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RESEARCH ARTICLE

Investigation of the Effects of Erzurum Province Wastewater Treatment Plant on the Karasu River Water Quality

Şenol Nuroğlu[1]✉ • Esat Mahmut Kocaman[2]

[1]Erzurum Metropolitan Municipality, Erzurum/Türkiye
[2]Atatürk University, Faculty of Fisheries and Aquaculture, Department of Aquaculture, Erzurum/Türkiye

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ABSTRACT

This study was carried out to investigate the effects of the wastewater treatment plant located in the Aziziye District of Erzurum Province on the Karasu River. For this purpose, water samples were taken from 3 stations for a year between 2022-2023. The mean water temperature was measured *in situ* during sampling as 13.8 ˚C, the mean pH value was 7.7, the mean electrical conductivity was 403 µs/cm, and the mean dissolved oxygen value was 6 mg/l. The mean total suspended solid (TSS) amount was determined as 46.7 mg/l, the mean chemical oxygen demand (COD) concentration was 28.9 mg/l, the mean biological oxygen demand (BOD) concentration was 18.5 mg/l, the mean total nitrogen (TN) concentration was 4.47 mg/l, the mean nitrate (NO_3) concentration was 5.35 mg/l, the mean nitrate nitrogen (NO_3-N) concentration was 1.21 mg/l, the mean total hardness (TH) was 155 mg/l, the mean ammonium (NH_4) concentration was 2.75 mg/l, and the mean ammonium nitrogen (NH_4-N) concentration was 2.16 mg/L. As a result, it was determined that the Wastewater Treatment Plant positively affected some water quality parameter values of the Karasu River.

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1. Introduction

Freshwater resources are one of the most essential natural resources on earth and are vital to humanity. Freshwater resources are utilized in various areas, such as drinking water supply, agricultural irrigation, industrial production and energy production. However, factors such as global climate change, population growth, urbanization and environmental pollution threaten the sustainability of water resources. Therefore, effective and fair management of water resources is of great importance to provide clean and sufficient water for future generations. Protecting water resources plays a critical role in the ecological balance of water, human health and economic development (Tomanbay, 1998). Streams are systems formed by the remaining water after evaporation of the precipitation falling on the earth's surface. Approximately 20% of rainfall evaporates. Most of the remaining part forms streams and flows towards the lakes or seas, while a small part seeps into the soil and constitutes groundwaters (Tanyolaç, 2009).

One of the main difficulties in maintaining water quality in rivers is the presence of pollutants. Heavy metals, industrial and man-made pollutants such as chemicals and sewage can enter rivers from a wide variety of sources such as factories, wastewater treatment plants, agricultural activities and urban runoff. Many criteria have been developed to determine the water quality of rivers. The Water Framework Directive,

✉ Correspondence
E-mail address: senolnuroglu25@gmail.com

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prepared by European countries and entered into force in our country in 2005, is among these criteria. This criterion classifies freshwater resources based on water temperature, pH, dissolved oxygen, ammonium-nitrogen, nitrite-nitrogen, nitrate-nitrogen, total phosphorus and chemical oxygen demand parameters. In our country, inland waters are classified into four main classes according to the Water Pollution Control Regulation, prepared in accordance with the mentioned directive, and the Intra-Continental Surface Water Standards included within the same law (Orman ve Su İşleri Bakanlığı, 2015; Varol et al., 2022).

Despite Türkiye being rich in terms of water resources, it is a country that may experience water problems in the near future if the necessary precautions are not taken. The country's average river potential is 186 km^3, and this amount reaches 196 km^3 by adding 10 km^3 of groundwater. Since the annual usable water amount per capita is 1,430 m^3, Türkiye is among the countries experiencing water shortage (Tomanbay, 1998). The Karasu River is of great importance for the province of Erzurum and other regions it passes through, as it hosts agricultural irrigation, energy production and biodiversity. However, problems such as pollution and overuse of rivers can have adverse effects on ecosystems and increase sustainability concerns. Therefore, protecting the natural and economic value of the Karasu River and managing it sustainably is of great importance (Eren & Kaya, 2020).

For this reason, our research was carried out to investigate the effects of the water coming out of the Wastewater Treatment Plant, which was established near the Karasu River and located in the exit section of Erzurum Province, on the water quality of the Karasu River.

