the Recep Tayyip Erdogan University Faculty of Fisheries Water Chemistry Laboratory.

Water Analysis. All of the samples were brought to the laboratory in a cooler vessel and analysed the same day. Physical parameters such as temperature (°C), pH, electrical conductivity (µS/cm) and dissolved oxygen (mg/L) were analysed on site using a Hach Lange (HQ40D) multi water quality meter. Chemical parameters such as nitrite (mg/L), nitrate (mg/L), phosphate (mg/L), sulphate (mg/L) were measured using a Hach Reagents and Hach Lange DR3900 spectrophotometer. The methods of chemical parameters included diazotization as nitrite, cadmium reduction as nitrate, ascorbic acid as phosphate, and barium sulphate turbidity as sulphate. The gravimetric method was used in order to measure suspended solids matter.

Statistical Analysis. The Kolmogorov-Smirnov test was used in order to check the normality of all data. The non-parametric Kruskal-Wallis H-test was used to determine differences between stations. Statistical analysis of all of the results was carried out using SPSS 21.0 software.

RESULTS

The physico-chemical findings of the water samples collected from the stations are shown in Table 2. The results of the analysis were compared with drinking and general usage water quality standards and regulations (Table 3).

TABLE 2
Some physico-chemical values of stations

Stations		Temperature (°C)	pH	EC (µS/cm)	DO (mg/L)	SPM (mg/L)	NO_2-N (mg/L)	NO_3-N (mg/L)	SO_4 (mg/L)	o-PO_4-P (mg/L)
MOM	Mean	15.78	7.94	242.38	10.70	29.30	0.016	0.492	17	0.153
	Std. Error	1.814	0.167	19.288	0.527	10.213	0.003	0.126	4.068	0.061
	Minimum	7.4	7.23	173	7.58	3.17	0.004	0.1	4	0.02
	Maximum	25.2	9.1	420	14.63	136.5	0.044	1.5	48	0.8
AGM	Mean	13.34	7.84	293.67	10.09	130.74	0.007	0.375	17.83	0.546
	Std. Error	1.471	0.106	26.453	0.257	50.744	0.003	0.107	2.964	0.272
	Minimum	7.81	6.97	150	8.64	17.46	0.001	0.1	6	0.04
	Maximum	22.2	8.27	409	11.36	604.1	0.039	1.5	37	3.33
DTM	Mean	13.91	7.83	235.33	10.40	159.61	0.054	0.225	11.25	0.717
	Std. Error	1.818	0.144	19.791	0.443	37.989	0.043	0.043	1.652	0.267
	Minimum	4	6.88	122	8.35	14.89	0.001	0	3	0.05
	Maximum	22.7	8.37	317	12.78	433.79	0.53	0.5	25	3.12
IRM	Mean	12.89	7.23	99.13	10.95	42.57	0.008	0.375	9.5	0.671
	Std. Error	1.662	0.171	6.828	0.408	5.025	0.002	0.103	3.489	0.366
	Minimum	5.2	6.3	58	9.01	0.56	0.001	0.1	2	0.04
	Maximum	20.4	8.06	124	12.88	63.8	0.022	1.3	43	4.29
SRM	Mean	13.85	7.24	112.58	10.13	68.68	0.013	0.333	7.917	0.199
	Std. Error	1.59	0.203	8.813	0.444	21.882	0.006	0.054	2.877	0.058
	Minimum	6.3	6.1	73.1	8.08	10.4	0.003	0	2	0.03
	Maximum	21.7	8.1	195	12.51	255.38	0.076	0.6	39	0.51
BRC	Mean	14.13	7.28	87.66	10.22	57.93	0.006	0.283	8.833	0.279
	Std. Error	1.301	0.153	4.368	0.266	17.192	0.001	0.061	2.081	0.134
	Minimum	8	6.31	66	9.02	9.4	0.001	0.1	4	0.02
	Maximum	21.8	7.78	117	11.64	210.32	0.015	0.7	29	1.66
FRM	Mean	13.30	7.76	59.68	10.53	39.90	0.006	0.3	4	0.262
	Std. Error	1.526	0.183	4.5344	0.358	8.072	0.003	0.056	1.665	0.048
	Minimum	4.5	6.12	40	9.12	4.76	0.001	0.1	0	0.05
	Maximum	20.3	8.7	98	12.3	100.75	0.036	0.8	21	0.57
HAH	Mean	16.54	7.85	138.58	10.00	18.13	0.016	0.333	7.333	0.274
	Std. Error	1.763	0.192	6.083	0.49	4.626	0.006	0.047	1.978	0.084
	Minimum	7.1	6.83	109.8	7.29	0.93	0.002	0.1	2	0.05
	Maximum	26.1	9.01	183	12.93	44.44	0.083	0.6	28	1.1
Total	Mean	14.22	7.62	158.63	10.38	68.36	0.016	0.34	10,458	0.388
	Std. Error	0.525	0.059	8.837	0.132	8.791	0.005	0.026	0.949	0.064
	Minimum	4	6.1	40	7.29	0.56	0.001	0	0	0.02
	Maximum	26.1	9.1	420	14.63	604.1	0.53	1.5	48	4.29

