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EVALUATION OF SURFACE WATER QUALITY IN PORSUK STREAM

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Abstract

Porsuk Stream passing from the borders of Eskişehir and Kütahya has a significant water supply, feeds Sakarya River, which has an important water potential in Turkey. In particular, Porsuk Stream is used as domestic water in the Eskişehir Provinces. Therefore, determination of water quality of Porsuk Stream has a great importance for the health of ecosystems for the region. Water samples were collected seasonally (May 2010 – February 2011) from 13 stations selected on the Porsuk Stream and temperature, pH, dissolved oxygen, salinity, conductivity, ammonium nitrogen, nitrite nitrogen, nitrate nitrogen, sulphate, phosphate, chemical oxygen demand, biochemical oxygen demand, total phosphorus, total chlorine, calcium, magnesium, sodium, potassium parameters were investigated. The detected physicochemical parameters were statistically compared among the stations and the effective factors were classified by using the Factor Analysis (FA). Also, Cluster Analysis (CA) was applied to the results to classify the stations according to physicochemical characteristics by using the PAST package program. The data observed were evaluated with national and international water quality criteria. This study presents the necessity and usefulness of statistical techniques such as CA, FA and One-Way ANOVA in order to get better information about the surface water quality monitoring studies.

Keywords: Water Quality, Porsuk Stream, Factor Analysis, Custer Analysis, ICP-OES.

PORSUK ÇAYI YÜZEY SUYU KALİTESİNİN DEĞERLENDİRİLMESİ

Özet

Porsuk Çayı, Kütahya ve Eskişehir il sınırlarından geçerek Türkiye'nin önemli su potansiyellerinden biri olan Sakarya Nehri'ni besleyen önemli bir akarsudur. Özellikle, Eskişehir iline kadar olan kısmının kullanma suyu olarak değerlendirilmesi nedeni ile Porsuk Çayı'nın su kalitesinin belirlenmesi bölgede bulunan ekosistemlerin sağlığı açısından büyük önem arz etmektedir. Su örnekleri Porsuk Çayı üzerinde seçilen 13 istasyondan (Mayıs 2010- Şubat 2011) mevsimsel olarak toplanmış ve sıcaklık, pH, çözünmüş oksijen, tuzluluk, iletkenlik, amonyum nitrojen, nitrit nitrojen, nitrat nitrojen, sülfat, fosfat, kimyasal oksijen ihtiyacı, biyokimyasal oksijen ihtiyacı, toplam fosfor, toplam klor, kalsiyum, magnezyum, sodyum, potasyum parametreleri belirlenmiştir. Tespit edilen fizikokimyasal parametreler istasyonlar arasında istatistiksel olarak karşılaştırılmış ve Faktör Analizi kullanılarak etkili faktörler sınıflandırılmıştır. Aynı zamanda, Past istatistik programı kullanılarak suda ölçülen parametrelere göre istasyonların benzerliğini belirlemek amacı ile kümeleme analizi uygulanmıştır. Elde edilen veriler uluslar arası ve ulusal su kalite kriterleri ile karşılaştırılmıştır. Bu çalışma, yüzey suyu izleme çalışmaları hakkında daha iyi bilgi edinebilmek için Kümeleme Analizi (CA), Faktör Analizi (FA) ve tek yönlü varyans analizi (One-Way ANOVA) gibi istatistiksel tekniklerin kullanımı ve gerekliliğini göstermiştir.

Anahtar Kelimeler: Su Kalitesi, Porsuk Çayı, Faktör Analizi, Kümeleme Analizi, ICP-OES.

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1. INTRODUCTION

Freshwater systems play an important role in assimilation or transporting domestic, and industrial wastewater and runoff from agricultural region. Domestic and industrial wastewater discharge constitutes a significant constant polluting source, whereas surface runoff is seasonal differences largely affected in the river basin. Seasonal variations in rains, surface runoff, interflow, groundwater flow and pumped in and outflows have a strong effect on river discharge and subsequently, on the concentration of pollutants in river water. The effective pollution control and water resource management in fresh water systems such as river and lake of a region required to identify the pollution sources and their quantitative contributions [1-2].

The problems of interpretation, characteristic changes in surface water quality parameters, and indicator parameter identification can be approached through the use of multivariate statistical techniques such as cluster analysis (CA) and factor analysis (FA). In recent years, multivariate statistical techniques have been used in surface and ground water pollution studies [2-9].

The aim of in the present study, water quality parameters (temperature, pH, dissolved oxygen, salinity, electrical conductivity, ammonium nitrogen, nitrite nitrogen, nitrate nitrogen sulphate, phosphate, chemical oxygen demand, biochemical oxygen demand, total chlorine, calcium, total phosphorus, potassium and sodium) of Porsuk Stream (an important branches of Sakarya River) was evaluated by using some statistical techniques.

2. MATERIAL AND METHODS

2.1. Study Area

The Porsuk Stream (length of 460 km) is the longest tributary of the Sakarya River (length 824 km). It arises from Murat Mountain to the south of the city of Kütahya, situated in Western Turkey. After Porsuk Stream passing from cities Eskişehir and Kütahya it joins the Sakarya River. Sampling stations on the Porsuk Stream are shown on the map (Figure 1 and Figure 2) and coordinates of stations were given in Table 1. Water samples were collected seasonally from Porsuk Stream in May 2010, August 2010, November 2010 and February 2011.