2. Materials and Methods

2.1. Study Site

The Karasu River, main branch of the Euphrates River, passes through the Aşkale District of Erzurum and heads towards Erzincan, also receiving the Tuzla Stream coming from the Palandöken Mountain, and after passing the Sansa Strait, it crosses the Erzincan Plain and from there enters the Kemah Strait, after deep and narrow straits, it joins the Murat River at the Keban Dam Lake. Our study covers the region within the borders of Erzurum Province. The map and coordinate data of the study area are presented in Figure 1 and Table 1, respectively.

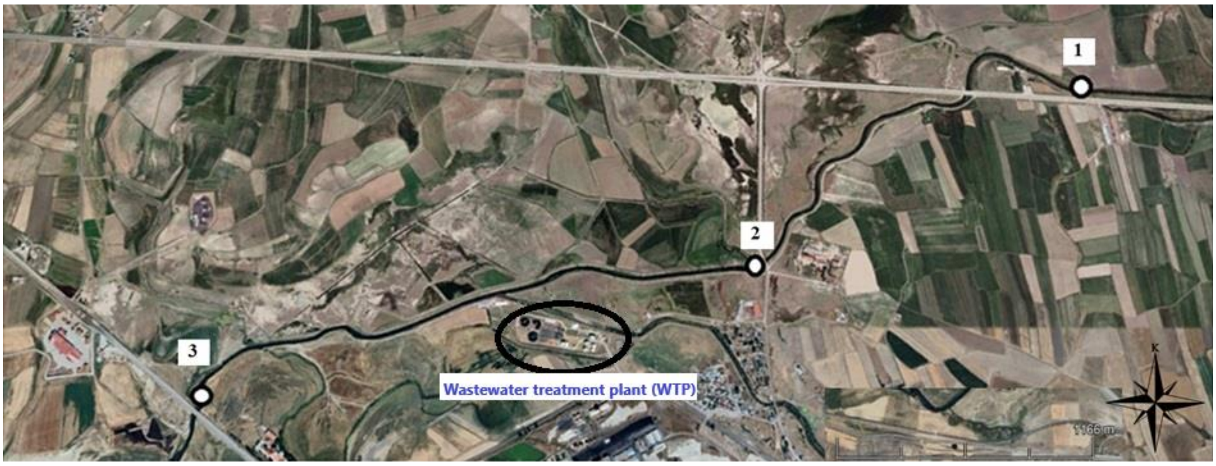

Figure 1. Map showing the Karasu River and stations (Water flow direction from 1 to 3).

Table 1. Coordinates of the stations.

Station	Latitude and Longitude
1	39°58'02"N 41°07'29"E
2	39°57'32"N 41°06'10"E
3	39°57'11"N 41°04'17"E

2.2. Field and Laboratory Studies

In this study, water samples were taken from 3 stations in the Karasu River within the borders of Erzurum Province between October 2022 and September 2023 with polyethylene sampling containers. Water temperature, DO, pH and electrical conductivity were recorded *in situ* using a multi-parameter measuring device (YSI Model).

The total suspended solid amount was determined by the Gravimetric method. Biochemical Oxygen Demand (BOD) was assayed by Manometric/SM 5210 B and Manometry method. BOD analysis was determined time period as 5 days. Chemical oxygen demand (COD) was determined by the Titrimetric/SM 5220 B Ready Kit Method. Total nitrogen (TN) was quantified using the Spectrometric/ISO 29441 Ready Kit Method. Ammonium (NH_4), Ammonium Nitrogen, Nitrate and Nitrate Nitrogen determinations were performed with the Spectrometric/SM 4500 Ready Kit Method. Total hardness was analysed by SM 4500 ready-made kits.

2.3. Data Evaluation

The changes in the data obtained throughout the study based on the season and stations were determined by One-Way (ANOVA) test using IBM SPSS 20. The significance levels of the differences were evaluated according to the DUNCAN test.

3. Results

Throughout the study, the changes in dissolved oxygen, electrical conductivity and water temperature values depending on the season and stations were found to be statistically significant ($p<0.05$). However, while the difference in pH value between seasons was found to be statistically significant ($p<0.05$), the difference between stations was statistically insignificant ($p>0.05$). The lowest pH value was measured as 7.54, and the highest value was 7.95. During the study period, the lowest electrical conductivity value measured during fieldwork was 214, and the highest was 578, whereas the lowest dissolved oxygen value was 3.02 mg/L and the highest was 8.74 mg/L. The lowest water temperature in the Karasu River was determined to be 3.4 °C, and the highest was 22.2 °C (Table 2).

Table 2. Changes in pH, dissolved oxygen, electrical conductivity and water temperature values of Karasu River depending on months and stations (Mean±Standard deviation).

