Determination of the Seasonal Water Quality of Aksu Creek (Giresun), Turkey

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Abstract

Aksu Creek, with 752 km^2 watershed, 61 km main channel length and 129.4 km diameter length, is an important water source in the close vicinity of Giresun. Some water quality and sediment parameters of Aksu Creek were determined by taking monthly samples, starting in January 2012 and end up in December 2012. The water quality parameters of dissolved oxygen, pH, temperature, salinity, total dissolved solids (TDS), conductivity, chlorophyll-a, oxidation reduction potential (ORP), biochemical oxygen demand ($BOİ_5$), total alkalinity, total hardness, total ammonia nitrogen (TAN), ammonia, nitrite, nitrate, chloride, total phosphate, soluble reactive phosphorus (SRP), total suspended solids (TSS) were analyzed. Additionally, pH and organic matter contents were measured from sediment samples. The means of obtained data were as follow; dissolved oxygen; 9,85 mgL^{-1}, pH; 7,47, temperature; 12,52°C, salinity; 0,14 ppt, TDS; 0,191 gL^{-1}, conductivity; 290 $mScm^{-1}$, ORP; -93,1 mV, $BOİ_5$; 2,7 mgL^{-1}, total alkalinity; 115,47 mgL^{-1}, total hardness; 156,47 mgL^{-1}, chlorophyll-a; 7,58 ugL^{-1}, TAN; 0,73 mgL^{-1}, ammonia; 0,002 mgL^{-1}, nitrite; 0,011 mgL^{-1}, nitrate; 1,354 mgL^{-1}, chloride; 0,44 mgL^{-1}, total phosphate; 0,672 mgL^{-1}, SRP; 0,045 mgL^{-1}, TSS; 2,954 gL^{-1}. Additionally, Sediment organic matter % and pH were averaged as 3,92 % and 7,4, respectively. Obtained data showed that the water quality of Aksu Creek may suitable for agricultural activities and may be a suitable living habitat for the living beings and getting into the category of mild contaminated according it's average total phosphate rate of 0,56 mgL^{-1} and nitrite rate of 0,011 mgL^{-1}. The creek, however, may be classified as clean water and has no threat regarding to rest of the detected parameters. Potential impacts of extensive agriculture especially hazelnut production, recreation, residential settlements, and other human activities were discussed.

Keywords: Giresun, Aksu Creek, Water Quality, Pollution, Ammonia, Nitrate, Phosphate.

Introduction

The quality and permanence of natural surface waters is a vital issue today. Surface waters are the most vulnerable sources to pollution and worldwide deterioration of water quality from both anthropogenic influences such as urban, industrial and agricultural activities, increasing consumption of water resources and natural processes such as changes in precipitation inputs, erosion, and weathering of crustal materials impair their use for drinking, industrial, agricultural, recreation or other purposes.

The Aksu Creek, a major water source of Giresun, originates from a natural reservoir in the forested area (elevation of about 340 m; North latitude 40°42′ and East longitude 38°28′) in Giresun. The river traverses a total distance of about 61 km before finally merging with Black Sea. It drains a catchments area of about 752 km^2. The river serves as a major source of domestic water supply of Giresun city and the surrounding area. The river during its course of about 61 km receives pollution load both from the point and non-point sources. It receives agricultural run-off from its catchments area directly or through its tributaries and wastewater drains.
The objectives of this study were: (1) To have an overall picture of the environmental impacts of pollutants and human actions on Aksu Creek; (2) pollution loads and water quality determination; (3) comparison of present data with previous published data from close neighborhood; (4) discussion of Aksu Creek case in terms of human impact on the environment with a view of providing insight for future management of similar freshwater resources.