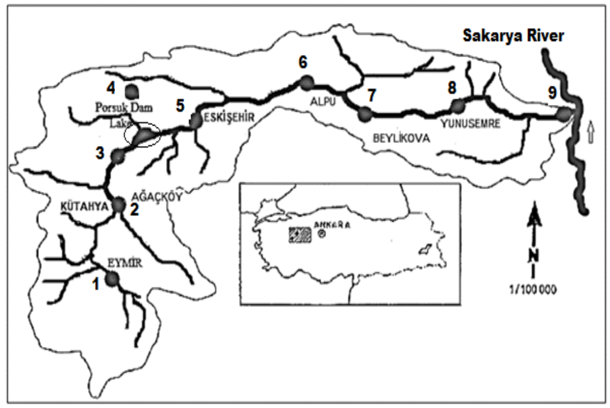

Figure 1 Stations of Porsuk Stream

Figure 2 Stations of Porsuk Dam Lake

Table 1 Coordinates and Elevations of Stations of Porsuk Stream

Stations	Coordinates	Elevations (m.)
1. Eymir	N:39° 19" 15.2' E:029° 59" 35.9'	1253
2.Ağaçköy	N:39°19"36.55' E:029°54"13.35'	939
3. Downstream of Kütahya	N:39° 33" 20.1' E: 030° 04" 07.9'	905
4.Porsuk Dam Lake		
4.1	N: 39^0 35`08.8`` E: $030^0$ 08`31.6``	892
4.2	N: 39^0 37`53.4`` E: $030^0$ 10`44.8``	892
4.3	N: 39^0 37`42.6`` E: $030^0$ 14`04.3``	892
4.4	N: 39^0 37`35.5`` E: $030^0$ 15`43.3``	892
4.5	N: 39^0 37`28.2` E: 030^0 13` 36. 0``	892
5. Upstream of Eskişehir	N.39° 39" 01.8' E:030° 22" 20.0'	844
6. Alpu	N.39° 46" 17.0' E:030° 58" 13.3'	782
7. Beylikova	N:39° 41" 02.6' E:031° 12" 20.6'	750
8. Yunusemre	N:39° 42" 04.0 E:031° 28" 39.6'	745
9. Confluence point with Sakarya River	N:39° 41" 15.3' E:031° 58" 45.1'	685

2.2. Physicochemical Analysis

Measurements of temperature (T), pH, dissolved oxygen (DO) and electrical conductivity (EC), salinity in water of Porsuk Stream were performed with Multi-measuring device (HQ40D) in the samples sites by.

Ammonium nitrogen (NH_4–N), nitrite nitrogen (NO_2–N), nitrate nitrogen (NO_3–N), sulphate (SO_4^{-2}) and, phosphate (PO_4^{-3}), chemical oxygen demand (COD) were measured by spectrophotometer (HACH LANGE DR 2800). Total chlorine was measured with HACH DR890. Biochemical oxygen demand (BOD) was measured using with ENOTEK tredemark device.

All of these parameters in water sampling were measured in the same day in laboratory [10-13].

Water samples of one liter that were taken at each sampling point were adjusted to pH 2 by adding 2 ml of nitric acid into each for determination of Ca, Mg, Na and K. Afterwards, the samples were filtered (cellulose nitrate, 0.45 μm) in such a way as to make their volumes to 100 ml.

For determination of total phosphorus (TP) in water, 100 ml from samples were transferred to a 250-ml beaker and 2 ml (1+1) of nitric acid and 1 ml (1+1) of hydrochloric acid were added. And then put on hot plate for evaporation to nearly dryness, making certain that the samples do not boil at 85^0C. Sample volume was come down to approximately 20 ml. Afterwards, the samples were filtered (cellulose nitrate, 0.45 μm) in such a way as to make their volumes to 50 ml with ultra-pure water.

Total phosphorus, calcium, magnesium, potassium and sodium elements were measured with VARIAN 720 ES ICP-OES [14].

2.3. Statistical Analysis

According to water quality parameters between stations significant differences was determined with Analysis of variance (One-way ANOVA) ($p<0.05$). Also, water quality data sets of Porsuk Stream were performed cluster analysis. Cluster analysis (CA) is a group of multivariate techniques and CA classifies of river water quality parameters so that each parameters is similar to the others in the cluster with respect to a predetermined selection criterion [1,7]. Factor analysis (FA) was used to obtain a smaller number of variables for the evaluation of surface water quality of Porsuk Stream . Many studies have determined that CA and FA techniques reliably classifies surface water of aquaticsytems as river, stream and lake. [1,2, 5,6, 15-18]

One- way ANOVA, Factor Analysis (FA) techniques were carried out with SPSS 17 packed program. CA was performed using PAST Bray Curtis Program.

3. RESULTS

3.1. One-way ANOVA Analysis

The annual mean water quality parameters results of Porsuk Stream stations and Porsuk Dam Lake stations were given Table 2 and 3. In Table 2, the data of station 4th. (The Porsuk Dam Lake) were shown by calculating the average rates of 4.1-4.5th stations.

According to annual mean temperature, pH, conductivity, total chlorine, nitrite nitrogen, nitrate nitrogen, COD parameters wasn't found statistical difference ($p>0.05$; Table 2). Also, there weren't statistical difference to all water quality parameters among stations of Porsuk Dam Lake ($p>0.05$; Table 3).

According to annual mean dissolved oxygen parameter, the lowest dissolved oxygen was found respectively in stations 3rd, 6th, 7th and 8th. Especially dissolved oxygen levels at stations 3rd and 6th were significantly lower than 1st, 2nd, 4th and 5th stations ($p<0.05$, Table 2). The lowest dissolved oxygen level was found in station 3rd in winter season (1.96 mg/L).

The highest sulfate levels were determined among stations in station 9th in spring, summer and winter seasons. According to the annual mean sulfate levels, station 9th were higher than other stations ($p<0.05$; Table 2). Station 3rd was higher than stations 1st, 2nd, 4th and 5th for BOD and ammonium nitrogen parameters.

The highest total chlorine was determined 0.28 mg/L in autumn season and Ca values were determined as 201 mg/L in station 9th in winter season (Table 2).

