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RESEARCH NOTE

Assessment of Surface Water Quality in the Atikhisar Reservoir and Sarıçay Creek (Çanakkale, Turkey)

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Abstract
This study was carried out to evaluate the surface water quality of the Atikhisar Reservoir and Sarıçay Creek. Multivariate statistical techniques such as cluster analysis (CA), principal component analysis (PCA), multidimensional Scaling (MDS), and univariate statistical techniques such as two-way ANOVA were used to analyze the data. Three different groups were formed based on Cluster analysis. Two-way ANOVA test results showed that interaction effects of any variables of the reservoir were non-significant but the interaction effects of pH in the creek were significant. Temperature (T), electrical conductivity (EC), oxygen saturation (OS), biological oxygen demand (BOD), chemical oxygen demand (COD), total phosphate (TP), total nitrate (TN), salinity (Sal), pH, Chl-*a*, and total suspended solids (TSS) of the reservoir were significantly different among seasons. While differences of T, EC, DO, TP, Chl-*a*, and TSS of the Sarıçay Creek were significant among seasons, only the differences of temperature among the stations were significant. Multi dimensional scaling (MDS) analysis results revealed that the variables such as EC, Sal, OS, T and TN affected the differences among the sites, while the other variable groups were showing a similarity with the COD, BOD, TSS, AD, TP, pH, DO and Chl-*a*. The principle component analysis (PCA) results showed that the eigenvalues of the first 5 PCA were larger than 1.00, suggesting that they explained 98 % of the total variation.
Keywords: Atikhisar reservoir, cluster analysis, multidimensional scaling, principal component analysis, Sarıçay, surface water quality.

Atıkhisar Barajı ve Sarıçay'daki Yüzey Suyu Kalitesinin Değerlendirilmesi (Çanakkale, Türkiye)

Özet
Bu çalışma Atıkhisar Barajı ve Sarıçay'ın yüzey suyu kalitesinin değerlendirilmesi amacıyla yapılmıştır. Bu amaçla, hem çok değişkenli analiz tekniklerinden Kümeleme Analizi (KA), Temel Bileşenler Analizi (TBA), Çok Boyutlu Ölçekleme Analizi (ÇBÖ) hem de tek değişkenli analiz tekniklerinden 2 yönlü varyans analizi (TWANOVA), verileri analiz etmek için kullanılmıştır. KA analizi sonuçlarına gore 3 farklı grup oluşmuştur. 2 yönlü ANOVA sonuçları, rezervuarda hiç bir değişkenin interaksiyon etkisinin istatistiksel olarak önemli olmadığı fakat sadece çayda pH'ın istatistiksel olarak interaksiyon etkinin önemli olduğunu göstermiştir. Buna ilaveten, rezervuarın, sıcaklık (T), iletkenlik (CE), oksijen saturasyonu (OS), biyolojik oksijen ihtiyacı (BOİ), kimyasal oksijen ihtiyacı (KOİ) toplam fosfor (TP), toplam azot (TN), tuzluluk (Sal), pH, toplam askıda madde (TSS) değerlerinin mevsimler arasında istatistiksel olarak önemli bulunmuştur. Sarıçay'da ölçülen sıcaklık, iletkenlik, çözünmüş oksijen, toplam fosfor, klorofil-a ve askıda katı madde verileri mevsimler arasında istatistiksel olarak önemli bulunmuşken, istasyonlar arasındaki sıcaklık önemli bulunmuştur. ÇBÖ analiz sonuçları iletkenlik, tuzluluk, oksijen saturasyonu, sıcaklık ve toplam azot gibi değişkenlerin istasyonların farklılığında, kimyasal oksijen ihtiyacı, biyolojik oksijen ihtiyacı, askıda katı madde, anyonik deterjan, toplam fosfor, pH, çözünmüş oksijen ve klorofil-a' nın ise benzerliğinde rol aldığını ortaya çıkarmıştır. TBA analiz sonuçları, ilk 5 bileşenin özdeğerlerinin 1'den büyük olduğu ve bu yüzden toplam varyasyonun % 98'ini açıkladığını göstermiştir.
Anahtar Kelimeler: Atikhisar Barajı, çok boyutlu ölçekleme analizi, kümeleme analizi, Sarıçay, temel bileşenler analizi, yüzey suyu kalitesi,

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INTRODUCTION

Rivers and reservoirs play a major role in drinking water, agricultural use, fishery, and electricity production, so protection of water quality is a very important issue and it should be kept at acceptable levels (Quyang et al. 2006). Anthropogenic impact such as urban, industrial and agricultural activities as well as natural processes (precipitation

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inputs, erosion, etc.) diminish the surface water quality and lower the use for drinking agricultural and other purposes (Carpenter et al. 1998). Polluted rivers and reservoirs affect aquatic life directly. The concentrations of toxic materials such as heavy metals, pesticides, and nutrients in excess can cause various problems such as loss of oxygen, fish deaths, loss of biodiversity, and they also have negative effects on human health. In a well-balanced aquatic ecosystem, the quality of water plays a critical role between the organisms and environment. It is also extremely important for the health of the ecosystem (Vousta et al. 2001, Ntengve 2006).

However, due to spatial and temporal fluctuations in water quality, a monitoring program providing a representative and reliable estimation of the quality of surface waters is necessary (Dixon and Chrisswell 1996). In such a program, the data sets include rich information about the behavior of the water resources. The assessment of the water quality can be performed by classification, modeling, and interpretation of the monitored data (Simeonov et al. 2003, Boyacığlu 2006).