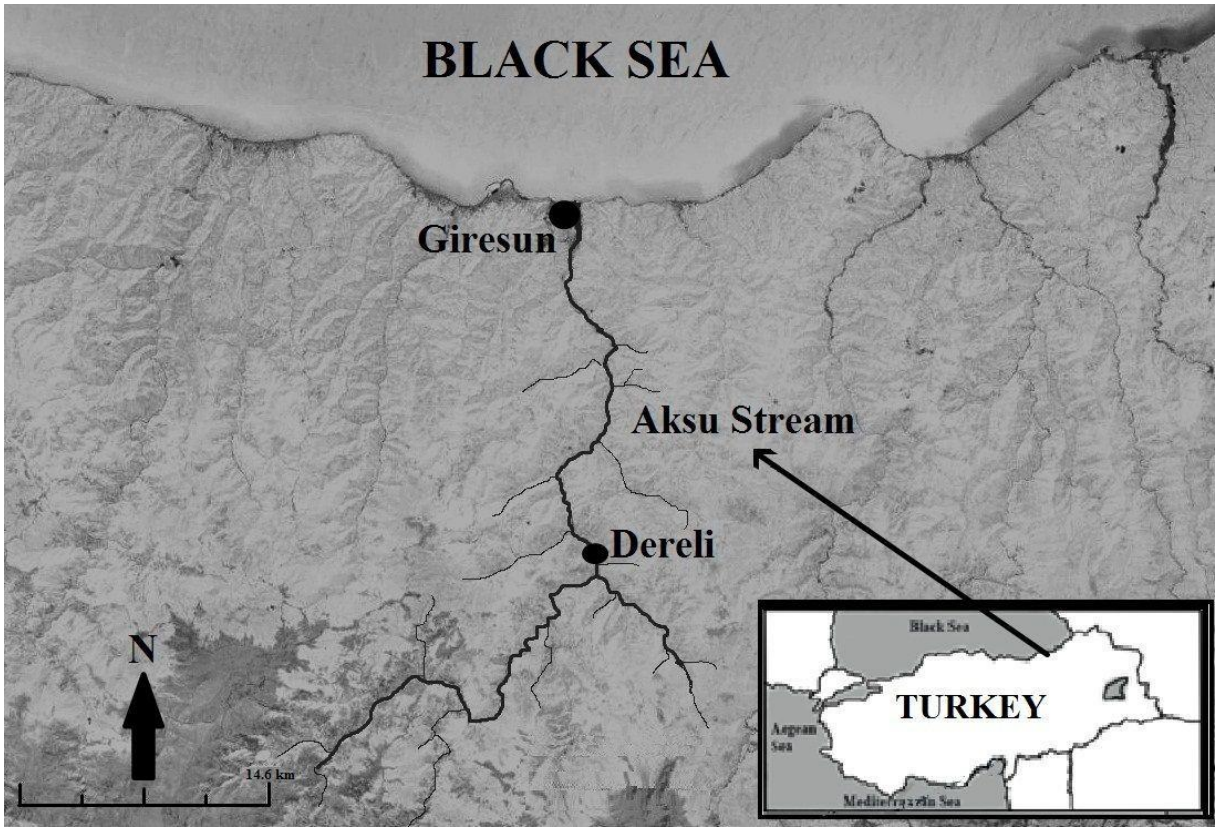

Figure 1 – Map of the study site.

2. Materials and Methods

2.1. Study Area

The Aksu basin is located in Giresun, Turkey between 40° North and 38° East (Fig. 1). It is an area of approximately 752 km^2. The land uses within the basin largely consist of, agricultural, commercial, industrial, mining, livestock, pasture, row crops, forestry, and water. Series of water quality problems have been identified from both point and non-point source pollutants such as nutrients, hydrocarbons, pesticides, and heavy metals. The construction of hydroelectric power station on the creek has also

changed the natural stream bed. Water samples were taken from three different stations as shown in Figure 1. The first station was in mountain area, right below the source. The area around the source of the creek is one of the Turkish fabulous plateaus and there are numerous recreational facilities including restaurants and hotels. The second station was chosen below Dereli town to see site effect of this town on the creek. Dereli with the altitude of 136 m, the population of 20,000 and the surface area of 845 km^2 is the third largest town of Giresun city. The sewage of the town directly drain to the creek without any treatments. Hazelnut production is the main income of the town and pesticide and fertilizers were administered intensely. There are also several trout farms on the creek in this town. The third station was on about 200 m inside from the Black Sea coastline. Around the third station, Giresun Industrial Area is located right on the both side of the creek and the plants were drained their effluent in it.