3.2. Cluster Analysis

Cluster analysis was used to detect similarity groups between the sampling stations [5]. As a result of clustering analysis done by taking physicochemical analysis data determined in the Porsuk Stream's water into account, four different clusters were specified: Cluster 1 corresponds to (Porsuk Dam Lake's Stations: 4.1-4.5th), cluster 2 corresponds to 3rd, 6th, 7th and 8th stations, cluster 3 corresponds to 1st, 2nd and 5th stations and cluster 4 corresponds to station 9th (Figure 3).

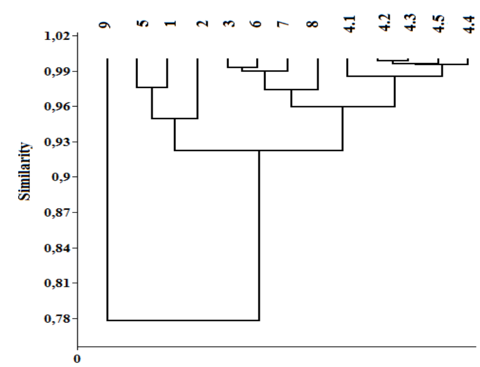

Figure 3 Dendogram showing clustering of stations according to surface water monitoring stations

3.3. Factor Analysis

Factor Analysis is a multivariate statistical technique. Factor analysis aims to explain observed relation between numerous variables in terms of simpler relations [8]. Suitability for factor analysis of the data set in order to determine was performed Kaiser-Meyer-Olkin (KMO) test. KMO value 0.74 was found in the present study and this value means that, the sampling adequacy was in a good level (> 0.7) [18].

Eigenvalues greater than 1 were taken as criterion for extraction of the principal components required to explain the sources of variances in the data. The scree plot is shown in Figure 4. This analysis led to the explanation of 71.83% of the variances in the data (Table 4).

Table 2. Annual mean and standard error of different water-quality parameters at different stations of the Porsuk Stream*
(Minimum-maximum); Mean±Standard Error. * The value with a different letter in the same row is different ($p<0.05$)

