Effects of hydraulics structures on dissolved oxygen concentration: A case study from the stream Harsit, Eastern Black Sea Basin, Turkey

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Abstract

A sufficient supply of dissolved oxygen (DO) is vital for all higher aquatic life. The problems associated with low concentrations of DO in rivers have been recognized for over a century. The impacts of low DO concentrations or, at the extreme, anaerobic conditions in a normally well oxygenated river system, are an unbalanced ecosystem with fish mortality, odors and other aesthetic nuisances.
The primary aim of this study is to determine the spatial and temporal variation of four physico-chemical variables including DO concentration, water temperature (T), pH and electrical conductivity (EC) in the stream Harsit, Eastern Black Sea Basin, Turkey. For this reason, a study was fortnightly conducted during the four seasons between March 2009 and February 2010 in five monitoring stations. The obtained data are evaluated according to Turkish Water Pollution Control Regulation (TWPCR), and also it is focused on the effects of hydraulics structures, namely Torul CFRD & HEPP, Kurtun CFRD & HEPP, and Dogankent HEPP, and the sand-gravel mining activities on the studied variables.
It was concluded that the stream Harsit has high-quality water according to the TWPCR in terms of DO, T and pH. Torul Dam generated a decrease with 13.18 % in the concentration value, and the minimum DO value with 9.23 mg/L was determined in the station after Torul CFRD and HEPP. However, Kurtun Dam increased the DO as 23.22 %, and the maximum DO value with 11.38 mg/L was obtained in the station after Kurtun CFRD & HEPP. Any negative effect from sand-gravel mining activities between the last two stations on the monitored variables was not observed.

Keywords: *Dissolved oxygen, Stream Harsit, Torul Dam, Kurtun Dam, Water quality*

Introduction

A sufficient supply of dissolved oxygen (DO) is vital for all higher aquatic life. The problems associated with low concentrations of DO in rivers have been recognized for over a century. The impacts of low DO concentrations or, at the extreme, anaerobic conditions in a normally well oxygenated river system, are an unbalanced ecosystem with fish mortality, odors and other aesthetic nuisances [1].
Natural waters in equilibrium with the atmosphere typically contain dissolved oxygen (DO) concentrations in the range from 5 to 15 mg/L O_2 depending on the water temperature, salinity and altitude [2]. The DO concentration present in water reflects atmospheric dissolution, as well

as autotrophic and heterotrophic processes that produce and consume oxygen, respectively. A fluctuation of DO near saturation, with diurnal variation due to the temperature and metabolism, implies relatively healthy waters. By contrast, a marked depression of DO below saturation indicates the stream receiving untreated waste water or an excessive amount of nutrients from non-point source pollution [3,4].

Analysis of DO is extremely important in determining water quality. It provides information on the biological and biochemical reactions occurring in a water body, and is, therefore, an important indicator of stream metabolism [5]. In situ measurements of this parameter can be used as a primary indicator of water quality, and regulatory agencies recommend a minimum DO requirement for maintenance of fish populations, e.g. DO ≥ 6 mg/L measured over at least one diurnal cycle [6].

The temperature of water is a very important parameter because of its effect on chemical reactions and reaction rates, aquatic life, and the suitability of the water for beneficial uses. Increased temperature, for example, can cause a change in the species of fish that can exist in the receiving water body. In addition, oxygen is less soluble in warm water than in cold water. The increase in the rate of biochemical reactions that accompanies an increase in temperature, combined with the decrease in the quantity of oxygen present in surface waters, can often cause serious depletions in DO concentrations in the summer months [7]. Temperature decreases cause an increase in the saturation concentration of DO. Changes in the saturation concentration affect the DO deficit and ultimately the reaeration driving force [8,9].

The aim of this study is to determine DO concentration, T, pH and EC values along with main branch of the stream Harsit, evaluate according to TWPCR, and also assess the effect of hydraulics structures and sand-gravel mining activities on DO concentration.