2.2. Water Analyses

The study was carried out between January 2012 and December 2012 on a monthly basis. Sampling bottles were washed with 1-2% HCl solutions, a day before use, then rinsed with distilled water, and dried in the drying oven. The sample bottles were labeled with date. All the chemicals used were of Analytic Grade. Water samples were taken from 10 cm depth by holding the bottles upward, and immediately transferred to the laboratories for analyses. Oxygen, temperature, pH and salinity were measured directly at the field by means of digital instruments (oxygen and salinity: YSI model 550 oxygen meter; pH: Hanna model HI8314 pH meter).
Chlorophyll *a* concentration was determined spectrophotometrically with 90 % acetone methanol method.

Other water quality parameters, such as chemical oxygen demand (COD), total alkalinity and hardness, total ammonia nitrogen, nitrite, nitrate, phosphate, sulphite, sulphate, chloride, potassium, sodium and silica, were measured on the same day in the Giresun University, Department of Biology Laboratories. Titration methods were used for total alkalinity and total hardness, and the results of both analyses were expressed as mg/L $CaCO_3$. Chloride (Cl_2) analyses were done by titration method with $Hg(NO_3)_2$. Chemical oxygen demand (COD) was analyzed by titration with ferrous ammonium sulphate, basically calculating the amount of oxygen spent to oxidize all organic matter in water. Nitrate (NO_3), nitrite (NO_2^-) and total ammonia nitrogen (TAN) (NH_3 + NH_4^+) as well as phosphate (PO_4^3) measurements were carried out according to standard procedures by using a Shimadzu brand UV-mini1240UV-vis model spectrophotometer. Water analyses were done according to procedures described by Boyd and Tucker,1992.

3. Results

The results of the study were given in Table 1. Results were given as mean of all measured twelve months from each station separately and presented by parameters under subtitles as follow.

Temperature

The temperature values varied from 2,49°C to 21,01°C on January and September, respectively, with the overall mean value of 12.52°C. The mean temperature values were 10,90°C, 12,72°C and 13,94°C for the station 1st, 2nd, and 3th, respectively. Water temperature has both direct and indirect effects on almost all aspects of river

ecology, such as the amount of dissolved oxygen. The seasonal temperature levels of the creek were not exceed the requirement of trout, native fish species of the Aksu Creek.

Table 1. Results of the study as the mean ± standard deviations the measurements by stations from January 2012 to December 2012.

Parameter	1. Station	2. Station	3. Station	Monthly Average
Temperature (°C)	10,90 ± 5,90	12,71 ± 6,20	13,93 ± 6,90	12,52
Dissolved Oxygen Saturation (%)	89,35 ± 17,8	91,87 ± 11,8	88,70 ± 14,1	89,96
Dissolved Oxygen (mgL^{-1})	10,10 ± 3,0	9,96 ± 2,95	9,55 ± 2,63	9,85
Total Alkalinity (mgL^{-1})	123 ± 44,17	106 ± 37,06	117 ± 41,12	115,47
Total Hardness (mgL^{-1})	168 ± 51,68	149 ± 48,30	152 ± 46,79	156,47
Total Phosphate (mgL^{-1})	0,501 ± 1,05	0,558 ± 0,83	0,622 ± 1,35	0,560
SRP (mgL^{-1})	0,037 ± 0,07	0,028 ± 0,02	0,069 ± 0,10	0,045
Salinity (ppt)	0,15 ± 0,05	0,13 ± 0,04	0,14 ± 0,04	0,14
Conductivity ($mScm^{-1}$)	312 ± 101,77	267 ± 99,05	291 ± 97,03	290
TDS (gL^{-1})	0,211 ± 0,08	0,173 ± 0,06	0,189 ± 0,06	0,191
Redox (mV)	-90,7 ± 40,5	-92,7 ± 39,6	-95,9 ± 40,6	-93,1
pH	7,42 ± 0,51	7,28 ± 0,54	7,56 ± 0,41	7,43
TAN (mgL^{-1})	0,83 ± 0,80	0,65 ± 0,68	0,72 ± 0,58	0,73
Nitrite (mgL^{-1})	0,012 ± 0,02	0,003 ± 0,003	0,018 ± 0,05	0,011
Nitrate (mgL^{-1})	1,336 ± 1,73	1,499 ± 2,40	1,227 ± 2,17	1,354
$BOİ_5$ (mgL^{-1})	2,4 ± 0,70	3,0 ± 0,81	2,7 ± 0,47	2,7
Chlorophyll-a (μgmL^{-1})	6,78 ± 6,51	7,88 ± 7,08	8,08 ± 6,88	7,58
Chloride (mgL^{-1})	0,37 ± 1,14	0,33 ± 0,66	0,61 ± 1,09	0,44
TSS (gL^{-1})	2,67 ± 1,75	2,78 ± 1,77	3,40 ± 2,10	2,954
Organic matter in Sediment %	2,94 ± 0,98	4,13 ± 1,43	4,70 ± 1,78	3,92
Sediment pH	7,3 ± 0,48	7,5 ± 0,43	7,6 ± 0,50	7,4