Multivariate statistical techniques such as Cluster Analysis (CA), Principal Component Analysis (PCA), and Multidimensional Scaling (MDS) analysis helps with the interpretation of the monitored data to better understand the behavior of the pollution sources, the water quality, ecological situation of the studied area, management of the water resources, and solution for the pollution problems (Vega et al. 1998, Lee et al. 2001, Simeonov et al. 2003, Shrestha and Kazama 2007).

The Atikhisar Reservoir and Sarıçay Creek supply drinking and irrigation waters for Çanakkale city. There are lots of factors threatening water quality of the sampling areas such as sewage and agricultural wastewater. Although there has been a few studies about Sarıçay Creek's water quality (Arık Çolakoğlu and Çakır 2004, Odabaşı and Büyükateş 2009) there are no studies on the Atikhisar reservoir's water quality. The purpose of this study was to apply multivariate statistical techniques such as CA, PCA and MDS to evaluate the seasonal variations of the water quality parameters, to extract temporal and spatial variations in water quality, to investigate the similarities or dissimilarities between the sampling sites.

MATERIAL AND METHODS

Study area

This study was carried out on the Atıkhisar Reservoir and Sarıçay Creek located in the North-Western part of Turkey. The reservoir, land filled, was built on Sarıçay Creek for drinking, irrigation and flood preventation. The reservoir has an average depth of 8.5 m and a maximum depth of 33 m with a surface area of 3.622 km^2 The reservoir is fed principally by Sarıçay Creek and its tributaries. Sarıçay Creek arises from Mount Ida located in Çanakkale with a length of 40 km with a discharge of 15-1300 m^3/s It flows into the Dardanelles in the Center of Çanakkale city, and therefore, it is exposed to domestic waste and agricultural runoff. The locations of the sampling sites are shown in Fig. 1.

Water Sampling

Water samples were collected between September 2005 and August 2006 from station 1-4 at the Atikhisar reservoir and station 5-8 on Sarıçay Creek seasonally (Table 1).

All samples were collected, preserved, and stored for analysis as outlined in the Standard Methods for the examinations of Water and Wastewater (Anonymous 1992). One and two litter polyethylene bottles were used to determine the chemical properties of the water. The bottles were kept at 4°C and were analyzed within 24 h (Table 2).

Statistical Methods

Three multivariate techniques and one univariate statistical technique were used to evaluate the surface water quality of the stations. SPSS for Windows (ver.15.0) and PAST for Windows (ver. 8.1) statistical package programs were used in analyzing the data sets.

Principal Component Analysis (PCA)

The Principal Component Analysis (PCA) is one of the commonly used tools to explain the variance of a large dataset of inter-correlated variables with a smaller set of independent variables (Simeonov et. al 2003). The objective of the PCA was to determine the hidden factors responsible for the data structure when the whole data set is considered (all sites, all parameters, all 104 cases all together) and when each site is treated separately (13 cases for each one of the 8 sides). In this way a comparison of the factors role could be made on a large scale (all sites together) or on a local scale (separate sites) (Spanos et al. 2003).

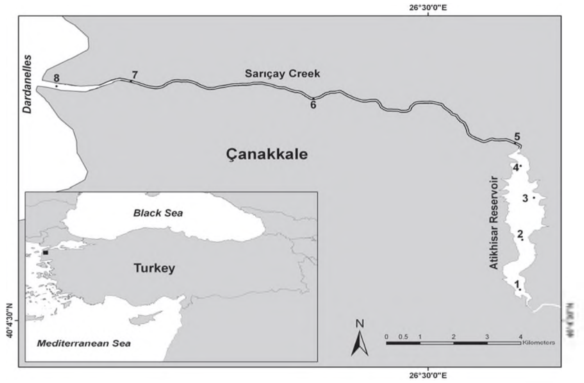

Fig 1. Map of the study area and the sampling stations in the Atikhisar Reservoir and Sarıçay Creek, Çanakkale

Table 1. Details of the sampling stations in Sarıçay Creek and the Atikhisar Reservoir.

Station	Coordinate	Depth (cm.)	Bottom Structure	Agricultural area around it	Settlement area around it
1.	40° 04' 56,65" N 26° 31' 32,69" E	200–250	Muddy, Detritus	present	absent
2.	40° 06' 05,01" N 26° 31' 50,53" E	150–200	Sandy, muddy	present	absent
3.	40° 06' 32,42" N 26° 31' 19,95" E	800–900	Muddy, Detritus	present	present (Atikhisar village)
4.	40° 07' 16,83" N 26° 31' 30,09" E	600–700	Detritus, stonny	present	absent
5.	40° 07' 39,02" N 26° 31' 30,77" E	30–40	Planty, muddy	Absent	absent
6.	40° 08' 22,29" N 26° 28' 17,91" E	50–60	Macrophytes, sandy	present	present (Saraycık village)
7.	40° 08' 41,05"N 26° 25' 08,85" E	40–50	Macrophytes, sandy, black muddy	Absent	present (Çanakkale)
8.	40° 08' 34,96" N 26° 24' 00,48" E	120–130	Black muddy	Absent	present (Çanakkale)

Table 2. Water quality data, units and analytical methods used during 2005-2006 for the surface waters of the Atıkhisar Reservoir and Sarıçay Creek.