The study area

In Turkey, there are 26 hydrological basins. With a recharge area of 24,077 km^2, Eastern Black Sea Basin is one of the most important hydrological basins in Turkey, and it is a major part of Caucasus Ecological Region together with Coruh and Aras Basins. Eastern Black Sea Basin consists of sub-watersheds such as the stream Melet, Pazar, Karadere and Firtina watersheds. The biggest of these sub-watersheds is the stream Harsit watershed.

The stream Harşit is formed by small streams joining together and originated from Vauk Mountains in the east border of Gumushane Province. After it is formed, Harsit passes through the towns and cities, namely Tekke, Gumushane, Torul, Ozkurtun, Kurtun and Dogankent, respectively, and poured into the Black Sea in Tirebolu Town. The length of its main branch is 143 km, and its catchment area is 3,280 km^2. There are two dams, namely Torul and Kurtun, and four hydroelectric power plants (HEPPs), namely Torul, Kurtun, Akkoy and Dogankent in operation for now on the stream Harsit.

Torul Dam & HEPP

The Torul concrete faced rock-fill dam (CFRD) is located in 14 km northwest of Torul Town of Gümüşhane Province, on the stream Harsit. Construction of the Torul CFRD and HEPP

(Fig. 1) was started in the year of 2000, completed in 2007, and in operation since 2008. The dam crest is 320 m in length and 12 m in width, and the maximum height and base widths are 142 m and 420 m, respectively. Reservoir area and volume of the Torul Dam in normal water elevation are 3.62 km^2 and 168 hm^3, respectively. Catchment area of the dam is 2,096 km^2. The main purpose of Torul Dam is to provide energy with an annual output of 322 GWh.

Figure 1 Views of the Torul CFRD & HEPP

Kurtun Dam & HEPP

The Kurtun CFRD is also located in 27 km northwest of Torul town of Gümüşhane Province, on the stream Harsit. Construction of the Kurtun CFRD and HEPP (Figure 2) was started in the year of 1995, completed in 2002, and it is in operation since 2003. This dam is the first instrumented CRFD in Turkey. The dam crest is 300 m in length and 12 m in width, and the maximum height and base widths are 133 m and 420 m, respectively. Reservoir area and volume of the Kurtun Dam in normal water elevation are 2.08 km^2 and 80.25 hm^3, respectively. Catchment area of the dam is 2,686 km^2. The main purpose of Kurtun Dam is to provide energy with an annual output of 198 GWh. In the Kurtun Dam Lake, culture fishing activities is also allowed for the area with 45,000 m^2. According to the data in 2008, rainbow trout production is 1500 t/y, but the capacity is 2,658 t/y [10].

Figure 2 Views of the Kurtun CFRD and its spillway

Five monitoring stations were selected along with the main branch of the stream Harsit. The first station was selected before the Torul Dam reservoir, and the second one was after the Torul HEPP. The third one was selected after the Kurtun HEPP and the fourth one was also after the Dogankent HEPP. Finally, the fifth station was selected in Tirebolu Town where sand-gravel mining activities are common, and the stream Harsit poured into the Black Sea. All of the stations are presented in Table 1.

Table 1 Localization of the surface water monitoring stations in the stream Harsit

Monitoring station	Coordinates	Altitude (m)	Km of the course
1. Torul	40° 33' 56.7" N - 39° 17' 54.6" E	910	0.0
2. Torul HEPP	40° 38' 41.1" N - 39° 11' 01.4" E	642	22.5
3. Kurtun HEPP	40° 42' 18.5" N - 39° 04' 11.8" E	497	39.0
4. Dogankent HEPP	40° 49' 18.6" N - 38° 54' 42.5" E	154	62.0
5. Tirebolu	41° 00' 16.1" N - 38° 50' 59.7" E	4	92.0

Materials and methods

Dissolved oxygen concentration (mg/L), temperature (°C), pH and electrical conductivity (mS/cm) were fortnightly determined *in situ* with a water quality checker (Horiba U-10) at five monitoring stations during the studied period (March 2009-February 2010). The studied variables were evaluated according to the intracontinental water quality classifications of the TWPCR which was published in the official gazette of Turkey [11]. The TWPCR divides inland waters into four classes, Class I: high quality water, Class II: slightly polluted water, Class III: polluted water, Class IV: too much polluted water (Table 2).