Parameters	Stations								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Temperature (ºC)	(4.80-19.70) 12.48±3.62[a]	(7.20-20.80) 14.93±3.11[a]	(10.30-22.60) 15.73±2.86[a]	(4.40-24.50) 15.55±1.66[a]	(4.80-12.50) 10.03±1.76[a]	(8.30-22.30) 14.95±3.22[a]	(6.80-25.20) 15.93±4.32[a]	(6.20-27.90) 16.43±4.94[a]	(6.30-25) 16.50±4.47[a]
pH	(7.31-8.02) 7.65±0.18[a]	(7.31-8.20) 7.78±0.45[a]	(7.15-8.20) 7.78±0.23[a]	(6.52-8.80) 7.58±0.16[a]	(7.07-8.10) 7.61±0.22[a]	(7.11-7.64) 7.43±0.12[a]	(7.38-7.84) 7.58±0.10[a]	(7.11-7.90) 7.46±0.17[a]	(7.11-8.38) 7.60±0.27[a]
DO (mg/L)	(7.74-12.13) 9.52±1.01[a]	(8.45-10.75) 9.12±0.55[a]	(1.96-3.40) 2.74±0.35[b]	(4.18-11.35) 8.20±0.58[a]	(6.50-11.58) 8.64±1.08[a]	(2.16-3.36) 2.96±0.28[b]	(3.47-5.95) 4.59±0.65[b]	(3.90-8) 5.80±1.09[ab]	(5.21-9.77) 7.25±1.16[a]
EC (µs/cm)	(326-1767) 745.25±342.4[a]	(397-1839) 805±345.63[a]	(537-1425) 830.5±202.5[a]	(335-2180) 844.40±176.34[a]	(347-1776) 745.50±344.06[a]	(715-1142) 833±103.48[a]	(697-1091) 827.5±1149.7[a]	(637-1293) 864.7±149.6[a]	(825-1500) 1149.7±139.6[a]
Salinity (‰)	(0.27-0.33) 0.29±0.01[a]	(0.27-0.33) 0.30±0.01[a]	(0.37-0.41) 0.40±0.009[ab]	(0.24-0.28) 0.27±0.00[a]	(0.27-0.33) 0.31±0.015[a]	(0.49-0.53) 0.51±0.008[b]	(0.47-0.54) 0.51±0.01[b]	(0.44-0.53) 0.48±0.01[b]	(0.69-0.94) 0.77±0.06[c]
SO_4^{-2} (mg/L)	(12.70-15) 14.23±2.91[a]	(4.97-16.10) 9.57±2.91[a]	(54.60-75.30) 67.43±5.60[b]	(29.20-40.60) 35.29±0.77[a]	(22.70-34.80) 30.73±3.48[a]	(60.80-66.90) 64.70±1.69[b]	(34.80-71) 58.23±10.16[b]	(44-78.60) 61.27±8.65[b]	(51.60-366) 201.20±78.88[c]
NH_4–N (mg /L)	(<0.015-0.024) 0.009±0.00[a]	(<0.015-0.059) 0.027±0.01[a]	(0.057-7.60) 2.78±1.78[b]	(<0.015-0.09) 0.017±0.00[a]	(0.015-1.58) 0.46±0.37[a]	(0.024-10.70) 4.41±2.64[b]	(0.024-8.16) 4.0±2.29[b]	(0.025-4.23) 2.13±1.21[b]	(0.028-2.45) 1.02±0.59[b]
NO_2–N (mg /L)	(0.001-0.018) 0.011±0.004[a]	(0.004-0.015) 0.009±0.00[a]	(0.037-0.156) 0.081±0.03[a]	(0.003-0.042) 0.012±0.00[a]	(0.025-0.046) 0.035±0.01[a]	(0.036-0.166) 0.093±0.03[a]	(0.040-0.256) 0.108±0.05[a]	(0.033-0.375) 0.127±0.08[a]	(0.009-0.137) 0.084±0.03[a]
NO_3–N (mg /L)	(0.40-1.40) 0.95±0.21[a]	(0.80-3.0) 1.40±0.53[a]	(0.20-3.70) 1.825±0.72[a]	(0.10-1.40) 0.66±0.08[a]	(0.90-1.80) 1.190±0.20[a]	(1-2.10) 1.48±0.22[a]	(0.30-2.30) 1.52±0.48[a]	(0.60-2.80) 1.55±0.45[a]	(0.90-3.04) 1.81±0.48[a]
PO_4^{-3} (mg /L)	(0.16-1.23) 0.53±0.24[a]	(0.15-0.58) 0.38±0.09[a]	(1.18-3.06) 1.85±0.42[bc]	(0.33-1.20) 0.64±0.06[a]	(0.61-1.62) 1.22±0.22[ab]	(2-2.65) 2.46±0.15[c]	(2.58-3.25) 2.81±0.15[c]	(1.94-2.90) 2.50±0.20[c]	(1.58-2.87) 2.45±0.30[c]
Total Chlorine (mg /L)	(0-0.05) 0.028±0.01[a]	(0-0.07) 0.035±0.01[a]	(0.020-0.170) 0.12±0.03[a]	(0-0.09) 0.03±0.01[a]	(0-0.14) 0.053±0.03[a]	(0.02-0.20) 0.08±0.04[a]	(0.05-0.18) 0.10±0.03[a]	(0.03-0.13) 0.078±0.03[a]	(0.07-0.28) 0.15±0.05[a]
BOD (mg/L)	(0-1) 0.25±0.0[a]	(0-3) 1±0.71[a]	(11-28) 19±3.76[b]	(0-12) 3.55±0.71[c]	(2-14) 5.50±2.84[c]	(10-24) 15.25±3.09[bc]	(8-23) 16.75±3.15[bc]	(10-19) 13.75±2.25[bc]	(13-27) 18.25±3.20[b]
COD (mg/L)	(<5-43.60) 21.78±12.57[a]	(<5- 45.40) 32.03±9.59[a]	(11.80-70.10) 49.38±10.50[a]	(23.10-69.70) 47.38±3.34[a]	(5.09-54.60) 40.75±11.94[a]	(23.06-67.80) 54.02±9.34[a]	(19.60-69.70) 54.25±9.66[a]	(25.30-79.30) 58.40±9.15[a]	(25.80-80.80) 54.08±7.95[a]
Ca (mg/L)	(54.50–181) 93.53±10.17[a]	(52.50–85) 89.60±48.48[a]	(69–179) 107.01±7.56[a]	(24.20–48.67) 34.13±0.61[b]	(33.70–52.40) 45.95±1.35[b]	(33.77–75.50) 52.91±3.08[b]	(33.70–74.50) 52.46±2.84[b]	(52.70–73.40) 61.41±1.7[ab]	(57–201) 118.11±8.62[a]
Mg (mg/L)	(19.80-27.20) 23.72±0.59[a]	(19.70-27.20) 23.74±0.60[a]	(25.30-37.70) 32.04±1.06[a]	(30.80-40) 35.78±0.29[a]	(34.70-42.10) 38.21±0.50[a]	(34.70-53.50) 42.89±1.36[a]	(34.70-53.90) 45.32±1.53[a]	(42-54) 46.47±0.95[a]	(46.50-176) 109.40±9.89[b]
Na (mg/L)	(7.85-10.40) 8.92±0.16[a]	(7.69-10.40) 8.70±0.19[a]	(17.40-31.40) 22.78±1.07[a]	(13-18.10) 15.50±0.13[a]	(12.7016.50) 14.35±0.24[a]	(12.70-65.56) 40.98±3.79[a]	(UDL-56.43) 25.90±4.33[a]	(35.20-54.50) 46.19±1.24[a]	(67.70-395) 197.78±24.72[b]
TP (mg/L)	(UDL-0.174) 0.079±0.013[a]	(UDL-0.20) 0.10±0.01[a]	(0.750-3.97) 1.68±0.22[b]	(UDL-0.71) 0.26±0.01[a]	(UDL-1.60) 0.63±0.09[a]	(UDL -2.81) 1.49±0.20[b]	(UDL-4.12) 2.13±0.30[b]	(0.92-4.41) 2.49±0.31[b]	(UDL-4.22) 1.47±0.32[b]
K (mg/L)	(2.51-4.59) 3.26±0.14[a]	(0.71-2.58) 2.02±0.15[a]	(5.48-8.91) 6.57±0.27[ab]	(3.61-5.69) 4.91±0.05[a]	(3.79-5.65) 4.82±0.12[a]	(3.79-11.60) 7.74±0.70[bc]	(4.82-12.70) 9.72±0.61[bc]	(7.24-17.80) 11.51±0.80[bc]	(10.40-26.30) 16.70±1.21[c]

Table 3 Annual mean and standard error of different water-quality parameters at different stations of the Porsuk Dam Lake[*] (Minimum-maximum); Mean±Standart Error. * The value with a different letter in the same row is different ($p<0.05$).