Data	Abbreviations	Units	Analytical methods
pH	pH	pH unit	pH meter (YSI), in situ
Dissolved Oxygen	DO	mg l^{-1}	Oxygen meter (YSI 100), in situ
Salinity	Sal	Ppt	Oxygen meter (YSI 100), in situ
Temperature	T	^{0}C	Oxygen meter (YSI 100), in situ
Oxygen Saturation	OS	%	Oxygen meter (YSI 100), in situ
Electrical Conductivity	EC	Umhos/cm	Oxygen meter (YSI 100), in situ
Biochemical Oxygen Demand	BOD_5	mg l^{-1}	WTW oxiotop
Chemical Oxygen Demand	COD	mg l^{-1}	Potassium Dichromate
Anionic Detergent	AD	mg l^{-1}	MBAS method
Total Phosphorus	TP	mg l^{-1}	Strickland and Parsons (1972)
Total Nitrate	TN	mg l^{-1}	Strickland and Parsons (1972)
Chlorofil-a	Chl-a	mg l^{-1}	Strickland and Parsons (1972)
Total Suspended Solids	TSS	mg l^{-1}	Gravimetric analysis

Cluster Analysis (CA)

The Cluster Analysis's (CA) aim was to find natural groupings of samples such that samples within a group are more similar to each other, generally, than samples, in different sites and times. The resulting clusters of objects should then exhibit high internal (within-cluster) homogeneity and high external (between clusters) heterogeneity (Shrestha and Kazama 2007). Hierarchical agglomerative clustering provides intuitive similarity relationships between any one sample and the entire data set and is typically illustrated by a dendrogram (McKenna 2003).

Multidimensional Scaling (MDS) Analysis

The Multidimensional Scaling technique (MDS) is a set of data analysis techniques, which allow one to infer the dimensions of the perceptual space of subjects. The primary outcome of MDS analysis is a spatial configuration, in which the objects are represented as points. The points in this spatial representation are arranged in such a way, that their distances correspond to the similarities of the objects: similar objects are represented by points that are close to each other, dissimilar objects by points that are far apart (Wunderlin et al. 2001, Bulut et al. 2008). In this study, MDS analysis was used to determine which physico-chemical variables play roles in similarities or dissimilarities between sites and seasons.

Two-Way Analysis of Variance

The 13 variables of Sarıçay Creek and the Atikhisar Reservoir were analyzed for season x station interaction effects using a two-way ANOVA. The Tukey HSD multiple comparison test was used for the different seasons and stations in the reservoir. Station 5 was chosen as the reference station due to very clean water. The Dunnet test was used to compare the reference station (station 5) with the others, namely station 6, 7 and 8.

RESULTS

Results of Principle Component Analysis (PCA)

As seen in Table 3, the eigenvalues of the first PCAs 5 were larger than 1.00, so it can be said that they explained 98% of the total variation.

According to Table 5, 6 of the 13 variables were at PC1, 4 variables were at PC2, 2 variables were at PC3, and 1 variable was at PC5. In PC1, temperature, anionic detergent, salinity, total nitrate, total phosphate, pH placed, and loadings of these 6 variables were in the same direction. The 6 variables in PC1 explained 31% of the total variation. According to the loadings, COD, BOD, and TSS in PC2 were in the same direction and explained 25.6% of the total variation. Both PC1 and PC2 explained 57.4% of total variation together. Oxygen saturation and dissolved oxygen in PC3 explained 19.9% of the total variation and was in the same

Table 3. The Principle Component eigenvalues and their proportions.

Component	Eigenvalue	Proportion	Cumulative
1	4.1279	0.318	0.318
2	3.3316	0.256	0.574
3	2.5931	0.199	0.773
4	1.6727	0.129	0.902
5	1.0117	0.078	0.980
6	0.2439	0.019	0.999
7	0.0190	0.001	1.000
8	0.0000	0.000	1.000
9	0.0000	0.000	1.000
10	0.0000	0.000	1.000
11	0.0000	0.000	1.000
12	-0.0000	-0.000	1.000
13	-0.0000	-0.000	1.000
Total	12.999		

Table 4. The Principle Component's coefficients and loadings of variables.

Variables	Coefficients					Loadings				
	PC1	PC2	PC3	PC4	PC5	PC1	PC2	PC3	PC4	PC5
T	0.318	0.051	0.286	0.461	0.049	0.645	0.093	0.461	-0.597	-0.050
CE	0.286	0.418	-0.048	0.027	-0.048	-0.581	0.764	0.135	0.035	-0.048
DO	0.025	-0.259	-0.426	0.416	-0.072	-0.051	-0.473	0.687	0.538	-0.073
OS	0.211	0.029	-0.523	0.165	-0.124	0.429	0.053	0.843	0.214	-0.125
COD	0.173	0.458	-0.215	-0.132	-0.164	-0.351	0.836	0.347	-0.171	-0.165
BOD_5	0.078	0.507	0.162	-0.086	-0.187	-0.159	0.925	-0.261	-0.111	-0.188
AD	-0.446	0.083	0.162	0.189	0.156	0.906	0.152	-0.260	0.244	0.157
TP	-0.283	0.143	-0.081	-0.445	0.491	0.574	0.260	0.131	-0.575	0.494
TN	-0.325	0.194	0.353	0.242	0.017	0.660	0.354	-0.568	0.312	0.018
Sal	-0.398	0.032	0.294	0.173	-0.251	0.808	0.058	-0.473	0.224	-0.253
pH	-0.415	0.010	-0.290	-0.102	-0.208	0.843	0.018	0.467	-0.131	-0.210
Chl-a	0.029	0.235	-0.172	0.351	0.717	-0.059	0.428	0.277	0.454	0.721
TSS	-0.144	0.409	-0.160	0.326	-0.164	0.293	0.746	0.258	0.421	-0.165

direction. Chl-*a* in PC5 explained alone 7% of total variation.