Dissolved Oxygen

Dissolved oxygen concentrations were ranged 5–15 mgL^{-1} at 0-30^{0}C water temperature. The average dissolved oxygen value was 9,85 mgL^{-1}, with the minimum of 6,29 mgL^{-1} in September, and the maximum of 15,75 mgL^{-1} in January. Oxygen saturation was averaged as 89,96 % which indicate that Aksu Creek can be classified as clean water. There were no significant differences between stations as dissolved oxygen concentrations ($p<0,05$).

Total Alkalinity

The standard desirable limit of alkalinity in drinking water is 120 ppm (WHO, 1984). The maximum permissible level is 600 ppm. Total alkalinity values of Aksu Creek water samples varied from 69 to 165 mgL^{-1} on April and September, respectively with the overall mean of 115 mgL^{-1}. The mean total alkalinity values were 123 mgL^{-1}, 106 mgL^{-1} and 117 mgL^{-1} for the station 1st, 2nd, and 3th, respectively. Alkalinity values were lower during rainy season and higher during summer seasons. The cause of alkalinity is the minerals which dissolve in water from soil. The various ionic species that contribute to alkalinity includes bicarbonates, hydroxides, phosphates borates and organic acids. The sewage, drain water, industrial effluents may lead to increase in alkalinity of surface water in future course of time.

Total Hardness

The WHO specified the total hardness to be within 200-600 mgL^{-1} of $CaCO_3$. Hardness values of Aksu Creek water samples varied from 91 to 203 mgL^{-1} on May and July, respectively. The observed hardness values were well within the limits prescribed by WHO, which is fit for drinking purpose and irrigation purpose too. Hardness values parallel to alkalinity were lower during rainy season and higher during summer seasons. Total hardness values were 156 mgL^{-1} as annual average with the max value of 203 mgL^{-1} measured in July and the min. value of 91 mgL^{-1} measured in May. Annual average values of total hardness were 168 mgL^{-1}, 149 mgL^{-1} and 152 mgL^{-1} for the station 1st, 2nd, and 3th, respectively.

Total Phosphate

The average total phosphate concentration was 0,560 mg/l with the minimum value of 0,04 mgL^{-1}, and the maximum value of 3,71 mgL^{-1}, recorded in February and May, respectively. Annual average values of total phosphorus were 0,50 mgL^{-1}, 0,56 mgL^{-1} and 0,62 mgL^{-1} for the station 1st, 2nd, and 3th, respectively. Soluble reactive phosphorus levels were averaged as 0,045 mgL^{-1} with the minimum of 0,007 mgL^{-1} and the maximum 0,219 mgL^{-1} in May.