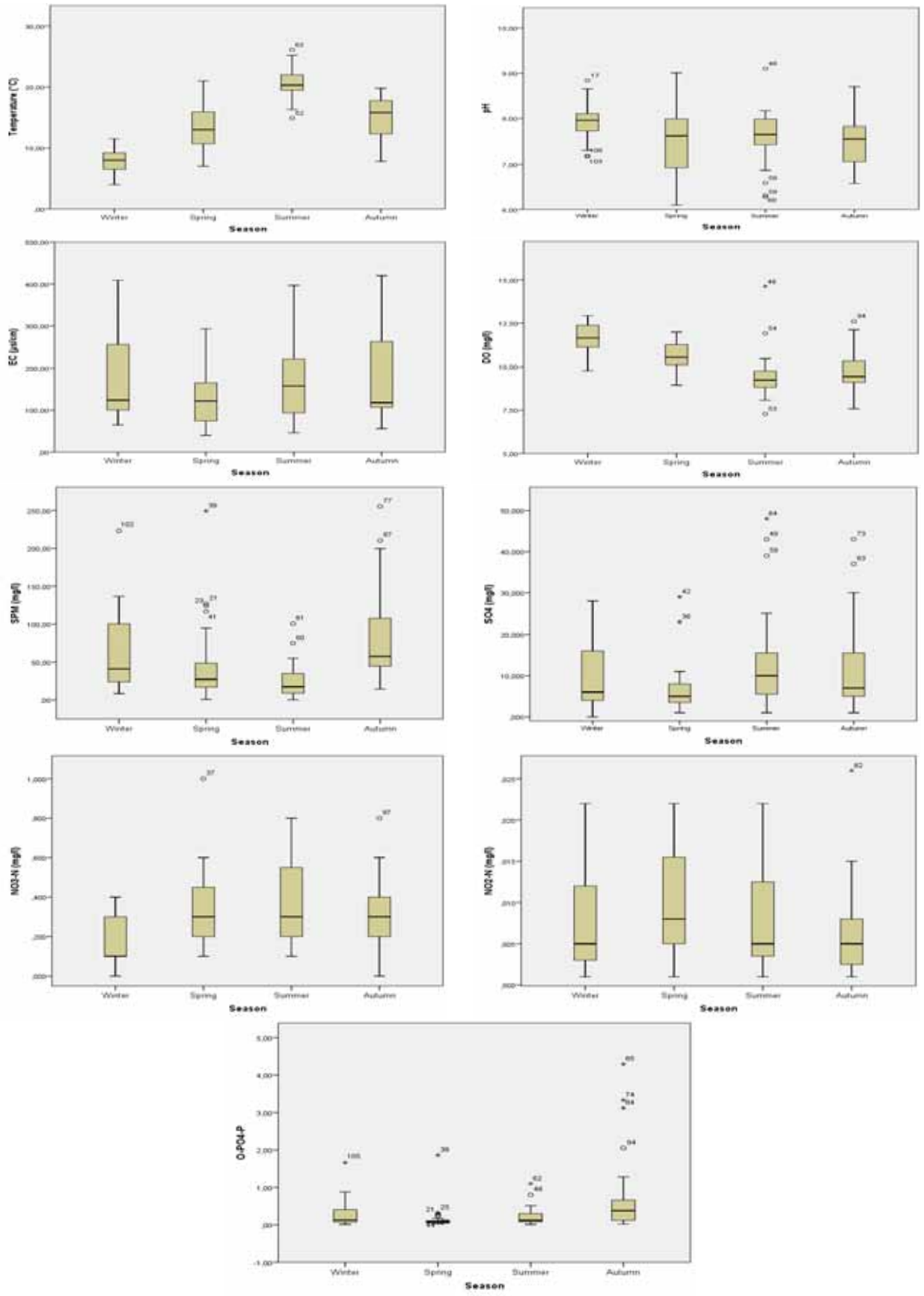

FIGURE 2
Seasonal variation of physicochemical parameters

TABLE 3
Comparison of stations with national and international drinking and general using water and national water quality standards and regulations.

Stations		Temperature (°C)	pH	EC (µS/cm)	DO (mg/L)	NO2-N (mg/L)	NO3_N (mg/L)	SO4 (mg/L)	o-PO4-P (mg/L)
MOM	YSKY (2016)	I	I	I	I		I	I	II
	TS266 (2013)	Acceptable	Acceptable	Acceptable				Acceptable	
	EPA (2012)		Acceptable			Acceptable	Acceptable	Acceptable	
	WHO (2017)		Acceptable	Acceptable				Acceptable	
AGM	YSKY (2016)	I	I	I	I		I	I	II
	TS266 (2013)	Acceptable	Acceptable	Acceptable				Acceptable	
	EPA (2012)		Acceptable			Acceptable	Acceptable	Acceptable	
	WHO (2017)		Acceptable	Acceptable				Acceptable	
DTM	YSKY (2016)	I	I	I	I		I	I	IV
	TS266 (2013)	Acceptable	Acceptable	Acceptable				Acceptable	
	EPA (2012)		Acceptable			Acceptable	Acceptable	Acceptable	
	WHO (2017)		Acceptable	Acceptable				Acceptable	
IRI	YSKY (2016)	I	I	I	I		I	I	IV