Table 2 Water quality classification for the studied variables according to the TWPCR

Variables		Intracontinental water quality classifications				Eutrophication control limit values for lakes, lagoons, marshes and dam reservoirs	
		Water quality classes				Usage area	
		Class I	Class II	Class III	Class IV	Reservation Recreation	Different uses
DO	(mg/L)	8	6	3	< 3	7.5	5
T	(°C)	25	25	30	< 30	-	-
pH		6.5 - 8.5	6.5 - 8.5	< 6.0 - > 9.0		6.5 - 8.5	6.0 10.5
EC	(mS/cm)	-	-	-	-	-	-

Results and discussion

Temporal distribution of dissolved oxygen concentration (mg/L) and water temperature (°C) values for each station are shown in Figures 3, 4, 5, 6 and 7, respectively; pH and electrical conductivity values (mS/cm) are shown in Figures 8, 9, 10, 11 and 12, respectively [12].

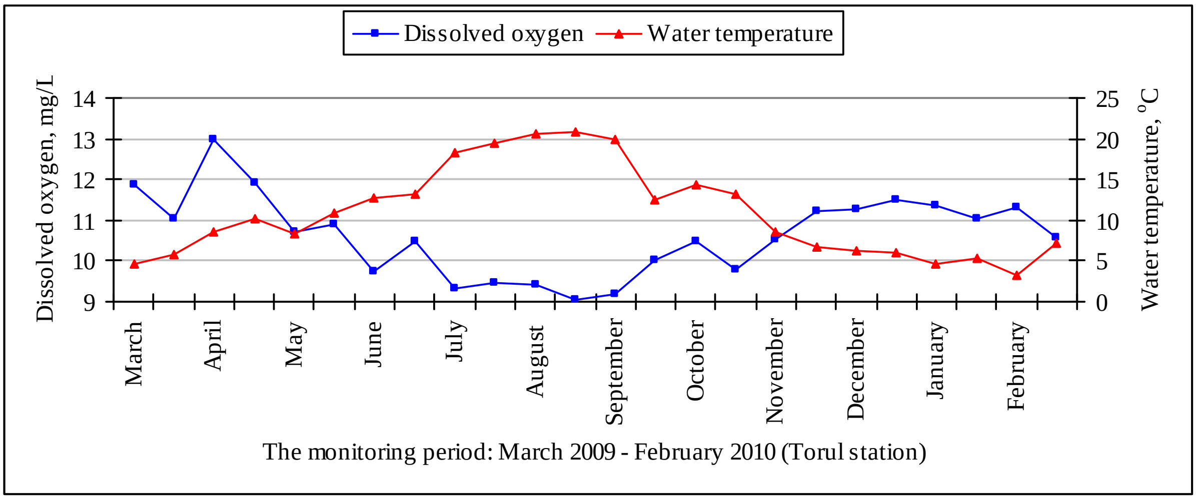

Figure 3 DO concentration and T values in Torul station

For Torul station the yearly average DO concentration value was determined as 10.63 mg/L with a range of 9.06-11.91 mg/L, and T value was 10.9 °C with a range of 3.3-20.9 °C. The lowest DO concentration values were observed in summer months due to the greatest T values. In this station, the stream Harsit has a first class water quality in terms of DO and T according to the TWPCR.