Soluble Reactive Phosphorus (SRP)

The mean Soluble Reactive Phosphorus (SRP) concentration was 0,045 mg/l with the minimum value of 0,007 mgL^{-1}, and maximum value of 0,219 mgL^{-1}, recorded in August and May, respectively. Annual average values of SRP were 0,037 mgL^{-1}, 0,028 mgL^{-1} and 0,069 mgL^{-1} for the station 1st, 2nd, and 3th, respectively.

pH

pH is the indicator of acidic or alkaline condition of water quality. The standard for any purpose such as drinking, irrigation and industrial in terms of pH is 6.5-8.5. In table 1, pH indicates slightly alkaline conditions. pH values, the mean, minimum and maximum were 7.47, 6.93 recorded in October and 8,72 recorded in June,

respectively. The mean pH values were 7.42, 7.29 and 7.57 for the station 1st, 2nd, and 3th, respectively. Rivers with a pH of 5.5 and below are particularly at risk. The pH of the surface water can be lowered by organic acids from decaying vegetation or the dissolution of sulphide minerals.

Total Ammonia Nitrogen (TAN)
Total Ammonia Nitrogen (TAN) concentrations were changed from as low as 0,1 mgL^{-1} to as high as 2,63 mgL^{-1} measured in September and February, respectively. The mean TAN value of stations were calculated as 0,83 mgL^{-1}, 0,65 mgL^{-1} and 0,72 mgL^{-1} for the 1st, 2nd, and 3rd stations, respectively with the overall mean value of the study as 0,73 mgL^{-1}

Nitrite (NO_2)
The average nitrite level was 0,011 mgL^{-1} with the maximum level of 0,101 mgL^{-1} measured in February and the minimum level of 0,001 mgL^{-1} measured in January. The mean nitrite levels of the stations were 0,012 mgL^{-1}, 0,003 mgL^{-1} and 0,018 mgL^{-1} for the first, second and third station, respectively.

Nitrate (NO_3)
The average nitrate level was 1,35 mgL^{-1} with the maximum value of 7,8 mgL^{-1} measured in December and the minimum 0,06 mgL^{-1} measured in July. The mean nitrate value of stations were 1,33 mgL^{-1}, 1,49 mgL^{-1} and 1,22 mgL^{-1} for the first, second and third stations, respectively.

Conductivity
The mean conductivity (EC) values ranged from 149 to 430 μscm^{-1} in April and October, respectively. This indicates that the creek water had different quality in different seasons. The higher EC Values indicate the presence of higher concentration of dissolved salts in the river water and EC values are a good measure of the relative difference in water quality between different aquifers. The mean conductivity values were 312 μscm^{-1}, 267 μscm^{-1} ve 291 μscm^{-1} for the station 1st, 2nd, and 3th, respectively.

TDS
The mean, minimum and maximum Total dissolved solid values were 0,191 gL^{-1}, 0,1 gL^{-1} measured in April and 0,29 gL^{-1} measured in August, respectively. The average values of stations were 0,21 gL^{-1}, 0,17 gL^{-1} and 0,19 gL^{-1}, respectively without no significant differences between them. High TDS levels can make water taste like minerals and make it unpleasant to drink, and can also cause water balance problems for organisms. On the contrary, low TDS levels may limit growth of aquatic life. TDS can cause toxicity through increases in salinity, changes in the ionic composition of the water and toxicity of individual ions. (Phyllis and Lawrence, 2007).

Redox
The average Oxidation-reduction value was -93,1 mV with the minimum of -171,03 mV, measured in December and the maximum of -36,40 measured in July. Stations means were 90,73 mV, -92,65 mV and -95,89 mV for the 1st, 2nd and 3rd stations, respectively.

Biological Oxygen Demand (BOD)
The annual mean of the BOD values were calculated as 2,7 mgL^{-1} with the maximum value of 3,58 mgL^{-1} measured in April and the minimum value of 1,97 mgL^{-1} measured in September. Measurements from stations were averaged as 2,43 mgL^{-1}, 3,04 mgL^{-1} and 2,74 mgL^{-1} for the first, second, and third stations, respectively.