	TS266 (2013)	Acceptable	Acceptable	Acceptable				Acceptable	
	EPA (2012)		Acceptable			Acceptable	Acceptable	Acceptable	
	WHO (2017)		Acceptable	Acceptable				Acceptable	
SRM	YSKY (2016)	I	I	I	I			I	II
	TS266 (2013)	Acceptable	Acceptable	Acceptable				Acceptable	
	EPA (2012)		Acceptable			Acceptable	Acceptable	Acceptable	
	WHO (2017)		Acceptable	Acceptable				Acceptable	
BRC	YSKY (2016)	I	I	I	I		I	I	II
	TS266 (2013)	Acceptable	Acceptable	Acceptable				Acceptable	
	EPA (2012)		Acceptable			Acceptable	Acceptable	Acceptable	
	WHO (2017)		Acceptable	Acceptable				Acceptable	
FRA	YSKY (2016)	I	I	I	I		I	I	II
	TS266 (2013)	Acceptable	Acceptable	Acceptable				Acceptable	
	EPA (2012)		Acceptable			Acceptable	Acceptable	Acceptable	
	WHO (2017)		Acceptable	Acceptable				Acceptable	
HAH	YSKY (2016)	I	I	I	I		I	I	II
	TS266 (2013)	Acceptable	Acceptable	Acceptable				Acceptable	
	EPA (2012)		Acceptable			Acceptable	Acceptable	Acceptable	
	WHO (2017)		Acceptable	Acceptable				Acceptable	