Results of Two-way ANOVA

ANOVA results were given in Table 5 and 6. For temperature, the season x station interaction effect was non-significant (p=1.000). Likewise, the differences among the stations were non-significant (p=0.998). On the other hand, statistically significant differences were observed among the seasons (p=0.000). Results of the Tukey test showed that there were significant differences between Autumn 2005 and Winter 2006 (p=0,007), Autumn 2005 and Summer 2006 (p=0.001), Winter 2006 and Spring 2006 (p=0.048), Winter 2006 and Summer 2006 (p=0.000), and Spring 2006 and Summer 2006 (p= 0.000). It is possible to conclude that differences among reservoir temperatures were non-significant spatially, but differences among the seasons for temperature were large enough to be significant.

In terms of the electrical conductivity (EC) of the reservoir, the season x station interaction effects were not significant (p=0.999). Likewise, the differences among the EC means of the stations were not important statistically (p=0.854). But, differences among the seasons were significant (p=0.000). The Tukey HSD indicated that the differences of the EC means were significant between Autumn-2005 and Winter-2006 (p=0.000), Winter-2006 and Spring-2006 (p=0.000), and Winter-2006 and Summer-2006 (p=0.000) statistically. While the EC of the reservoir did not change spatially, it changed temporally.

For the dissolved oxygen (DO) in the reservoir, the season x station interaction effects were non-significant statistically (p=1.000). Similarly, the differences among the DO means of the stations and seasons were found to be non-significant (p=0.559, p=0.148). So, the DO of the reservoir changed both spatially and temporally.

The season x station interaction effects were non-significant for the oxygen saturation (OS) in the reservoir (p=1.000). Although the differences among observed means of the stations OS were found to be non-significant (p=0.209), differences among seasons were significant (p=0.01). The Tukey HSD test indicated that differences among the OS means were significant between Autumn-2005 and Summer-2006 (p=0.020), and Winter-2006 and Summer-2006 (p=0.038). The OS of the reservoir did not change among the stations, but changed seasonally.

The season x station interaction effects were non-significant for the chemical oxygen demand (COD) of the reservoir (p=1.000). Likewise, the differences among the observed means of the stations COD and seasons were found to be non-significant (p=0.935, p=0.823). The COD of the reservoir did not change among the stations and seasons.

The season x station interaction effects were non-significant for the biological oxygen demand (BOD) of the reservoir (p=0.886). The differences among the observed means of the stations BOD ascertained was non-significant (p=0.886). But, it was seen that differences among the seasons were significant (p=0.009). In the result of the Tukey HSD test, the differences of the BOD observed means were found to be significant between winter-2006 and spring-2006 (p=0.018). In conclusion, the BOD of the reservoir did not change among the stations, but changed seasonally.

For the anionic detergent (AD) of the reservoir, the interaction effect of the seasonx station was found to be non-significant (p=0.985). Likewise, the differences among the observed means of both stations and season's AD were determined as non-

Table 5. The results of the two-way ANOVA (station, season, stationxseason), mean ± standard error and probability (p) of the physicochemical variables in the Atikhisar Reservoir.