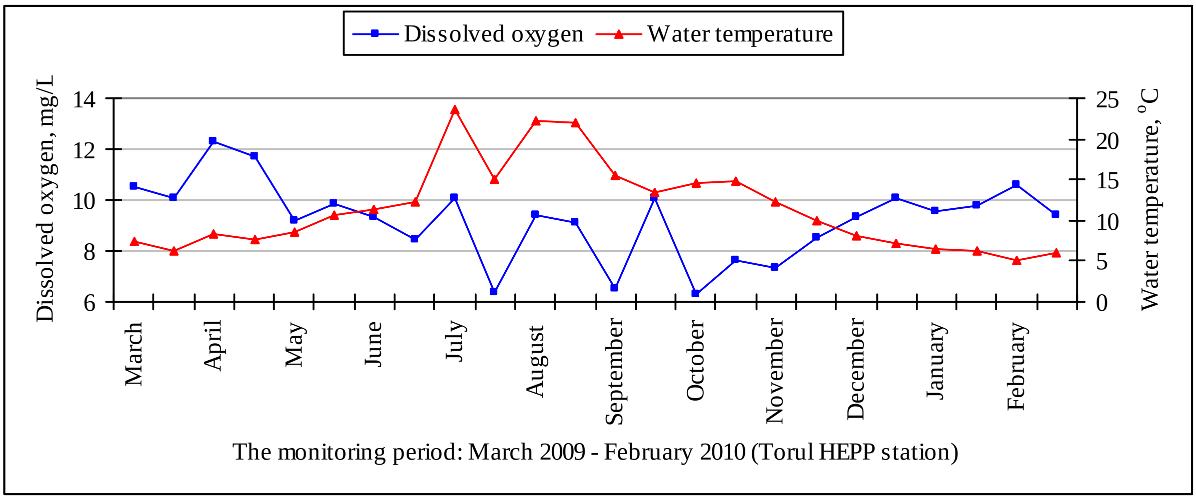

Figure 4 DO concentration and T values in Torul HEPP station

For Torul HEPP station the yearly average DO concentration value was determined as 9.23 mg/L with a range of 6.33-12.29 mg/L, and T value was 11.5 °C with a range of 5.0-23.6 °C.

The lowest DO concentration values were observed in the autumn months. In this station, the stream Harsit has a first class water quality in terms of DO (except for the autumn season) and T according to the TWPCR.

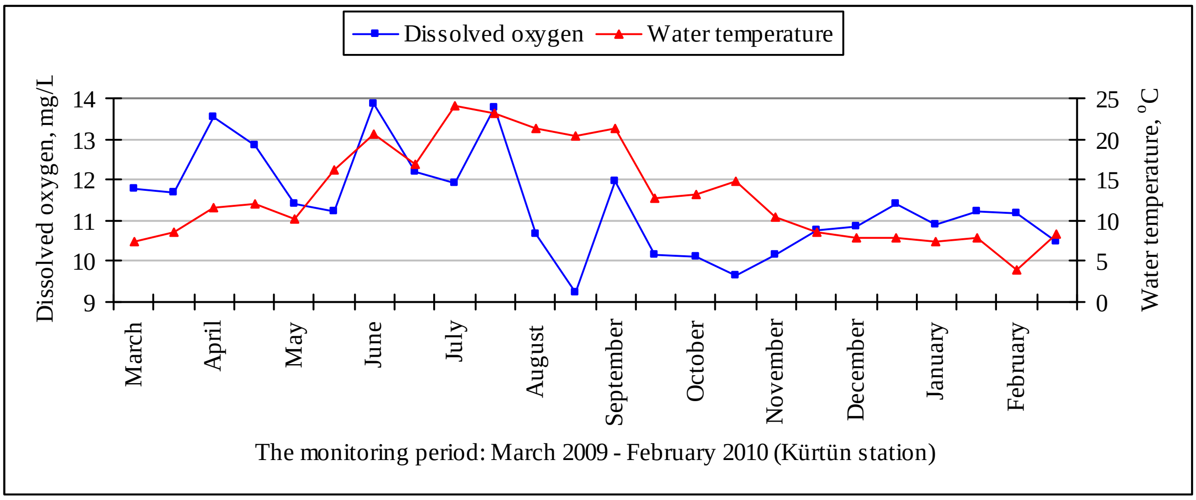

Figure 5 DO concentration and T values in Kurtun station

For Kurtun station the yearly average DO concentration value was determined as 11.34 mg/L with a range of 9.21-13.85 mg/L, and T value was 13.2 °C with a range of 4.0-23.1 °C. The lowest DO concentration values were observed in the autumn months. In this station, the stream Harsit has a first class water quality in terms of DO and T according to the TWPCR.