	Stations				
Parameters	**4.1**	**4.2**	**4.3**	**4.4**	**4.5**
Temperature (ºC)	(4.40-23.90) 15.31±4.21[a]	(4.50-23.80) 15.35±4.16[a]	(5.0-23.80) 15.78±4.07[a]	(4.60-24.30) 15.72±4.24[a]	(4.90-24.50) 15.61±4.21[a]
pH	(7.10-8.60) 7.61±0.34[a]	(6.53-8.65) 7.44±0.45[a]	(6.52-8.75) 7.51±0.46[a]	(7.01-8.80) 7.65±0.41[a]	(7.10-8.68) 7.68±0.37[a]
DO (mg/L)	(4.22-11.19) 8.30±1.47[a]	(4.21-11.05) 8.20±1.44[a]	(4.20-10.05) 8.11±1.36[a]	(4.18-11.35) 8.27±1.50[a]	(4.21-11.32) 8.14±1.47[a]
EC (µs/cm)	(339-2180) 840±447.17[a]	(345-2177) 845.25±444.44[a]	(341-2171) 845.50±442.47[a]	(339-2170) 841.50±443.45[a]	(335-2170) 849.75±441.27[a]
Salinity (‰)	(0.25-0.27) 0.265±0.005[a]	(0.25-0.28) 0.265±0.009[a]	(0.25-0.28) 0.268±0.006[a]	(0.24-0.28) 0.268±0.009[a]	(0.26-0.28) 0.27±0.006[a]
SO_4^{-2} (mg/L)	(32.16-38.90) 35.83±1.52[a]	(29.20-38.60) 35.56±2.15[a]	(30.15-38.10) 35.59±1.84[a]	(29.90-37.46) 33.57±1.63[a]	(30.60-40.60) 35.90±2.13[a]
NH_4–N (mg /L)	(0.02-2.34) 0.62±0.47[a]	(0.018-1.72) 0.45±0.30[a]	(<0.015-0.044) 0.021±0.009[a]	(<0.015-0.045) 0.023±0.009[a]	(<0.015-0.060) 0.022±0.010[a]
NO_2–N (mg /L)	(0.018-0.042) 0.026±0.006[a]	(0.014-0.028) 0.019±0.003[a]	(0.006-0.016) 0.011±0.002[a]	(0.008-0.015) 0.012±0.001[a]	(0.012-0.017) 0.015±0.001[a]
NO_3–N (mg /L)	(0.56-0.92) 0.72±0.08[a]	(0.53-1.30) 0.78±0.18[a]	(0.44-0.98) 0.68±0.21[a]	(0.40-1.40) 0.86±0.21[a]	(0.40-0.75) 0.50±0.08[a]
PO_4^{-3} (mg /L)	(0.38-0.98) 0.76±0.13[a]	(0.36-0.75) 0.56±0.08[a]	(0.36-0.82) 0.54±0.10[a]	(0.33-0.80) 0.48±0.11[a]	(0.44-1.20) 0.85±0.16[a]
Total Chlorine (mg /L)	(0.01-0.06) 0.03±0.01[a]	(0-0.02) 0.01±0.00[a]	(0-0.05) 0.02±0.01[a]	(0-0.07) 0.03±0.02[a]	(0-0.09) 0.04±0.02[a]
BOD (mg/L)	(3.0-12.0) 7.0±1.96[a]	(3.0-8.0) 4.25±1.25[a]	(2.0-5.0) 3.25±0.63[a]	(1.0-5.0) 2.50±0.87[a]	(1.0-6.0) 3.0±1.08[a]
COD (mg/L)	(23.15-59.90) 48.79±8.60[a]	(23.11-57.10) 45.88±7.71[a]	(23.10-55.50) 46.83±7.92[a]	(23.11-55.90) 45.93±7.69[a]	(23.14-56.40) 45.59±7.59[a]
Ca (mg/L)	(31.50-48.67) 38.64±1.29[a]	(31.20-48.05) 37.00±1.33[a]	(24.40-34.20) 29.72±0.85[a]	(24.20-43.47) 33.41±1.35[a]	(25.30-38.89) 33.03±0.99[a]
Mg (mg/L)	(30.80-39.50) 35.47±0.66[a]	(31.20-39.40) 35.67±0.64[a]	(31.20-39.80) 35.59±0.67[a]	(31.60-39.40) 35.95±0.60[a]	(30.90-40.0) 35.63±0.72[a]
Na (mg/L)	(13.80-18.10) 16.24±0.30[a]	(13.70-17.64) 15.81±0.30[a]	(13.40-16.40) 14.75±0.23[a]	(13.40-17.78) 15.64±0.30[a]	(13.0-17.93) 15.61±0.33[a]
TP (mg/L)	(0-0.51) 0.27±0.03[a]	(UDL-0.63) 0.21±0.03[a]	(0.082-0.438) 0.223±0.02[a]	(0.085-0.702) 0.348±0.04[a]	(0.077-0.879) 0.403±0.05[a]
K (mg/L)	(4.12-5.69) 5.07±0.11[a]	(3.77-5.44) 4.93±0.13[a]	(3.75-5.18) 4.80±0.11[a]	(3.61-5.64) 5.00±0.15[a]	(3.730-5.380) 4.840±0.123[a]

UDL: Under the detection limit

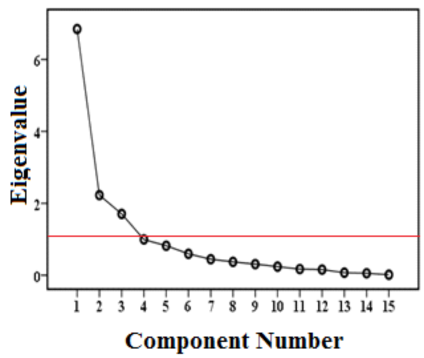

Figure 4. Scree Plot

Table 4 Extracted values of various factor analysis parameters for Porsuk Stream (n=52)

Component	Extraction Sums of Squared Loadings			Rotation Sums of Squared Loading		
	Total	% of Varians	Cumulative %	Total	% of Varians	Cumulative %
1	6.844	45.630	45.630	5.067	33.782	33.782
2	2.227	14.846	60.476	3.494	23.293	57.075
3	1.704	11.359	71.835	2.214	14.760	71.835

The parameter loading for the three components from the principal component analysis of the data set are given in Table 5.