Month	Station	pH	Dissolved oxygen (mg/l)	Electrical conductivity (µS/cm)	Water temperature (ºC)
October	1	7.60±0.33^{Cb}	5.62±0.43^{Ia}	346±4.68^{Kb}	16.5±1.66^{Kc}
	2	7.62 ± 0^{Ca}	5.27±0$^{\text{İ}c}$	346±0^{Kb}	16 ± 0^{Aa}
	3	7.63±0.01^{Ca}	5.77±0.54^{Ia}	367.50±23.60^{Ka}	15±1.10^{Ab}
November	1	7.65±0.03^{Ba}	6.26±0.86^{Ia}	424.33±87.26^{Aa}	14.67±1^{Aa}
	2	7.64±0.02^{Ca}	6.17±0.75^{Hb}	402.50±84.25^{Gb}	13.25±2.70^{Bb}
	3	7.66±0.04^{Ba}	6.27±0.69^{Fa}	395.40±76.11^{Hc}	12.32±3.07^{Cc}
December	1	7.65±0.03^{Ba}	6.36±0.66^{Ga}	412.83±79.87^{Ea}	11.83±3.00^{Ca}
	2	7.64±0.05^{Ca}	6.32±0.62^{Ga}	403.14±77.55^{Fb}	10.86±3.70^{Eb}
	3	7.63±0.05^{Ca}	6.32±0.58^{Ea}	397.75±73.77^{Gc}	10.10±4.01^{Fc}
January	1	7.63±0.05^{Ca}	6.33±0.54^{Hb}	409.11±76.72^{Ga}	9.64±3.99^{Fa}
	2	7.62±0.05^{Ca}	6.39±0.55^{Fa}	403.20±74.85^{Eb}	9.08±4.16^{Hb}
	3	7.61±0.05^{Ca}	6.42±0.53^{Da}	400.09±71.95^{Dc}	8.56±4.29$^{\text{İ}c}$
February	1	7.61±0.05^{Ca}	6.48±0.54^{Fc}	411.33±78.51^{Fa}	8.33±4.18$^{\text{İ}a}$
	2	7.61±0.05^{Ca}	6.65±0.80^{Cb}	405.15±78.40^{Db}	8.22±4.03^{Jb}
	3	7.62±0.05^{Ca}	6.79±0.93^{Aa}	402.29±76.20^{Cc}	8.14±3.89^{Kc}
March	1	7.62±0.05^{Ca}	6.92±1.02^{Ba}	414±85.88^{Da}	8.06±3.77^{Jc}
	2	7.64±0.09^{Ca}	6.86±1.02^{Ab}	413.94±83.10^{Bc}	8.18±3.67^{Kb}
	3	7.65±0.11^{Ba}	6.81±1.00^{Ac}	414.41±80.59^{Bb}	8.27±3.58^{Ja}
April	1	7.66±0.10^{Aa}	6.81±0.98^{Ca}	417.89±79.60^{Ba}	8.38±3.51^{Ic}
	2	7.67±0.12^{Aa}	6.76±0.98^{Bb}	417.63±77.45^{Ab}	8.53±3.47$^{\text{İ}b}$
	3	7.69±0.13^{Aa}	6.75±0.95^{Bb}	417.25±75.47^{Ac}	8.67±3.43^{Ia}
May	1	7.69±0.13^{Aa}	6.76±0.93^{Da}	416.33±73.74^{Ca}	8.80±3.40^{Hc}
	2	7.70±0.13^{Aa}	6.74±0.91^{Ba}	407.14±83.61^{Cb}	9.04±3.51^{Ib}
	3	7.70±0.13^{Aa}	6.73±0.89^{Ba}	398.83±90.68^{Fc}	9.27±3.60^{Ha}
June	1	7.70±0.13^{Aa}	6.73±0.87^{Da}	393.63±92.23$^{\text{İ}a}$	9.48±3.67^{Gc}
	2	7.70±0.12^{Aa}	6.67±0.90^{Cb}	391.48±90.96$^{\text{İ}b}$	9.76±3.84^{Gb}
	3	7.70±0.12^{Aa}	6.63±0.91^{Cb}	389.96±89.50^{Jc}	10.00±3.96^{Ga}
July	1	7.70±0.12^{Aa}	6.62±0.89^{Ea}	391.19±88.03^{Ja}	10.24±4.08^{Ec}
	2	7.70±0.12^{Aa}	6.52±1.00^{Eb}	390.50±86.50^{Jb}	10.64±4.50^{Fb}
	3	7.70±0.12^{Aa}	6.46±1.03^{Dc}	390.31±84.98$^{\text{İ}c}$	11.01±4.85^{Ea}
August	1	7.70±0.11^{Aa}	6.39±1.08^{Ga}	394.93±87.21^{Ia}	11.39±5.18^{Dc}
	2	7.70±0.11^{Aa}	6.30±1.18^{Gb}	394.90±85.77^{Ia}	11.68±5.34^{Db}
	3	7.70±0.11^{Aa}	6.22±1.22^{Gc}	394.66±84.42^{Ib}	11.95±5.48^{Da}
September	1	7.70±0.11^{Aa}	6.19±1.23$^{\text{İ}a}$	399.55±87.64^{Ha}	12.22±5.61^{Bc}
	2	7.70±0.11^{Aa}	6.09±1.33^{Ib}	399.26±86.35^{Hb}	12.36±5.58^{Cb}
	3	7.70±0.11^{Aa}	6.02±1.38^{Hc}	399.29±85.09^{Eb}	12.48±5.55^{Ba}