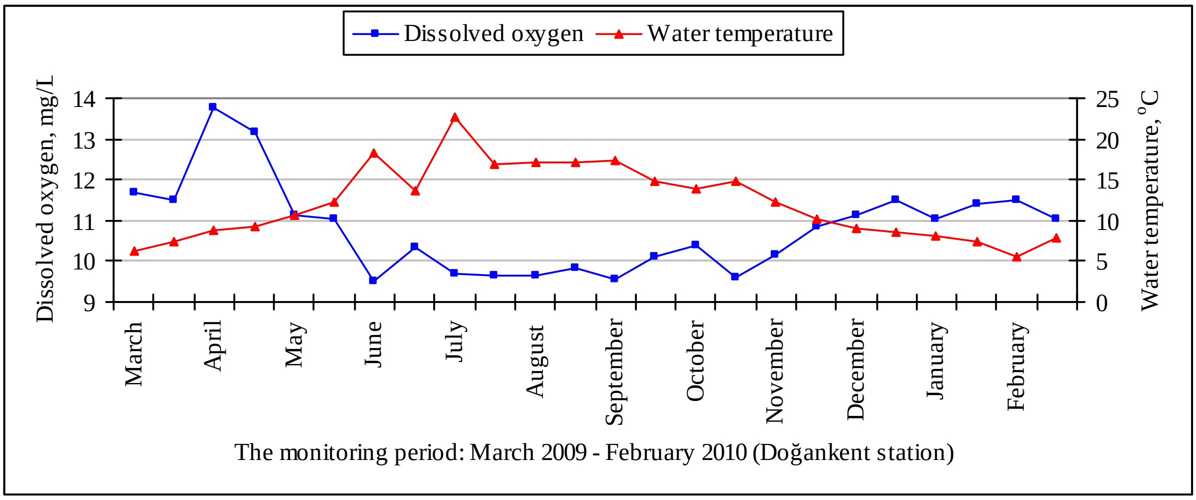

Figure 6 DO concentration and T values in Dogankent station

For Dogankent station the yearly average DO concentration value was determined as 10.81 mg/L with a range of 9.49-13.77 mg/L, and T value was 12.1 °C with a range of 5.5-22.8 °C. The lowest DO concentration values were observed in the summer months due to the greatest temperature values. In this station, the stream Harsit has a first class water quality in terms of DO and T according to the TWPCR.