Chlorophyll-a
Chlorophyll-a averaged as 7,58 μgmL^{-1} for the whole year and showed its minimum value with 0,10 μgmL^{-1} in January and the maximum value with 18,80 μgmL^{-1} in October. The mean Chlorophyll-a levels of the stations were 6,78 μgmL^{-1}, 7,88 μgmL^{-1} and 8,08 μgmL^{-1} for the first, second and third stations, respectively.

Chloride
Chlorides are important in detecting the contamination of surface water by waste water and effluents (Omekachi et al., 2011). The permissible limits of chloride in drinking water are 250 ppm (WHO, 1984). The mean value of chloride was 0,44 mgL^{-1} with the maximum value of 2,767 mgL^{-1}, and the minimum 0,003 mgL^{-1} measured in December and August, respectively. The first, second, and third stations chloride level were averaged as 0,370 mgL^{-1}, 0,331 mgL^{-1} and 0,609 mgL^{-1}, respectively. The values of chloride observed in the present study were very low. The chloride salts in excess of 100 ppm give salty taste to water. When combined with calcium and magnesium, may increase the corrosive activity of water.

TSS (Total Suspended Solids)
The mean TDS value was 2,95 gL^{-1} with the maximum value of 7,72 gL^{-1} measured in May and the minimum value of 0,78 gL^{-1} measured in October. Stations' means were 2,67 gL^{-1}, 2,78 gL^{-1} and 3,41 gL^{-1} for the first, second and third stations, respectively.

Measurements in sediment
Organic matter % and pH of sediment were measured during the twelve months long study period on collected sediment samples. Organic matter % was averaged as 3,92 % with the maximum value of 5,98 % measured in August and the minimum value of 2,67 % measured in October. Station values were 2,9 %, 4,1 % and 4,7 % for the 1st, 2nd, and 3rd stations with the significant differences between 1st and 3rd stations values ($p<0,05$).

pH measurements in sediment was averaged as 7,4 with the maximum in June as 8, and the minimum in November as 6,8. The stations' means were 7, 2, 7,4 and 7,5 for the 1st, 2nd, and 3rd stations, respectively.

4. Discussion

Aksu Stream has Class I water quality (Republic of Turkey Ministry of Environment and Forest 2004) according to the physicochemical properties of collecting sites (Table 1). Nitrate nitrogen values ranged from 0.06 to 7,80 mg/l in sites with the average of 1,35 mg/l. Ammonium nitrogen values ranged between 0.101 and 2.634 mg/l. The total phosphorus values recorded were between 0.04 and 3.71 mg/l. The dissolved oxygen values were between 6.29 and 15.75 mg/l. The electrical conductivity recorded were between 149 and 430 (µS/cm). The temperature values were between 2.49 and 21.01 °C.

There was an inverse relation between temperature and dissolved oxygen levels through the year. except November. The lowest mean dissolved oxygen concentration was measured in September when the temperature was the highest. Similar situation was declared from the nearby water source Melet River (Ustaoğlu et al., 2017).

pH measurements of the study were always above the neutral level of 7 showing the slightly alkaline conditions of Aksu River. Rivers with a pH of 5.5 and below are particularly at risk. The pH of the surface water can be lowered by organic acids from decaying vegetation or the dissolution of sulphide minerals. The risk associated with low pH was not subject for Aksu River since, pH levels were all above 6.93.

Conductivity levels were consistently parallel to TDS levels all year round. High TDS levels can make water taste like minerals and make it unpleasant to drink, and can also cause water balance problems for organisms. The max TDS level of the study measured as 430 mgL^{-1} on October. On the contrary, low TDS levels may limit growth of aquatic life. TDS can cause toxicity through increases in salinity, changes in the ionic composition of the water and toxicity of individual ions (Weber-Scannell and Duffy, 2007). Electrical conductivity (EC) is widely used for monitoring the mixing of fresh water and saline water, separating stream hydrographs, and geophysical mapping of contaminated groundwater. Especially on the second sampling station mixing from the saline water month by month were observed. In general, high conductivity values were common towards the end of the dry season during a period characterized by little or no inflow. Low records were made at the end of the wet season. The mean electrical conductivity (EC) of 290 µS/cm was very similar to level of 201.31 µs/cm from Maruf Dam (Mutlu and Kutlu, 2017) but below the levels recorded from the Tigris Stream which varies between 315 µS/cm and 353 µS/cm (Varol et al., 2012).