Table 5 Results of the factor analysis for water quality parameters of Porsuk Stream

Parameters	Component		
	1	2	3
Na	.939		
K	.902		
Mg	.840		
TP	.810		
NH_4–N	.745		
NO_2–N	.696		
BOD		.836	
Salinity		.811	
NO_3–N		.711	
PO_4^{-3}		.692	
SO_4^{3-}		.683	
Total Chlorine	.503	.512	
Conductivity			.925
pH			.889
Dissolved Oxygen	-.516		-.588

The first factor (F1) explained 33.78 % of total variance and F1 was namely as nutrient factor. F1 factor occurred Na, K, Mg, TP, ammonium nitrogen, total chlorine and nitrite nitrogen parameters. F2 factor explained % 23.29 of total variance and the second factor (F2) was entitled as domestic and agricultural drainage factor. F2 factor occurred from BOD, salinity, nitrate nitrogen, phosphate, sulfate, total chlorine parameters, and all parameters positively loaded in this factor. The third factor explained % 14.76 of total variance and F3 factor namely as ionic factor. Because conductivity and pH parameters were positively loaded in this factor. Also dissolved oxygen was negative effective in F3 and F1 (Table 5).

4. DISCUSSION

On the Porsuk Stream at the chosen stations, the physicochemical data's values seasonally measured water samples were formed and they were compared with European Commission's water quality directive, 2006 criteria required to protect fresh water fish and by taking account of Inter-Continental's Water Pollution Control Regulations Water Supplies Quality Criteria existed in Turkish Environment Regulations.

According to European Commission's water quality directive (EC Directive) criteria required to protect fresh water fish, it is stated that the ammonium (NH_4) rate in waters should be 1 mg/L and lower for Cyprinids [19]. In this study, the found ammonium rates were under 1 mg/L at stations 1st, 2nd and 4th (Porsuk Dam Lake) in all seasons (Table 2 and 3). But ammonium nitrogen rates were lower than 1 mg/L except for summer season at station 5th. On the other hand, according to Turkish Regulations (2012) [20], in terms of ammonium nitrogen rates stations 1st, 2nd and 4th were first class quality in all seasons. What is more, especially, stations 3rd, 6th, 7th and 9th were fourth class in terms of ammonium nitrogen in spring and summer. The highest ammonium nitrogen rate was determined to be as 10.7 mg/L at station 6th in summer season. Ammonium nitrogen is especially found high at the chosen stations after than Eskişehir and Kütahya where domestic and industrial waste is intense. It is stated that the waste material amount based on Kütahya city such as the fertilizer factory, the magnesite factory the waste water of municipality, Seyit Ömer Thermal Plant which are in Kütahya has affected the Porsuk Stream negatively [21]. It was stated that the fertilizer factory in Kütahya has directly dumped its waste waters containing nitrite, nitrate and ammonium; however, after 1994 the waste containing ammonium has diminished [22]. When the results are examined, it is found that at station 3th, determined as Kütahya exit, the levels of ammonium nitrogen, especially, in summer and spring seasons were quite above water quality standards. According to Eskişehir City Environment Condition Report 2008 [23], ammonium nitrogen rates at Regülator Bridge, Hasanbey Bridge, Alpu Yeşildoğan and Beylikova stations were found to be 0 mg/L. According to the findings obtained in this study, it has been observed that Eskişehir based ammonium dumping is especially quite high at stations 6th and 7th (Table 2).

According to EC Directives (2006) [19], it is stated that dissolved oxygen rates in the waters where Cyprinids are found should not be under 4 mg/L. Annual average dissolved rates on the Porsuk Stream the highest rate is at the station 1th (9.52 mg/L) and the lowest rate is at the station 3rd (2.74 mg/L) (Table 2). As regards EC criteria, dissolved oxygen rates are found to be especially suitable for fish health at the stations 1st, 2nd, 4th, 5th and 9th. Moreover, with regard to Turkish Regulations 2012, although they may change seasonally, through the year dissolved oxygen rates has been observed to be generally first class quality at stations 1st, 2nd, 4th ve 5th; at 9th stations second class quality; at stations 7th and 8th third class quality and at station 6th fourth class water quality. Dissolved oxygen is needed for living beings which live in aerobic environments to do their metabolic activities and dissolved oxygen level in waters shows natural assimilative capacity. Therefore, dissolved oxygen is one of the most important parameter in observing water quality changing supporting the life of living beings, in ensuring the ecological balance, in calculating the assimilation capacity of receiving environment, in estimating aging periods of lakes and seas, in purification wasted waters and in clearance processing of drinking water, in controlling water pollution and observing waste [24]. Kalyoncu et al. (2008) [25], stated that the lowest oxygen levels of Aksu Stream are at the sampling point after mixing domestic waste. Uyanık et al. (2005) [26], in the study they did on the Eğri Stream, the lowest dissolved oxygen levels were shown to be after mixing domestic and industrial wastes. The results obtained are parallel with the others researchers' results. In the waters of the Porsuk Stream, dissolved oxygen levels were found to be quite low especially at the stations 3rd and 6th. This situation may be the result of the two stations being at the exit points of the two cities and domestic, agricultural and industrial waste being really influential. And, not being able to find any fish at stations 3rd, 6th, 7th and 8th could be an indication of low dissolved oxygen levels, in addition, the annual average dissolved oxygen levels are not enough for fish health. At station 4th dissolved oxygen levels shown a change year long between 4.18-11.35 mg/L and according to EC Directives, 2006, these levels were found to be suitable for Cyprinids. Yılmaz et al. 1998 [27], studied some water quality parameters on the Porsuk Dam Lake to see whether they are influential on growing of fish. Besides, they found that oxygen levels changed between 3.2-11.65 mg/L. They pointed that especially as the temperature rise, the oxygen amount needed by fish increased and they found that there is a negative correlation between heat and dissolved oxygen levels.