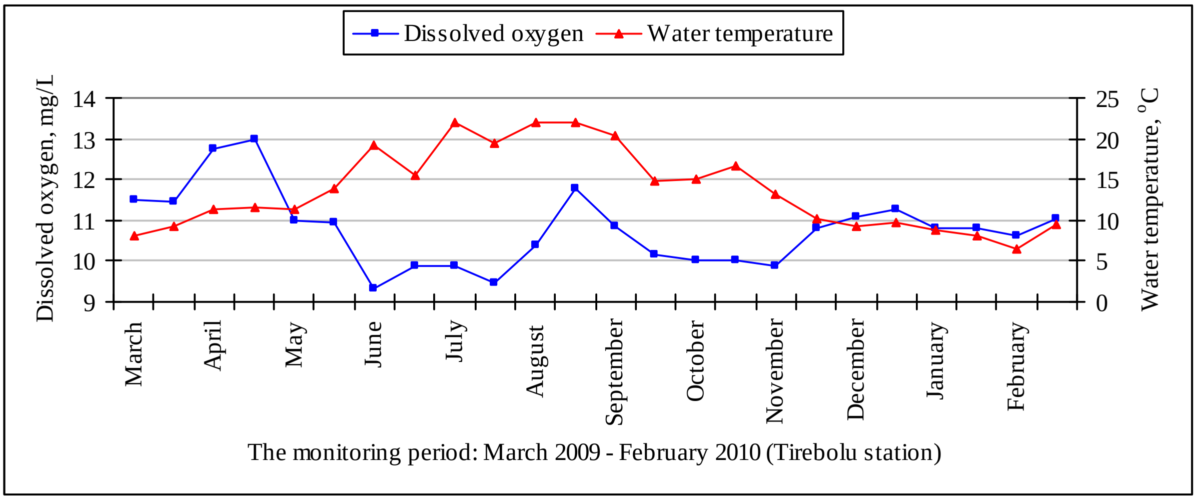

Figure 7 DO concentration and T values in Tirebolu station

For Tirebolu station the yearly average DO concentration value was determined as 10.78 mg/L with a range of 9.34-12.96 mg/L, and T value was 13.7 °C with a range of 6.5-22.0 °C. The lowest DO concentration values were observed in the summer months due to the greatest temperature values. In this station, the stream Harsit has a first class water quality in terms of DO and T according to the TWPCR.

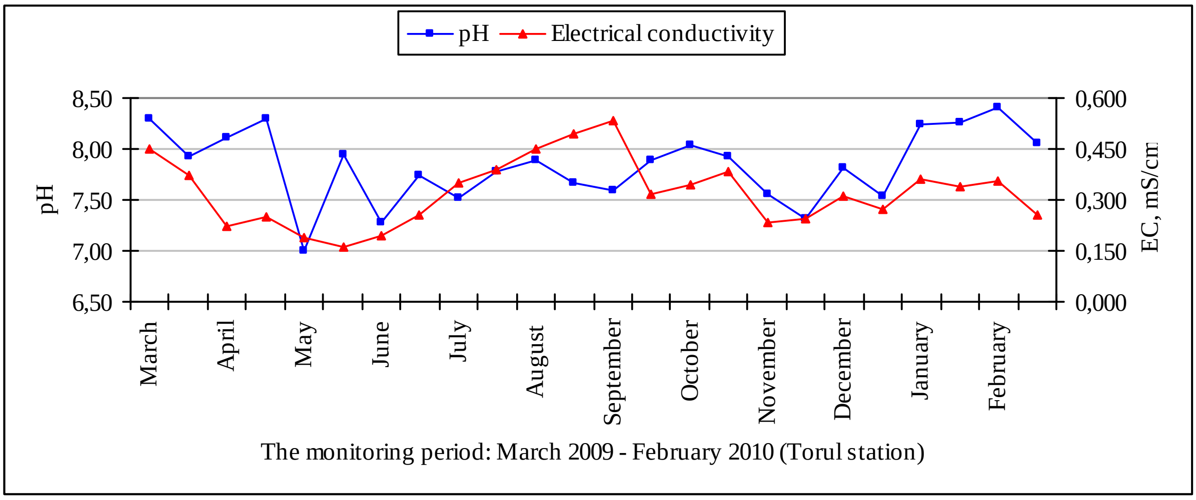

Figure 8 pH and EC values in Torul station

For Torul station, the yearly average pH value was determined as 7.84 with a range of 7.00-8.40, and EC value was 0.322 mS/cm with a range of 0.159-0.533 mS/cm.