Variables	Season	Stations in Atikhisar Reservoir				p
		1 x±SE	2 x±SE	3 x±SE	4 x±SE	p-stations x seasons p-stations p-seasons
T(⁰C)	Autumn	16.77±3.25Aa	17.27±2.82 Aa	17.73±2.90 Aa	17.63±2.88 Aa	1.000
	Winter	8.90±1.99Ab	10.13±2.65Ab	10.53±2.27Ab	10.46±2.72Ab	0.998
	Spring	15.87±4.21Aa	15.17±4.38Aa	15.67±4.74Aa	16.06±4.34Aa	0.000
	Summer	27.03±0.33Ac	26.43±0.53Ac	25.73±0.93Ac	25.76±0.77Ac	
EC(μmhos/cm)	Autumn	307.50±19.72Ab	314.13±13.90Ab	309.30±9.58Ab	309.00±15.96Ab	0.999
	Winter	228.33±21.77Ac	238.47±29.77Aa	232.00±24.05Ac	232.30±24.09Ac	0.854
	Spring	323.13±20.13Aa	311.63±17.88Ab	305.20±20.77Ab	302.27±18.15Ab	0.000
	Summer	340.20±23.09Aa	344.97±19.12Aa	322.33±19.39Aa	327.27±22.14Aa	
DO(mg l⁻¹)	Autumn	8.27±0.38Aa	8.1833±0.20Aa	7.9267±0.51Aa	7.53±0.54Aa	1.00
	Winter	8.87±0.32Aa	8.37±0.75Aa	7.66±0.22Aa	7.9400±0.40Aa	0.559
	Spring	7.67±0.75Aa	7.80±0.72Aa	7.31±0.68Aa	7.32±0.71Aa	0.148
	Summer	7.29±1.16Aa	7.19±1.01Aa	7.15±1.02Aa	6.9133±0.74Aa	
OS(%)	Autumn	91.27±2.28Aa	91.67±1.17Aa	89.300±1.65Aa	83.33± 0.16Aa	1.00
	Winter	89.67±3.16Aa	91.37±3.77Aa	86.23±4.10Aa	85.00±4.59Aa	0.209
	Spring	84.60±6.32Ab	83.70±3.51Ab	81.57±3.55Ab	79.93±3.15Ab	0.01
	Summer	82.03±5.49Ab	80.20±5.88Ab	79.63±7.11Ab	76.43±5.22Ab	
COD(mg l⁻¹)	Autumn	5.00±0.16Aa	3.00±1.15Aa	3.33±0.33Aa	3.67±0.88Aa	1.00
	Winter	3.66±0.88Aa	5.00±1.00Aa	5.33±1.33Aa	2.67±0.66Aa	0.935
	Spring	3.66±0.88Aa	5.33±0.66Aa	5.00±0.31Aa	4.67±1.20Aa	0.823
	Summer	2.33±0.88Aa	5.33±2.02Aa	4.00±1.52Aa	5.67±1.05Aa	
BOD(mg l⁻¹)	Autumn	0.20±0.00Ab	0.17±0.03Ac	0.20±0.05Ac	0.13±0.03Bb	0.886
	Winter	0.23±0.03Ab	0.13±0.03Bc	0.10±0.00Bd	0.10±0.00Bb	0.886
	Spring	0.27±0.12Ba	0.37±0.12Aa	0.37±0.08Aa	0.33±0.12Aa	0.009
	Summer	0.23±0.08Bb	0.27±0.12Bb	0.30±0.10Ab	0.37±0.16Aa	
AD(mg l⁻¹)	Autumn	0.10±0.04Aa	0.07±0.04Aa	0.13±0.06Aa	0.14±0.07Aa	0.985
	Winter	0.03± 0.02Aa	0.06±0.04Aa	0.10±0.07Aa	0.01±0.01Aa	0.547
	Spring	0.06 ±0.05Aa	0.07±0.05Aa	0.10±0.10Aa	0.07±0.06Aa	0.399
	Summer	0.11±0.02Aa	0.07±0.03Aa	0.12±0.04Aa	0.09±0.01Aa	
TP(μg l⁻¹)	Autumn	9.94±0.18Ba	9.55±0.33Ba	15.10±6.03Aa	13.27±3.26Aa	0.781
	Winter	9.24±0.11Aa	10.59±0.84Aa	9.23±0.23Ab	9.88±0.66Ab	0.469
	Spring	8.82±0.43Aa	10.15±1.04Aa	9.60±0.83Ab	8.53±0.71Ab	0.024
	Summer	6.47±1.68Ab	7.95±0.26Ab	8.80±0.33Ab	7.82±0.29Ab	
TN(μg l⁻¹)	Autumn	18.09±4.39Aa	16.88±3.24Ba	21.11±2.15Aa	15.57±2.07Ba	0.793
	Winter	14.38±3.89Ba	12.77±0.29Bb	19.28±4.88Aa	11.15±1.16Bb	0.595
	Spring	10.83±1.40Ab	14.09±6.75Aa	10.48±1.92Ab	13.28±3.94Aa	0.123
	Summer	8.88±0.85Ab	5.36±2.55Bc	9.60±0.91Ab	9.93±3.88Ab	
Sal(ppt)	Autumn	0.20±0.00Aa	0.20±0.00Aa	0.20±0.00A	0.20±0.00Aa	0.999
	Winter	0.13±0.03Ab	0.13±0.03 Ab	0.13±0.03 Aaa	0.13±0.03 Ab	0.945
	Spring	0.17±0.03 Aa	0.17±0.03Aa	0.13±0.03A	0.17±0.03Aa	0.001
	Summer	0.20±0.00 Aa	0.20±0.00 Aa	0.20±0.00Aa	0.20±0.00Aa	
pH	Autumn	7.87±0.11Ab	8.05±0.11Aa	7.96±0.10Ab	7.86±0.18Ab	0.999
	Winter	7.71±0.19Ab	7.62±0.15Ab	7.66±0.07Ab	7.66±0.07Ab	0.999
	Spring	8.16±0.08Aa	8.12±0.08Aa	8.03±0.09Aa	8.04±0.10Aa	0.002
	Summer	8.40±0.43Aa	8.35±0.38Aa	8.15±0.24Aa	8.36±0.43Aab	
Chl-a(μg l⁻¹)	Autumn	8.77± 0.78Ab	8.34±1.52Ab	8.87±1.36Ab	7.89±2.03Ab	0.267
	Winter	2.35±1.15Bc	1.55±0.59Bc	2.56±0.29Bc	4.47±2.70Ac	0.09
	Spring	12.79±2.40Ab	7.52±4.42Bb	12.96±2.79Aa	7.74±3.69Bb	0.001
	Summer	23.42±6.98Aa	10.66±1.88Ba	12.46±3.32Ba	9.58±1.66Ba	
TSS(g l⁻¹)	Autumn	0.004±0.00Ac	0.001±0.00Ab	0.001±0.00Ac	0.001±0.00Ab	0.557
	Winter	0.008±0.00Bc	0.004±0.00Ab	0.003±0.00Bc	0.002±0.00Bb	0.292
	Spring	0.013±0.001Ab	0.008±0.001Bb	0.008±0.001Bb	0.005±0.001Bb	0.001
	Summer	0.025±0.005Ba	0.018±0.002Ba	0.022±0.007Ba	0.032±0.01Aa	

Note 1. Differences among the stations displayed by capital letters in the same rows are significant (?=0.05).
Note 2. Differences among the seasons displayed by lower-case letters in the same columns are significant (?=0.05).

significant (p=0.547, p=0.399). So, it was seen AD in the reservoir didn't change among the seasons and stations.

The season x station interaction effects were non-significant for the total phosphate (TP) in the reservoir (p=0.781). Likewise, differences among the observed means among the stations was found to be non-significant (p=0.469). After all, the differences among the observed means of the seasons were significant (p=0.024). The Tukey HSD tests showed that differences among the TP means were significant between Autumn-2005 and Summer-2006 (p=0.014). The TP of the reservoir did not change among the stations but changed seasonally.