On the Porsuk Stream, BOD rates for station 1st in summer and spring and for station 2nd in autumn and winter were measured as 0 mg/L. BOD values are the most important criterion for organic pollution. According to EC Directives (2006) [19], it is stated that BOD's rates should not be above 6 mg/L in the waters where Cyprinids are found. The measured BOD rates on the Porsuk Stream at the stations 3nd, 6th, 7th, 8. and 9th at all levels and at the stations 4th ve 5th only in summer season were found to be higher than EC Directives. BOD's rates measured at stations 1st and 2nd are quite lower than EC Directives in the measurement periods. According to EC criteria, the annual average BOD's rates are suitable respectively in stations : 1st (0.25 mg/L), 2nd (1.00 mg/L), 4th (3.55 mg/L) and 5th (5.50 mg/L) (Table 2). According to Turkish Regulations (2012) [20], the Porsuk Stream 1st and 2nd stations were found to be first class water quality in all seasons. But in other stations, although changeable seasonally, especially at station 3rd in summer and winter and at the stations 6th, 7th and 9th, in winter, water quality is found to be fourth class quality (Table 2). What's more, in terms of annual average BOD's rates, stations 1st, 2nd and 4th were found to be first class water quality, station 5th second class water quality, and the other stations were found to be third class water quality.

The highest COD's rate was found to be at station 9th in summer season by 80.3 mg/L. It was stated that, as regards COD's rates, in summer and winter seasons, stations 8th was found to be fourth class water quality. With regard to annual average COD's level, according Turkish Regulations 2012, stations 6th, 7th, 8th and 9th are third class water quality. Furthermore, although stations 3th and 4th were second class water quality, they were found to be close to boundary value.

It was identified that along with the Porsuk Stream, the Ankara Stream, Çarksuyu and Karasu caused organic matters pollution on Sakarya River [28]. It was pointed out that according to National Environment Action Plan, with regard to BOD parameter Porsuk Stream being fourth class water quality, the Sakarya River before the Porsuk Stream being found to be first class water quality, falling up to third class water quality after the Porsuk and Ankara Stream, all shows that the Porsuk Stream affects Sakarya River's organic pollution in a negative way and this shows a parallel with the results of the study [28]. According to EC Directives 2006 [19], pH rates should be between 6-9 for Cyprinids in waters. On the Porsuk Stream, all the obtained pH values are in this gap and there is not any risk for fish health according to EC criteria.

According to EC Directives, 2006 [19], it is stated that nitrite nitrogen rates should be equal to 0.03 mg/L or lower in the waters where Cyprinids are found. The lowest nitrite nitrogen rate was found to be 0.001 mg/L in autumn and the highest nitrite nitrogen rate by 0.375 mg/L at station 8th in summer season Annual average nitrite nitrogen rates were found to be below 0.03 mg/L at stations 1st, 2nd and 9th. According to Türkish Regulations 2012 [20], stations 1st and 2nd were first class; station 4th was second class; station 5th third class and the other stations were fourth class quality. In a study carried out by Bakış et al. 2011 [29], it was specified that the Porsuk Stream's nitrite nitrogen rates were the highest at Kütahya's sewage treatment plant, at dam exit, and in Alpu region. In 2005, it was stated that the part from the Porsuk Stream Kütahya's exit point until the Sakarya River was fourth class quality. The findings obtained in this study are paralleled with literature [29]. Nitrite is a by-product in biological oxidation that is turning into ammonium nitrate and the concentration of nitrite is usually low in natural waters. But in places where organic pollution taking place high concentration levels could occur [30]. According to Turkish Regulations (2012) [20], as regards to nitrate nitrogen rates, all the working stations on the Porsuk Stream are first class water quality. Nitrate nitrogen is an important factor in limiting or increasing algae growing. Nitrate nitrogen's, being an indispensable element for phytoplanktons to grow intensively, normal rates in waters is 1-10 mg/L. In oligotrophic waters ammonium rates is low, whereas in eutrophic waters is quite high [31]. According to Turkish Regulations (2012) [20], measured sulphate rate at all stations was found to be first class water quality except for station 9th. The highest sulphate rate was measured as 366 mg/L at station 9th in summer season. There are a lot of farm lands in the region where the Porsuk Stream flow into the Sakarya River. The reason for high sulphate rates could especially be the intense agricultural activities. Among the stations, the highest phosphate rate was measured as 3.25 mg/L at station 7th in summer season. It was especially stated that phosphate rate didn't change much through seasons, but during summer months it increased a little. Tepe et al. (2006) [32], identified water quality on the Hasan Stream, and they determined that phosphate levels increased monthly during summer months. They explained that this situation could be the result of using phosphate fertilizers and increasing the transfer of phosphorus in water to the soil by rooted above-water plants growing during summer months. The findings obtained from this study support this situation. The lowest electricity conductivity rate of the Porsuk Stream was measured as 326 µs/cm at station 1st in winter season, while the highest rate was measured as 2180 µs/cm at 4.1th station in spring season. And the annual average conducting rate was measured as 745.25 µs/cm at station 1st. The reason for decreased conducting rate at all stations in winter season could be explained by increasing of rainfall.

Salinity values especially at stations 3rd, 6th, 7th and 9th were to be found higher than the other stations in all seasons. The fertilizer both natural and artificial used in agricultural lands, domestic waste water and geologic structure of the river bed could increase salinity rate. Because high concentration of salt in water leads to aridity in the soil, this is an unwanted circumstance [31]. The highest salinity rate in the Porsuk Stream's water was found to be as ‰ 0.94 at station 9th in summer season. Because of its location at the last point of the Porsuk Stream, station 9th is at a point where the pollution loads accumulate and it can be said that intensive agricultural activities increase the salinity rate.