The lowest measured annual winter temperature was recorded at 4 ºC during the winter (December, Değirmendere station), whilst the highest summer temperature was recorded at 26.1 ºC during the summer (July, Hopa Station). The total average annual water temperature of all of the streams was determined to be 14.22±0.525 ºC (Figure 2). No statistically significant value differences were found between streams. The differences in temperature values of streams were not statistically significant.

The lowest annual pH value was recorded at 6.10 during the spring, (April, Salarha station), whilst the maximum was recorded at 9.10 during the summer (June, Melet station). The total annual average water pH value of all the streams was determined to be 7.62±0.059 (Figure 2). No statistically significant value differences were found between streams.

The lowest annual EC value was measured at 40 µS/cm during the spring (April, Fırtına station) with a minimum, whereas the highest value was recorded at 420 µS/cm during the autumn (September, Melet station). The annual average EC value for all of the streams was determined to be 158.63±8.837 µS/cm (Figure 2). There were statistically significant differences found between the Fırtına versus Melet, Aksu, Değirmendere, and Hopa streams, between the Büyükdere versus the Melet, Aksu, and Değirmendere streams, between the İyidere versus the Melet, Aksu, and Değirmendere streams, as well as between the Salarha versus the Melet, Aksu, and Değirmendere streams.

The minimum annual DO value was measured at 7.29 mg/L during the summer (June, Hopa station), whilst a maximum DO value of 14.63 mg/L was also recorded during the summer (June, Melet station). The total annual average DO value of all of streams was determined to be 10.38±0.132 mg/L (Figure 2). No statistically significant value differences were found between streams.

SPM values throughout the year were measured in the summer the lowest SPM value was recorded at 0.56 mg/L during the winter (December, İyidere station), whereas the highest SPM value was recorded at 604.10 mg/L during the summer (August, Aksu station). The total annual mean SPM value of all streams was to be 68.36±8.791 mg/L (Figure 2). There were statistically significant differences found between the Hopa, Aksu, and Değirmendere streams, as well as between the Melet and Değirmendere streams.

The lowest annual NO_2-N was recorded at 0.001 mg/L across all four seasons in the months of

in January, May, July, August, and September at the Fırtına, İyidere, Aksu, Büyükdere, and Değirmendere stations, whilst the highest value was recorded at 0.53 mg/L during the winter (December, Değirmendere station). The total annual NO_2-N value for all of the streams was calculated to be 0.016±0.005 (Figure 2). There were statistically significant value differences found between the Fırtına and Melet streams.

The lowest annual NO_3-N was recorded at 0 mg/L during the autumn and winter months (January and October, Değirmendere and Salarha stations), whist the highest value was recorded at 1.50 mg/L during the summer and autumn (June and October, Melet and Aksu stations). The total annual NO_3-N value for all of the streams determined to be 0.340±0.026 (Figure 2). No statistically significant value differences were found between streams.

The lowest annual SO_4 value was recorded at 0 mg/L during the winter (December, Fırtına station), whereas the highest value was recorded at 48 mg/L during summer (August, Melet station). The annual average SO_4 value for all of the streams was determined to be 10.458±0.949 mg/L (Figure 2). There were statistically significant value differences found between the Fırtına, Melet, Aksu, and Değirmendere streams.

The lowest annual o-PO_4-P values was recorded at 0.02 mg/L during the winter and spring (February and March, Büyükdere and Melet stations), whereas the highest o-PO_4-P value as recorded at 4.29 mg/L during the autumn (October, İyidere station). The total annual mean o-PO_4-P value for all of the streams was determined to be 0.388±0.064 (Figure 2). No statistically significant value differences were found between streams.