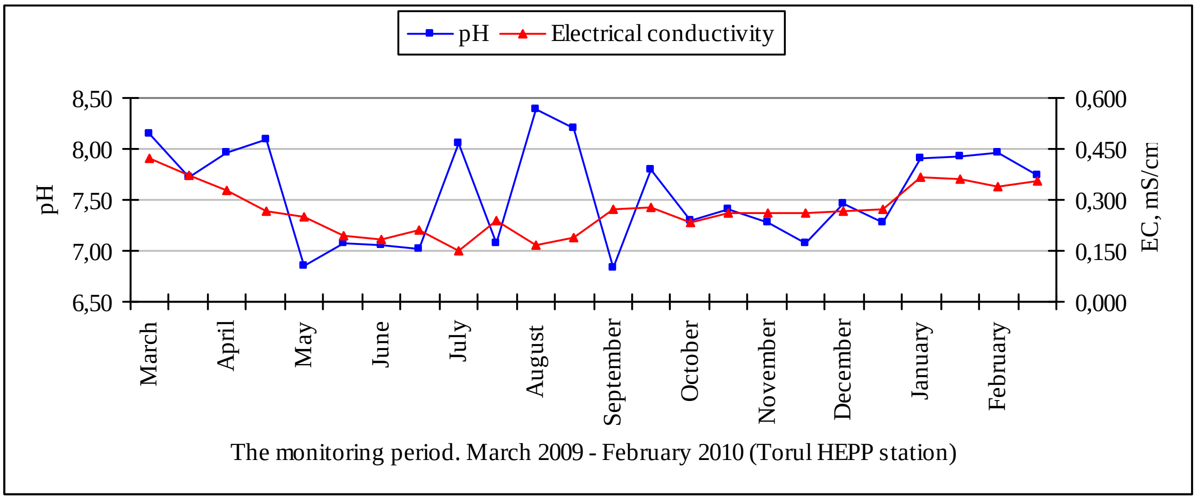

Figure 9 pH and EC values in Torul HEPP station

For Torul HEPP station, the yearly average pH value was determined as 7.57 with a range of 6.83-8.39, and EC value was 0.271 mS/cm with a range of 0.152-0.423 mS/cm.

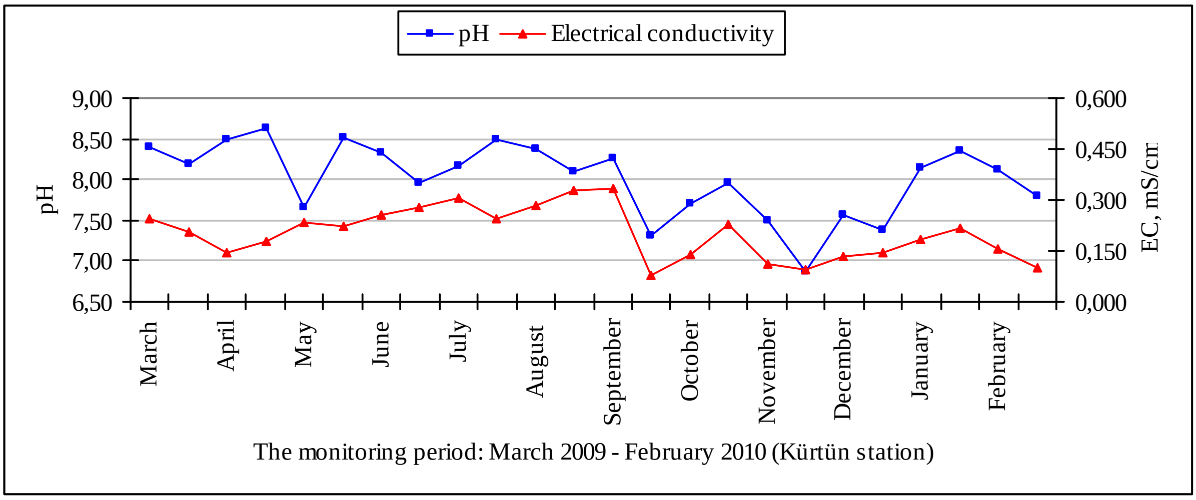

Figure 10 pH and EC values in Kurtun station

For Kurtun station, the yearly average pH value was determined as 8.01 with a range of 6.87-8.63, and EC value was 0.202 mS/cm with a range of 0.078-0.335 mS/cm.