A, B, C, D, E, F, G, H, I, J, K, L Capital letters indicate the difference between months, and the difference between means having different letters in the same column is statistically significant ($p<0.05$).
a, b, c Lowercase letters indicate within the same month the difference between stations, and the difference between means having different letters the same column is statistically significant ($p<0.05$).

In this study, the changes in total hardness, COD, BOD, and TSS values depending on the season and stations were found to be statistically significant ($p<0.05$). The lowest total hardness change was measured as 127 mg/l $CaCO_3$, the highest was 195 mg/l $CaCO_3$; the lowest COD value was measured as 14.4 mg/l, the highest was 130 mg/l, the lowest BOD value was measured as 9 mg/l, the highest was 90 mg/l, the lowest TSS was measured as 3 mg/l and the highest was 455 mg/l (Table 3).

Table 3. Changes in total hardness, COD, BOD and TSS values of Karasu River depending on months and stations (Mean±Standard deviation).

Month	Station	Total hardness (mg/l $CaCO_3$)	COD (mg/l)	BOD (mg/l)	TSS (mg/l)
October	1	139.87±107.64^{Jc}	19.18±106.66^{Aa}	16.51±102.11^{Aa}	14.70±98.29^{Ea}
	2	142.00±0^{Kb}	17.40±0^{Ib}	10.00±0Jb	8.00±0^{Kb}
	3	150.00±8.76^{Ka}	17.20±0.22$^{\text{İc}}$	9.50±0.55^{Kc}	6.50±1.64^{Kc}
November	1	165.00±23.54^{Ab}	18.00±1.21^{Ha}	10.00±0.87^{Ja}	11.00±6.87$^{\text{İa}}$
	2	165.25±20.08^{Aa}	17.58±1.29^{Hb}	10.00±0.74^{Ja}	10.25±6.02^{Jb}
	3	160.40±20.44^{Ac}	16.94±1.74^{Kc}	9.80±0.77^{Jb}	10.20±5.33$^{\text{İb}}$
December	1	161.17±18.63^{Ba}	17.22±1.70^{Ja}	10.17±1.10$^{\text{İb}}$	13.50±9.00^{Ga}
	2	158.86±18.13^{Bb}	17.04±1.63^{Jb}	10.14±1.01$^{\text{İc}}$	12.43±8.73^{Fb}
	3	156.50±18.07^{Bc}	17.04±1.52^{Jb}	10.25±0.99$^{\text{İa}}$	11.75±8.34^{Gc}
January	1	155.78±17.12^{Ca}	17.26±1.56^{Ja}	10.44±1.09^{Ib}	12.67±8.28^{Ha}
	2	153.70±17.40^{Gb}	17.23±1.48$^{\text{İb}}$	10.50±1.04^{Ia}	11.90±8.18^{Hb}
	3	153.55±16.58^{Gc}	17.30±1.43^{Ia}	10.55±1.00^{Ia}	11.27±8.04^{Hc}
February	1	154.00±15.92^{Ea}	17.69±1.90^{Ia}	10.83±1.36^{Ha}	10.92±7.78^{Ja}
	2	152.23±16.49$^{\text{İb}}$	17.56±1.88^{Hb}	10.77±1.33^{Hb}	10.31±7.77$^{\text{İb}}$
	3	151.43±16.15$^{\text{İc}}$	17.41±1.89^{Hc}	10.75±1.28^{Hb}	9.93±7.61^{Jc}
March	1	152.87±16.51^{Hc}	17.56±1.90$^{\text{İc}}$	10.87±1.31^{Hc}	9.97±7.34^{Kc}
	2	153.94±16.51^{Fa}	18.71±4.87^{Gb}	11.63±3.23^{Gb}	10.47±7.37^{Ib}
	3	153.82±16.02^{Fb}	19.61±5.96^{Ga}	12.24±3.98^{Ga}	10.85±7.31a^{I}
April	1	153.89±15.56^{Fb}	20.41±6.68^{Gc}	12.72±4.37^{Gc}	11.14±7.20^{Ic}
	2	154.47±15.34^{Ca}	20.76±6.66^{Fb}	12.95±4.36^{Fb}	12.03±7.97^{Gb}
	3	154.45±14.95^{Ca}	21.17±6.74^{Fa}	13.20±4.39^{Fa}	13.33±9.64^{Fa}
May	1	154.62±14.60^{Da}	21.64±6.90^{Fc}	13.52±4.52^{Fc}	15.45±13.43^{Fc}
	2	154.32±14.33^{Db}	26.56±23.72^{Eb}	17.00±16.65^{Db}	35.43±93.19^{Eb}
	3	153.91±14.14^{Ec}	30.63±30.11^{Ca}	19.65±20.54^{Ca}	51.89±119.78^{Ca}
June	1	153.75±13.86^{Ga}	33.10±31.79^{Ba}	21.33±21.68^{Ba}	63.90±130.78^{Aa}
	2	153.12±13.93^{Hb}	32.80±31.18^{Ab}	21.14±21.26^{Ab}	62.14±128.39^{Ab}
	3	152.27±14.31^{Ic}	32.44±30.62^{Ac}	20.90±20.87^{Ac}	60.56±126.12^{Ac}
July	1	152.15±14.05$^{\text{İa}}$	32.23±30.06^{Ca}	20.76±20.49^{Ca}	59.65±123.82^{Ba}
	2	151.25±14.57^{Jb}	31.68±29.65^{Bb}	20.41±20.20^{Bb}	57.77±121.96^{Bb}
	3	151.24±14.32^{Jb}	31.12±29.28^{Bc}	20.05±19.94^{Bc}	55.98±120.19^{Bc}
August	1	152.37±15.34^{Ib}	30.89±28.81^{Da}	19.90±19.62^{Da}	54.45±118.44^{Ca}
	2	152.35±15.08^{Ib}	30.47±28.43^{Cb}	16.91±19.36^{Ec}	52.85±116.82^{Cb}
	3	152.72±14.98^{Ha}	30.05±28.07^{Dc}	19.31±19.12^{Db}	51.45±115.23^{Dc}
September	1	154.00±16.45^{Ec}	29.81±27.67^{Ea}	19.15±18.85^{Ea}	50.32±113.63^{Da}
	2	154.24±16.26^{Eb}	29.55±27.30^{Db}	18.97±18.60^{Cb}	49.01±112.19^{Db}
	3	154.31±16.03^{Da}	29.22±26.97^{Ec}	18.74±18.38^{Ec}	47.76±110.80^{Ec}

A, B, C, D, E, F, G, H, I, J, K, L Capital letters indicate the difference between months, and the difference between means having different letters in the same column is statistically significant ($p<0.05$).
a, b, c Lowercase letters indicate within the same month the difference between stations, and the difference between means having different letters the same column is statistically significant ($p<0.05$).

In this study we conducted in the Karasu River, the changes in total nitrogen, nitrate, nitrate nitrogen, ammonium, and ammonium nitrogen depending on the season and stations were found to be statistically significant ($p<0.05$). The mean total nitrogen concentration was determined as 4.75 mg/L. It was determined that total nitrogen concentration increased in February and March during the research period. In our work, the lowest nitrate concentration was measured as 2.15 mg/L and the highest as 7.06 mg/L. On the other hand, the lowest nitrate nitrogen concentration was determined as 0.48 mg/L and the highest as 2.83 mg/L. Nitrate concentration, similar to the total nitrogen concentration, was found to be higher in February and March than in other months. The mean values of ammonium and ammonium nitrogen concentrations were measured as 3 mg/L and 2.24 mg/L, respectively (Table 4).

Table 4. Changes in TN, NO_3, NO_3-N, NH_4, NH_4-N concentrations of Karasu River depending on months and stations (Mean±Standard Deviation, mg/L).