In terms of the total nitrate (TN) in the reservoir, the season x station interaction effects were non-significant (p=0.793). Likewise, the differences among the observed means of the stations and seasons COD were found to be non-significant (p=0.595, p=0.123). In conclusion, the TP in the reservoir did not change among the seasons and stations.

The season x station interaction effect were non-significant for salinity in the reservoir (p=0.999). Likewise, the differences among the observed salinity means of the stations were found to be non-significant (p=0.945). But, differences among the observed means of the seasons were significant (p=0.001). The Tukey HSD test suggested that the differences among salinity means were significant between Autumn-2005 and Winter-2006 (p=0.002), and Winter-2006 and Summer-2006 (p=0.002). Accordingly, the salinity of the reservoir did not change among the stations but changed seasonally.

For the pH levels of the reservoir, the station x season interaction effects were non-significant (p=0.999). Likewise, the differences among the observed means of the pH in the stations were non-significant (p=0.999). On the other hand, the differences among the observed means of the seasons was significant (p=0.002). The Tukey HSD test results showed that the differences among the pH means were significant between Winter-2006 and Spring-2006 (p=0.043), and Winter-2006 and Summer-2006 (p=0.001). In short, the pH of the reservoir didn't change among the stations, but changed seasonally.

In terms of the Chl-*a* of the reservoir, the season x station interaction effects were non-significant (p=0.267). Similarly, there were no differences among the observed means of the Chl-*a* of the stations (p=0.09). However, the differences among the observed means of Chl-*a* the seasons were highly significant (p=0.001). Tukey HSD test indicated that differences among the Chl-*a* means were significant between Autumn-2005 and Winter-2006 (p=0.037), Autumn-2005 and Summer-2006 (p=0.045), Winter-2006 and Spring-2006 (p=0.004). In conclusion, it can be said that the Chl-*a* level of the reservoir didn't change among the stations, but changed seasonally.

The season x station interaction effects were non-significant for the total suspended solids (TSS) in the reservoir (p=0.577). Likewise, the differences among the observed means of the TSS at the stations was non-significant (p=0.292). On the other hand, there were differences among the observed means of the seasons TSS (p=0.001). The Tukey HSD test results showed that the differences among the TSS means were significant between Summer - 2006 and the other 3 seasons (p=0.001). This suggests that the TSS level of the reservoir did not change among seasons but changed seasonally.

According to table 6, the 13 variables taken from station 5-8 at the Atikhisar Reservoir for four seasons (Autumn- 2005, Winter-1006, Spring-2006 and Summer-2006) were analyzed using the two-way variance of analysis (ANOVA). Later, a Post Hoc Test (Tukey HSD) was made to determine the different seasons. The Dunnett test was performed to determine the different stations from the reference station, considering station 5 as the reference (control group) station.

The station x season interaction effects were non-significant for the temperature (T) of Sarıçay Creek (p=0.390). On the other hand, the differences among the observed means of both seasons and stations were significant (p=0.018, p=0.001). The Tukey HSD test showed that the differences among the temperature means were significant between Autumn-2005 and winter-2006 (p=0.001), Autumn 2005 and Spring - 2006 (p=0.045), autumn 2005 and Summer 2006 (P=0.05), and Winter 2006 and Spring-2006 (p=0.001). The Dunnett test results indicated that the differences among temperature means of station 5-7 (p=0.022), and station 5-8 (P=0.011) were significant, but were non-significant for stations 5 and 6 (p=0.111). Accordingly, the temperature in Sarıçay Creek changed among the stations seasonally.

The station x season interaction effects were non-significant for the electrical conductivity (EC) of Sarıçay Creek (p=0.390). Although the differences among the observed EC means of the seasons were significant (p=0.002), differences among the means of the stations EC were non-significant (p=0.114). The Tukey Test showed that the differences among the observed means of the EC were significant between Winter-2006 and Summer-2006 (p=0.015). The Dunnett test revealed that differences among the observed the EC means of station 6, 7, 8 and station 5 (reference station) were non-significant. EC of Sarıçay Creek changed among seasons, but did not change among stations.

For the dissolved oxygen (DO) of Sarıçay Creek, the station x season interaction effects were non-significant (p=0.246). Likewise, the differences among the observed DO means of the seasons and stations were non-significant (p=0.3128,

Table 6. The results of the two-way ANOVA (station, season, stationxseason), mean ±standard error and probability (p) of the physicochemical variables in Sarıçay Creek.