DISCUSSION

Upon the evaluation of the results of this study, it was observed that the parameters had varied between 4 - 26.1 °C for T, 6.1 - 9.1 for pH, 40 - 420 µS/cm for EC, 0.3 - 604.1 mg/L for SPM and 7.29 - 14.63 mg/L for DO. Other parameters were measured between 0.001 - 0.53 mg/L for as NO_2-N, 0 - 1.5 mg/L NO_3-N, 0.01 - 4.29 mg/L for o-PO_4-P, and 0 - 48 mg/L for SO_4.

Numerous physicochemical studies on water quality have been carried out in the study basin. Gedik et al. [13] had investigated the physicochemical water quality of Fırtına Stream. They had found pH values to be 7.16, EC values to be 54.77 µS/cm, and DO values to be 10.71 mg/L. In our study, the annual average values were determined to be 7.76 for pH, 59.68 µS/cm for EC, 10.53 mg/L for DO, 39.90 mg/L for SPM, 0.006 mg/L for nitrite nitrogen, 0.30 mg/L for nitrate nitrogen, 0.261 mg/L for orthophosphate phosphorus, and 4 mg/L for sulphate. Verep et al. [14] had examined the water quality of the İyidere Stream and had determined values to be 7.50 for pH, 57.60 µS/cm for EC, 11.10 mg/L for DO, and 17.40 mg/L for SPM. The annual average values in our study for the same stream were found to be 7.23 for pH, 99.13 µS/cm for EC, 10.95 mg/L for DO, 42.57 mg/L for SPM. Fevzioglu et al. [15] had investigated the water quality of the Salarha stream--to which the results of our study are comparatively similar [15]. Özoktay [16] had investigated of water quality of the Melet Stream, as well as Turnasuyu and Akçaova Creeks. In that study, the annual mean values of physicochemical variables had ranged between 6.35 and 8.52 for pH, 7.63 - 11.84 mg/L for DO, 6.73 - 918 µS/cm for EC, and 4 - 35 mg/L for sulphate. Our study had found 7.94 for pH, 10.70 mg/L for DO, 242.38 µS/cm for EC, and 17 mg/L for sulphate. Şengün [17] had examined of water quality of the Aksu stream, and had determined the annual mean values to be 7.47 for pH, 290 mS/cm for EC, and 1.354 mg/L for NO_3-N. In our study, these results were found to be lower in the Aksu stream (pH: 7.44, EC: 293.67 µS/cm, NO_3-N: 0.375 mg/L). Uncumusaoğlu and Akkan [18] had studied the water quality of Yağlıdere stream, and had recorded the annual minimum and maximum values as being 6.96 and 8.57 for pH, 175 and 428 mS/cm for EC, 7.04 and 15.52 mg/L for DO, 0.311 and 2.100 mg/L for NO_3-N, 0.001 and 0.038 mg/L for NO_2-N, and 0.008 and 0.354 mg/L for O-PO4. In our study, minimum and maximum values for all of stream in question were recorded at 6.1 and 9.1 for pH, 40 for 420 µS/cm for EC, 7.29 and 14.63 mg/L for DO, 0.001 and 0.53 mg/L for NO_2-N, 0 and 1.5 mg/L for NO_3-N, and 0.01 and 4.29 mg/L for o-PO_4-P.

In considering past and current physiochemical research on the Black Sea river basin, it can be said that there are no significant differences between the basic parameters, however agricultural and small scale industrial activities as well as domestic wastewaters have started to cause polluted water conditions in recent years in terms of nutrients.

On the other hand, if we were make to a general assessment of basin streams in terms of their physiochemical properties, based to our observations it can be said that that the waters of the Eastern Black Sea streams generally have are mild in temperature (14.22 °C), mildly alkaline (7.62), rich in oxygen (10.38 mg/L), lacking in dissolved solids (158.63 µS/cm), and have a moderate level of turbidity (68.36 mg/L).

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