Month	Station	TN	NO_3	NO_3-N	NH_4	NH_4-N
October	1	4.82 ± 0.40^{Aa}	5.47 ± 0.19^{Aa}	1.96 ± 0.02^{Aa}	3.58 ± 0.67^{Aa}	2.32 ± 0.06^{Aa}
	2	4.36 ± 0^{Fb}	4.94 ± 0^{Kb}	1.12 ± 0^{Eb}	3.05 ± 5.44^{Ac}	2.37 ± 0^{Bc}
	3	4.41 ± 0.05^{Eb}	4.78 ± 0.18^{Jc}	1.08 ± 0.05^{Gc}	3.58 ± 0.58^{Ab}	2.78 ± 0.45^{Ab}
November	1	4.45 ± 0.08^{Ha}	5.54 ± 1.15^{İb}	1.25 ± 0.27^{Fa}	3.19 ± 0.74^{Ba}	2.48 ± 0.57^{Ba}
	2	4.37 ± 0.16^{Eb}	5.48 ± 0.99^{İc}	1.24 ± 0.23^{Da}	3.04 ± 0.69^{Ab}	2.36 ± 0.54^{Bb}
	3	4.39 ± 0.15^{Eb}	5.64 ± 0.94^{Ha}	1.27 ± 0.22^{Ea}	2.95 ± 0.64^{Cc}	2.29 ± 0.49^{Cc}
December	1	4.51 ± 0.31^{Gc}	6.52 ± 2.19^{Eb}	1.47 ± 0.50^{Ca}	2.77 ± 0.71^{Fb}	2.15 ± 0.55^{Ec}
	2	4.58 ± 0.34^{Db}	6.36 ± 2.06^{Ea}	1.43 ± 0.47^{Ba}	2.81 ± 0.66^{Da}	2.23 ± 0.55^{Cb}
	3	4.65 ± 0.37^{Ca}	6.24 ± 1.94^{Ec}	1.40 ± 0.45^{Cb}	2.83 ± 0.62^{Ea}	2.30 ± 0.54^{Ca}
January	1	4.77 ± 0.48^{Eb}	6.83 ± 2.49^{Ca}	1.54 ± 0.58^{Ba}	2.85 ± 0.59^{Ec}	2.31 ± 0.51^{Db}
	2	4.81 ± 0.47^{Bb}	6.70 ± 2.38^{Cb}	1.51 ± 0.55^{Aa}	2.93 ± 0.60^{Cb}	2.36 ± 0.50^{Ba}
	3	4.87 ± 0.49^{Ba}	6.57 ± 2.31^{Cc}	1.48 ± 0.54^{Bb}	2.99 ± 0.61^{Ca}	2.40 ± 0.50^{Ba}
February	1	5.01 ± 0.66^{Ca}	7.06 ± 2.76^{Ba}	1.59 ± 0.64^{Ba}	3.01 ± 0.58^{Db}	2.41 ± 0.48^{Ca}
	2	5.00 ± 0.64^{Aa}	6.93 ± 2.69^{Ab}	1.56 ± 0.62^{Aa}	3.05 ± 0.58^{Aa}	2.43 ± 0.46^{Aa}
	3	5.01 ± 0.61^{Aa}	6.84 ± 2.62^{Ac}	1.54 ± 0.60^{Aa}	3.08 ± 0.57^{Ba}	2.45 ± 0.45^{Ba}
March	1	5.07 ± 0.64^{Ba}	7.03 ± 2.63^{Ba}	1.59 ± 0.60^{Ba}	3.08 ± 0.55^{Ca}	2.44 ± 0.44^{Ba}
	2	4.97 ± 0.72^{Ab}	6.89 ± 2.60^{Bb}	1.56 ± 0.60^{Aa}	2.99 ± 0.63^{Bb}	2.37 ± 0.51^{Bb}
	3	4.89 ± 0.77^{Bc}	6.73 ± 2.60^{Bb}	1.52 ± 0.60^{Ab}	2.92 ± 0.68^{Dc}	2.31 ± 0.55^{Cc}