Variables	Season	Stations in Sarıçay Creek 5 x±SE	6 x±SE	7 x±SE	8 x±SE	p: p-stations x seasons / p-stations / p-seasons
T(^{0}C)	Autumn	14.70±1.15Aa	15.03±0.22Ab	14.03±0.54Ab	16.47±0.96Ab	0.390
	Winter	7.33±1.14Ac	9.33±1.25Ac	9.13±1.37Ac	8.57±1.17Ac	0.018
	Spring	13.56± 1.14Ba	19.533±3.53Aa	20.63±2.95Aa	19.20±2.41Ab	0.001
	Summer	18.40±1.70Ba	19.73±0.86Ba	23.17±0.67Aa	24.00±1.16Aa	
EC(μmhos/cm)	Autumn	315.90±13.60Bb	331.93±11.20Bb	388.93±22.83Ab	278.17±38.98Ca	0.390
	Winter	240.10±27.84Bd	238.40±16.09Bd	249.73±25.91Bd	270.47±22.98Aa	0.114
	Spring	294.57±20.81Ac	271.73± 12.18Bc	261.92±47.68Bc	290.25±35.16Aa	0.002
	Summer	356.63±45.30Ba	521.67±15.05Aa	491.73±14.61Aa	223.73±9.22Cb	
DO(mg l^{-1})	Autumn	7.95±0.83Ab	7.14±0.86Ab	7.99±0.18Aa	6.03±0.96Ac	0.246
	Winter	9.15± 0.38Aa	8.18±0.30Aa	8.52±0.41Aa	8.49±0.71Aa	0.212
	Spring	6.81±0.99c	6.13±0.99Ac	6.68±0.78Ab	7.11±0.85Ab	0.312
	Summer	7.08±0.51Ac	5.86±0.16Bc	6.93±0.70Ab	7.40±1.24Ab	
OS(%)	Autumn	84.83±6.60Aa	75.43±6.72Aa	88.26±3.47Aa	84.83±1.09Aa	0.246
	Winter	88.20±0.70Aa	86.16±3.52Aa	85.26±4.67Aa	82.50±5.37Aa	0.09
	Spring	70.20±4.20Aa	77.06±4.3Aa	76.46±1.06Aa	83.43±4.19Aa	0.123
	Summer	76.23±4.82Aa	70.96±3.72Aa	93.06±8.67Aa	79.90±8.22Aa	
COD(mg l^{-1})	Autumn	4.33±1.45Aa	3.33±1.20Aa	3.66±0.88Aa	4.00±1.15Aa	0.06
	Winter	2.66± 0.33Aa	3.00±0.57Aa	2.33±0.33Aa	3.66±0.33Aa	0.212
	Spring	2.00±0.01Aa	12.00±0.99Aa	12.33±2.63Aa	3.67±1.66Aa	0.318
	Summer	6.00± 1.73Aa	7.00±2.51Aa	11.66±0.58Aa	2.66±0.66Aa	
BOD(mg l^{-1})	Autumn	0.10±0.05Aa	0.20±0.05Aa	0.33±0.03Aa	0.30±0.05Aa	0.491
	Winter	0.30±0.02Aa	0.40±0.01Aa	3.46±0.03Aa	0.27±0.08Aa	0.309
	Spring	0.43±0.03Aa	0.76±0.08Aa	8.63±0.07Aa	6.10±0.08Aa	0.523
	Summer	0.73±0.12Aa	17.13±0.16Aa	4.96±0.46Aa	0.70±0.09Aa	
AD(mg l^{-1})	Autumn	0.017±0.001Cb	0.047±0.002Bb	0.180±0.01Aa	0.097±0.005Bb	0.547
	Winter	0.030±0.001CBb	0.057±0.004Bb	0.083±0.007Bb	0.143±0.005Ab	0.366
	Spring	0.123±0.006Ba	0.130±0.008Ba	0.063±0.001Cb	0.307±0.010Aa	0.201
	Summer	0.130±0.04Aa	0.040±0.01Bb	0.070±0.01Bb	0.110±0.03Ab	
TP(μg l^{-1})	Autumn	10.05± 0.04Aa	10.62±0.04Aa	11.56±0.04Aa	11.79±1.39Aa	0.572
	Winter	8.83±0.30Aa	9.22±0.28Aa	9.24±0.18Aa	9.14±0.12Aa	0.09
	Spring	9.43±0.51Aa	10.96±1.80Aa	9.49±0.10Aa	9.51±0.38Aa	0.001
	Summer	6.84±0.94Aa	8.81±0.94Aa	8.88±0.56Aa	9.64±0.51Aa	
TN(μg l^{-1})	Autumn	19.46± 2.94Ba	16.73±2.55Ba	18.01±2.99Ba	37.68±1.96Aa	0.765
	Winter	13.37±0.51Aa	13.37±0.43Aa	11.46±2.10Aa	13.22±2.25Ab	0.424
	Spring	11.58±1.30Aa	15.14±4.76Aa	16.60±1.60Aa	16.02±1.75Ab	0.123
	Summer	14.29±1.75Aa	15.62±1.16Aa	17.14±3.90Aa	17.61±3.29Ab	
Sal(ppt)	Autumn	0.20±0.01Ca	0.23±0.03Ca	2.33±0.12Ba	13.90±1.00Aa	0.441
	Winter	0.13±0.03Ca	0.1±0.03Ca	1.17±0.96Ba	11.70±0.60Aa	0.234
	Spring	0.17±0.03Ba	0.20±0.03Ba	0.26±0.03Ba	11.90±0.51Aa	0.001
	Summer	0.20±0.01Ba	0.27±0.03Ba	0.43±0.08Ba	14.47±0.25Aa	
pH	Autumn	7.76±0.14Ba	7.21±0.05Bb	7.81±0.17aB	8.30±0.20Aa	0.004
	Winter	7.65±0.04Ba	8.22±0.24Aa	7.63±0.09Bb	7.81±0.13Bb	0.001
	Spring	7.43±0.15Ba	7.56±0.07Bb	8.16±0.37Aa	8.09±0.34Aa	0.002
	Summer	7.33±0.27Ba	7.49±0.12Bb	8.35±0.12Ab	8.31±0.08Aa	
Chl-a(μg l^{-1})	Autumn	8.26±2.88Ab	7.85±3.02Bb	10.23±0.56Aa	9.20±0.57Aa	0.991
	Winter	4.36±2.18Ac	4.07±2.80Ac	4.31±2.67Ab	1.24±0.60Bb	0.795
	Spring	9.79±1.46Ab	7.98±0.39Bb	11.54±1.02Aa	7.12±1.50Ba	0.004
	Summer	11.44±0.98Aa	10.14±1.15Aa	10.91±2.26Aa	12.34±0.35Aa	
TSS(g l^{-1})	Autumn	0.000±0.000Ab	0.000±0.000Ac	0.000±0.000Ac	0.000±0.000Ab	0.236
	Winter	0.000±0.000Ab	0.000±0.000Ac	0.000±0.000Ac	0.000±0.000Ab	0.118
	Spring	0.005±0.003Aa	0.005±0.003Ab	0.005±0.003Ab	0.010±0.005Aa	0.001
	Summer	0.012±0.006Aa	0.144±0.080Aa	0.141±0.080Aa	0.000±0.000Ab	

Note 1. Differences among the stations displayed by capital letters in the same rows are significant (?=0.05).
Note 2. Differences among the seasons displayed by lower-case letters in the same columns are significant (?=0.05).

p=0.212). The Dunnett test revealed that the differences among the observed DO means of station 5 (reference station) and station 6, 7, and 8 were non-significant.