Total alkalinity (TA) and total hardness (TH) levels were closely parallel to each other showing us that they are mainly originated from limestone. High TA and TH levels were recorded around the end of the dry season while low levels were noted in the middle of the rain season (Tepe and Boyd, 2001). The sewage, drain water, industrial effluents may lead to increase in alkalinity of surface water in future course of time (Tepe and Boyd, 2002).

The seasonal increase in both total and soluble reactive phosphorus levels in summer months in Aksu River can be attributed to increased residential population and agricultural activities because of hazelnuts harvest (Tepe and Boyd, 2003).

BOD_5 is another important factors used to assess the water quality regarding organic matter both suspended and dissolved. The high BOD_5 values in the downstream sites indicated organic matter being input during its course. The range of BOD_5 levels (1,97-3,58 mgL^{-1}) in the present study were in agreement with the levels of a study from Melet River (0,6-4,8 mgL^{-1}) (Ustaoğlu et al., 2017)

At present, one of the most common ecological problems of inland water bodies is eutrophication. Nitrogen and phosphorus are main nutrients enriched in water body. The geology of the drainage basin is the principle factor that determines the phosphorus level in rivers (Y. Tepe and Boyd, 2002). The mean total phosphorus level of Aksu River (0,56 mgL^{-1}) was similar to that of Ulubat Lake (0,42 mgL^{-1}) (Filik Iscen et al., 2008), but greater than that of Gölbaşı Lake (0,22 mgL^{-1}) (Bozkurt and Tepe, 2011). Land runoff and pollutants from the hazelnut gardens should be the main input resources of nutrient for Aksu River. As spring is the agriculture time along the river, surplus nitrogen and phosphorous are fertilized in spring. Therefore, river water contained the highest nutrient concentration in spring and summer. TAN

concentrations (0,73 mgL^{-1}) were above the Turkish standard value of 0,2 indicating slight eutrophication (class II) in Melet River.

The values of chloride observed in the present study (0,437 mgL^{-1}) were low. The chlorine salts in excess of 100 ppm give salty taste to water. When combined with calcium and magnesium, may increase the corrosive activity of water. Maximum salinity was observed in October, the dry season. Salinity showed no specific relation with other characteristics.

The higher chlorophyll-a values were reached in summer and during winter and autumn chlorophyll-a was lower than 5 μgL^{-1}. Unfavorable conditions, such as high amount of suspended solids carried from the river and elevated level of pollutants, that inhibit extensive algal development in Aksu River. The elevated levels of chlorophyll-a reported in summer can be explained as a direct consequence of the summer solar radiation peak plus the over-enrichment of nutrients such as SRP and nitrite. Elevated summer chlorophyll-a concentrations were also reported from Sarıçay Creek (23,42 µgL-1) (Akbulut et al., 2010).

The decomposition of organic matter in bed sediment consumes oxygen from the surface water which potentially adverse effects on fish and benthic organism. Organic matter % was averaged as 3,92 % with the maximum value of 4,69 % measured in August and the minimum value of 2,93 % measured in April. Our results were in consistent with the organic content of the sediment samples from Melet River (Ordu -Turkey), which varied between 2,9 % and 9,1 % with a mean value of 5,8 % (Ustaoğlu et al., 2017). Rainfall caused an increase in sediment organic matter levels, which originated from water runoff of intensive agriculture, pasture activities and untreated wastewater discharges (Tepe and Boyd, 2002).

5. Conclusion

The detailed physico-chemical study on the water quality of Aksu River over a period of one year revealed that the water is fit for drinking and irrigation with some form of treatment. River water quality study provides an informative data and helps to understand the contamination of wastewater in Aksu River and influences the ecology of river. Aksu River receives pollutants both organic and inorganic, were found to originate from illegal logging, agricultural activities, unsustainable development and household activities of people. These waste materials were ultimately contaminating the river water.

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