April	1	4.83 ± 0.80^{Da}	6.65 ± 2.55^{Da}	1.50 ± 0.59^{Ca}	2.88 ± 0.68^{Ea}	2.27 ± 0.56^{Da}
	2	4.73 ± 0.87^{Cb}	6.52 ± 2.54^{Db}	1.47 ± 0.58^{Ba}	2.79 ± 0.77^{Db}	2.20 ± 0.63^{Cb}
	3	4.66 ± 0.90^{Cc}	6.40 ± 2.53^{Dc}	1.45 ± 0.58^{Ba}	2.71 ± 0.82^{Fc}	2.14 ± 0.66^{Dc}
May	1	4.63 ± 0.89^{Fa}	6.33 ± 2.49^{Fa}	1.43 ± 0.57^{Da}	2.67 ± 0.82^{Ga}	2.11 ± 0.66^{Ea}
	2	4.58 ± 0.90^{Db}	6.27 ± 2.44^{Fb}	1.42 ± 0.56^{Ba}	2.65 ± 0.81^{Fb}	2.09 ± 0.65^{Da}
	3	4.54 ± 0.90^{Db}	6.22 ± 2.40^{Eb}	1.40 ± 0.55^{Ca}	2.63 ± 0.79^{Gc}	2.08 ± 0.64^{Ea}
June	1	4.48 ± 0.93^{Ha}	6.15 ± 2.38^{Ga}	1.39 ± 0.54^{Da}	2.60 ± 0.80^{Ha}	2.05 ± 0.65^{Fa}
	2	4.42 ± 0.96^{Eb}	6.04 ± 2.39^{Gb}	1.36 ± 0.55^{Ca}	2.55 ± 0.82^{Ga}	2.01 ± 0.66^{Fa}
	3	4.37 ± 0.97^{Fb}	5.94 ± 2.39^{Fc}	1.34 ± 0.55^{Da}	2.51 ± 0.83^{Gb}	1.98 ± 0.67^{Fb}
July	1	4.37 ± 0.95^{Ia}	5.91 ± 2.35^{Ha}	1.34 ± 0.54^{Ea}	2.50 ± 0.81^{Ia}	1.96 ± 0.66^{Ga}
	2	4.36 ± 0.94^{Fa}	5.81 ± 2.38^{Hb}	1.31 ± 0.54^{Ca}	2.53 ± 0.81^{Ga}	1.99 ± 0.66^{Fa}
	3	4.36 ± 0.92^{Fa}	5.71 ± 2.39^{Gc}	1.29 ± 0.55^{Da}	2.54 ± 0.80^{Ha}	2.00 ± 0.65^{Fa}
August	1	4.39 ± 0.93^{Ia}	5.64 ± 2.38^{Ia}	1.27 ± 0.54^{Fa}	2.61 ± 0.87^{Hb}	2.05 ± 0.70^{Fa}
	2	4.39 ± 0.91^{Ea}	5.54 ± 2.41^{Ib}	1.25 ± 0.55^{Da}	2.64 ± 0.88^{Fa}	2.07 ± 0.70^{Ea}
	3	4.39 ± 0.90^{Ea}	5.45 ± 2.43^{Ic}	1.23 ± 0.55^{Ea}	2.66 ± 0.87^{Fa}	2.09 ± 0.69^{Ea}
September	1	4.41 ± 0.89^{Ia}	5.47 ± 2.39^{Ja}	1.24 ± 0.55^{Fa}	2.68 ± 0.86^{Gb}	2.10 ± 0.68^{Eb}
	2	4.42 ± 0.88^{Ea}	5.38 ± 2.43^{Jb}	1.21 ± 0.55^{Da}	2.71 ± 0.88^{Ea}	2.13 ± 0.69^{Da}
	3	4.44 ± 0.87^{Ea}	5.28 ± 2.45^{İc}	1.19 ± 0.56^{Fa}	2.75 ± 0.89^{Fa}	2.16 ± 0.71^{Da}