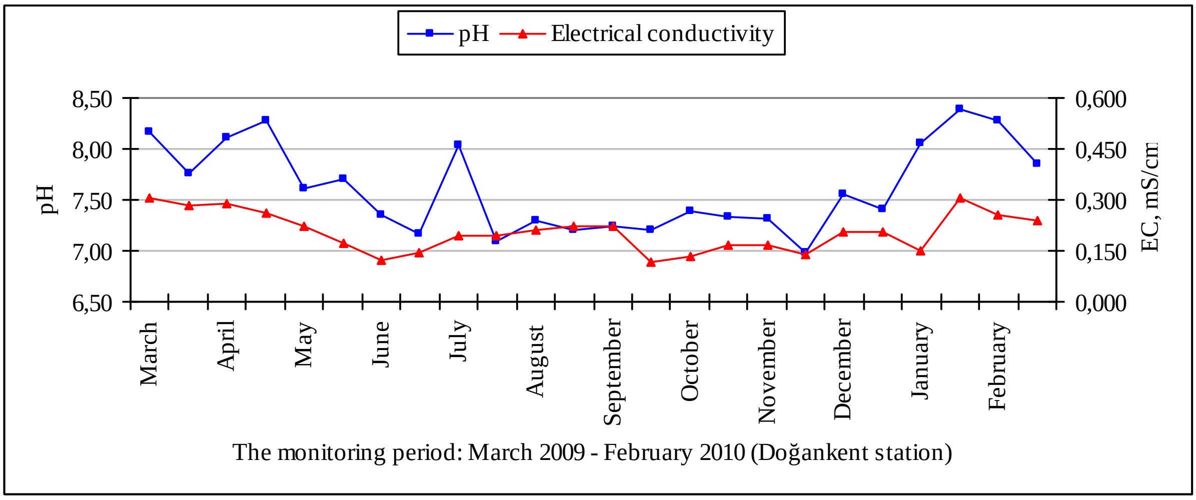

Figure 11 pH and EC values in Dogankent station

For Dogankent station, the yearly average pH value was determined as 7.62 with a range of 6.98-8.38, and EC value was 0.206 mS/cm with a range of 0.114-0.306 mS/cm.

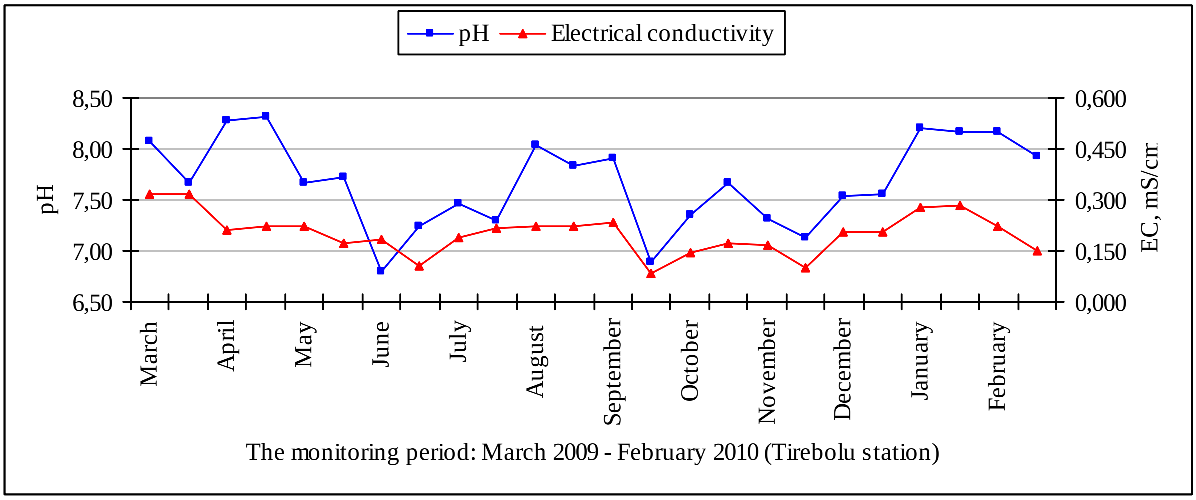

Figure 12 pH and EC values in Tirebolu station

For Tirebolu station, the yearly average pH value was determined as 7.68 with a range of 6.80-8.32, and EC value was 0.202 mS/cm with a range of 0.100-0.319 mS/cm.
pH values for each station are compatible with the values proposed by the TWPCR, and the stream Harsit has also first class water quality in terms of pH.

Conclusion

It was concluded that the stream Harsit has high-quality water according to the TWPCR in terms of DO concentration, temperature and pH. Torul Dam generated a decrease with 13.18 % in the concentration value, and the minimum DO concentration value with 9.23 mg/L was determined in the station after this dam. However, Kurtun Dam increased the DO concentration as 23.22 %, and the maximum concentration value with 11.38 mg/L was obtained in the station after this dam. Any negative effect from sand-gravel mining activities between the last two stations on the monitored variables was not observed.

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