The pollution of Karaçay was analyzed with physicochemical and biological parameters by Kara et al. 2004 [33]. They specified that the rates of nitrite, phosphate and conductivity were quite high and dissolved oxygen rates were low at the stations. They linked this condition with region being under the influence of domestic, industrial and pollution. The results obtained from this study show parallels with literature knowledge especially at stations 3rd, 6th, 7th and 8th.

In the field of study, the highest mean Ca level was found to be as (78.40 mg/L) in spring season at the station 3rd, at the station 9th in the summer and autumn season and at the station 1th it was found to be as (181 mg/L) in winter. Mg was found to be the highest at station 9th in all seasons and annual average Mg level was 109.40 mg/L at station 9th. On the Porsuk Dam Lake (stations 4.1-4.5th), Ca levels showed a change at the stations between 24.20 and 48.67. Also Mg levels were determined between 30.80 and 40 mg/L (Table 3).

Sodium element was determined at the highest level at station 9th in all seasons. It was determined that according to Turkish Regulations, as regards Na levels, in station 9th was found to be fourth class in summer season and in spring and winter to be third class quality.

According to Turkish Regulations [20], total phosphorus levels, at stations 3rd, 6th, 7th and 8th in all seasons, station 5th in summer season, and station 9th in autumn and spring seasons were found to be fourth class. On the Porsuk Dam Lake, the determined average highest phosphorus level was found to be at the station 4.5th in spring season and the lowest level was found to be at station 4.3th in summer season. Porsuk Dam Lake, as for total phosphorus was found to be second class quality in all seasons. The most important resources of phosphorus in the fresh waters are wastewaters and fertilizer. The extreme increasing of phosphorus may lead to eutrophication by accelerating vegetative production [34].

At the Porsuk Stream's stations the determined potassium element was found to be the highest at station 9th in spring, summer and autumn seasons. At Porsuk Dam Lakes' stations, the stated average potassium element levels showed a change between 4.80 mg/L and 5.07 mg/L all the year round.

According to BEBKA Environment Condition Report 2011 [35], when Porsuk Stream enters into Kütahya city, it is first class quality, but after leaving the city it was stated that the Stream water is first class quality in terms of dissolved oxygen, BOD and COD levels while it decreases fourth class quality in terms of ammonia nitrogen. They added that when Porsuk passed through Eskişehir city there was no discharge, but a bit after city center's exit the Porsuk Stream was under the pressure of Eskişehir Organized Industrial Zone treated wastewaters, some industrial establishment's purified wastewaters, wastewaters from wastewater treatment plants of Eskişehir Water and Sewerage Administration and animal production, unpurified domestic and industrial wastewaters before joining Sakarya River when it passed through Alpu, Beylikova ve Yunusemre towns.The results of this study are in parallels with BEBKA Environment Report, (2011) [35].

According to factor analysis (FA) results done by using measured water quality parameters on the Porsuk Stream, three factors were determined explaining % 71.83 of the total variant (Table 4). Liu, et al. 2003 [36], classified factor load as strong (< 0.75), moderate (middle) (0.75-0.50) and weak (0.50-0.30). According to factor analyzing results, in this study the first factor (F1) % 33.78 of the total variant (Table 4). Because Na, K, Mg and the total P parameters had a strong positive load in factor 1. (F1), this factor was named as nutrient factor (Table 5). In the second factor explaining % 23.29 the total variant BOD, salinity and nitrate nitrogen were strong positive influential and as for phosphate, sulphate, and the total chlorine were positive influential, this factor was named as domestic and agricultural drainage factor. The third factor explained % 14.76 of the total variant, besides it had conductivity in F3 and pH parameters had strong positive load and dissolved oxygen was negative influential in this factor (Table 5). Altın et al. (2009) [8], determined a factor analysis by using certain physicochemical parameters of Porsuk Stream for ten years (1995-2005) on seasonal periods. They reported that the Porsuk Stream was exposed to organic, inorganic, mineral and microbial pollution from domestic, industrial and agricultural activities.

Cluster analysis can utilize for detect similarity groups between the sampling stations [8]. As a result of clustering analysis four different clusters were specified in Porsuk Stream (Figure 3). Stations 3rd, 6th, 7th and 8th were created a cluster (cluster 2) (Figure 3). The water quality of this stations is quite low and and they show a high similarity to each other. The station 3rd is located at the point where Kütahya's industrial, domestic and sewage flow into the Porsuk Stream. While the Porsuk Stream passes through Eskişehir city center, by taking the industrial wastewaters and city's sewage, it irrigates Alpu's and Beylikova's lands and the remaining waters joins into Sakarya River near Beyliköprü Bridge [22, 37, 38]. Also, Porsuk Dam Lake stations were formed a cluster and the first station (4.1th) at entrance of Porsuk Dam Lake were found close to cluster 2. According to clustering analysis results, the station 9th is located in the lowest basin of the Porsuk Stream and it is subjected to intense pollution drainage, the found low similarity level is an expected result.

5. CONCLUSIONS

Porsuk Stream provides drinking and utility water for two Turkish cities (Kutahya and Eskisehir) with a total population of one million. Carrying the pollution load of Eskişehir and Kütahya, the Porsuk Stream heavily affects the water quality of the Sakarya River, which one of the most important river of Turkey, and even the Black Sea. The rehabilitation of the Porsuk Stream's pollution load and lowering its pollution rates to acceptable levels will play a useful role in the health of the Porsuk Stream's Basin and the other related ecosystems.

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