A, B, C, D, E, F, G, H, I, J, K, L Capital letters indicate the difference between months, and the difference between means having different letters in the same column is statistically significant ($p<0.05$).
a, b, c Lowercase letters indicate within the same month the difference between stations, and the difference between means having different letters the same column is statistically significant ($p<0.05$).

4. Discussion and Conclusion

Water samples were taken from the sections of Karasu River before and after the Erzurum Province Wastewater Treatment Plant, and nitrogen and nitrogen fractions were analysed. During our research, the *in situ* mean water temperature was 13.8 ˚C, the mean pH value was 7.7, the mean electrical conductivity was 403 µs/cm, and the mean dissolved oxygen value was 6 mg/l. The mean total suspended solids (TSS) amount was determined as 46.7 mg/l, the mean chemical oxygen demand (COD) concentration was 28.9 mg/l, the mean biological oxygen demand (BOD) concentration was 18.5 mg/l, the mean total nitrogen (TN) concentration was 4.47 mg/l, the mean nitrate (NO_3) concentration was 5.35 mg/l, the mean nitrate nitrogen (NO_3-N) concentration was 1.21 mg/l, the mean total hardness (TH) was 155 mg/l, the mean ammonium (NH_4) concentration was 2.75 mg/l, the mean ammonium nitrogen (NH_4-N) concentration was 2.16 mg/L.

When the data obtained in this research was evaluated according to the Intra-Continental Surface Water Standards (Orman ve Su İşleri Bakanlığı, 2015), it was determined that the Karasu River water was in Class I waters according to the water temperature and the nitrate nitrogen. pH, electrical conductivity and COD in the Class II waters according to the dissolved oxygen value, in the Class III waters according to the BOD and total nitrogen value and in the Class IV waters according to and ammonium nitrogen concentrations (Table 5).

Table 5. Intra-Continental Surface Water Standards (Orman ve Su İşleri Bakanlığı, 2015) and the Karasu River water class.

Parameter	I. Class	II. Class	III. Class	IV. Class	Water quality of Karasu River	Class
Water temperature (°C)	≤ 25	≤ 25	30 ≤	30 ≤	*13.8*	*I.*
pH	6.5-8.5	6.5-8.5	6.0-9.0	< 6.0 or > 9.0	*7.7*	*II.*
Electrical conductivity (µS/cm)	< 400	1000	3000	> 3000	*403*	*II.*
NH_4-N (mg/L)	< 0.2	1	2	> 2	*2.16*	*IV.*
NO_3-N (mg/L)	< 5	10	20	> 20	*1.21*	*I.*
TN (mg/L)	< 0.5	1.5	5	> 5	*4.47*	*III.*
BOD (mg/L)	< 4	8	20	> 20	*18.5*	*III.*
COD (mg/L)	< 25	50	70	> 70	*28.9*	*II.*

In a study investigating heavy metal pollution in the Karasu River, various heavy metals such as Copper (Cu), Zinc (Zn), Manganese (Mn), Lead (Pb), Nickel (Ni), Cadmium (Cd) and Iron (Fe) were assayed. Researchers reported that the water quality of the water samples was in classes IV, IV, IV, II and II, respectively (Sönmez et al., 2013). In another study evaluating the river according to its heavy metal concentrations, it was reported that the river faces intense pollution elements and that if the situation continued, the ecological balance could be negatively impacted (Sönmez et al., 2012). Similarly, in this research, it was determined that it is in the I, II, III and IV water classes.

In this study, when the differences between the stations were examined, it was determined that although higher values were measured from station 1 due to the season, the values at station 3 were measured lower. When we look at the values of TN, ammonia nitrogen and nitrate nitrogen in particular, the average values were found to be 0,96 mg/L, 2,61 mg/L, 4,17 mg/L at 1st station respectively, while these values 1,69 mg/L, 2,50 mg/L, 7,45 mg/L were found to be at 3rd station. However, the decrease in the concentration of ammonia nitrogen and the increase in the concentration of nitrate nitrogen, which is used by plants, may also affect the low plant biomass in the 3rd stations. Meanwhile, when COD and BOD values were compared, it was determined that the values at the 3rd station (28.78 mg/L and 18.42 mg/L) were lower than the values at the 1st station (29.77 mg/L and 19.38 mg/L). As a result of this indicates that the water quality of the Karasu River did not change or little different of water quality parameter, and some parameters were lower than 1st station after the treatment plant outlet water and that the treatment plant made a positive contribution. The Karasu River is not used source as a drinking water. In this research was measured the high levels of nitrogen and its fractions in the river, and its showed that there is an anthropogenic effect on there. For this reason, mass fish deaths, increased mosquito formation and diarrhea-like illnesses are observed, especially during periods when temperatures increase

In addition to this, in a study conducted between December 2015 and November 2016, it was determined that the water quality of the Karasu River exceeded the limit values for NH_4-N, BOD_5, Co, fecal coliform, Ba, Cu, Zn and dissolved oxygen parameters according to the regulation on the quality of surface waters and that they are the main parameters affecting the quality of the water. Alver and Baştürk (2019) reported that the water quality of the Karasu River was determined to be "moderate" according to the National Sanitation Foundation Water Quality Index (NSF WQI), "poor" according to the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) and "poor" according to the Oregon Water Quality Index (OWQI). However, our current study shows that when all parameters are examined, a medium (III. Class) pollution level is generally determined.

In conclusion, according to some water quality parameter values, the Karasu River is in the I, II, III and IV water classes. It is thought that the river is under the influence of anthropogenic pollutants. Therefore, it is recommended to regularly monitor the river and take the necessary precautions to reduce its effects.

Conflict of Interest

The authors declare that they have no conflict of interest.

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