With regard to the oxygen saturation (OS) of Sarıçay Creek, the station x season interaction effects were non-significant (p=0.246). Similarly, the differences among observed OS means of the seasons and the stations were non-significant (p=0.123, p=0.092). The Dunnett test indicated that the differences among the observed OS means of station 5 (reference station) and station 6, 7, and 8 were non-significant.

For the chemical oxygen demand (COD) of the creek, the station x season interaction effects were non-significant (p=0.060). Similarly, the differences among the observed COD means of the seasons and the stations were non-significant (p=0.318, p=0.212). The Dunnett test showed that the differences between the means of station 5's COD (reference station), and station 6, 7, and 8 were non-significant.

The station x season interaction effects were non-significant for the biological oxygen demand

(BOD) of the creek (p=0.491). The differences among the observed means of the seasons and the stations BOD were also non-significant (p=0.523, p=0.309). The Dunnett test showed that the differences between the observed means of stations 5's COD and station 5, 6, and 7 were non-significant.

The anionic detergent (AD) of the creeks, the station x season interaction effects were non-significant (p=0.547). Equally, the differences among the observed means of the seasons and stations AD were also found to be non-significant (p=0.201, p=0.366). The Dunnett test showed that the differences between the observed means of stations 5's AD and station 5, 6, and 7 were non-significant. In short, the AD of Sarıçay Creek didn't change among the seasons and stations.

For the total phosphate (TP) of the creek, it was seen that the season x station interaction effects were non-significant (p=0.572). Similarly, the differences among the observed means stations TP were non-significant (p=0.091). However, the differences among the means of the seasons TP were significant ($p < 0.001$). The Tukey test results showed that the differences among the TP means were significant between Autumn-2005 and Winter 2006 (p=0.005), and Autumn-2005 and Summer-2006 ($P < 0.001$). The Dunnett test illustrated the differences between the observed means of reference station 5' TP and the other stations 6, 7's TP were non-significant. In result, the TP in Sarıçay Creek changed among the seasons but didn't change among the stations.

For the total nitrate (TN) in the creek, the station x season interaction effects were non-significant (p=0.765). Equally, the differences among the observed means of the seasons TN and stations TN were non-significant (p=0.123, p=0.424). The Dunnett test illustrated that the differences between the observed means of reference station 4' TN and the other stations 5, 6, and 7's TN were non-significant. This suggests that the TN in Sarıçay Creek didn't change among the seasons and stations.

The station x season interaction effects were non-significant for the salinity (Sal) of the creek (p=0.441). Similarly, the differences among the observed means of the seasons Sal were non-significant (p=0.234). But the differences among the observed means of the stations were significant. The Dunnett test suggested that the differences between the observed means of the reference station 5' Sal and station 8' Sal were significant (p=0.001).

The season x station interaction effects were significant for the pH of the creek (p=0.004). The Dunnett test indicated that the differences between the observed means of station 5 and station 6' pH were non-significant (p=0.879), but the differences between the observed means of station 5's and station 6' pH (p=0.006), and the station 5's pH and station 8's pH (p=0.001) were significant. The pH pointing out acidity and alkalinity of the water can vary widely in freshwaters due to natural causes as well as anthropogenic inputs and it affects aquatic life significantly (Mason, 1996). It was considered that the pH of Sarıçay Creek was influenced by domestic wastewater, sewage runoff, industrial and agricultural activities.

The season x station interaction effects were non-significant for the Chlorophyll-a (Chl-*a*) of the creek (p=0.991). Likewise, the differences among the observed means of the stations Chl-*a* were non-significant (p=0.795). But, the differences among the means of seasons Chl-*a* was found to be highly significant (p=0.095). The Tukey HSD test designated that the differences among the Chl-*a* means were significant between Winter-2006 and Spring-2006 (p=0.048), and Winter-2005 and Summer-2006 (p=0.004). The Dunnett test showed that the differences between the means of reference station 5 and the other station 6, 7' Chl-*a* were non-significant. In conclusion, it can be said that the Chl-*a* level of the reservoir didn't change with the stations, but changed seasonally.

Lastly, the season x station interaction effects were non-significant for the total suspended solids (TSS) of the creek (p=0.236). Similarly, the differences among the observed means of the stations TSS were non-significant (p=0.118). On the other hand, the differences among the means of the seasons TSS were found to be highly significant (p=0.001). The Tukey HSD test results showed that the differences of the TSS means were significant between Autumn - 2005 and Summer - 2006 (p=0.004), and Spring -2006 and Summer-2006 (p=0.011). The Dunnett test showed that the differences between the means of reference station 5 and the other station 6, 7' TSS were non-significant. In conclusion, the means of the creek TSS changed among the seasons, but did not change among the stations.

Results of Cluster Analysis

Similarity groups among the sampling sites were investigated using Cluster Analysis (CA). Input data set was treated using the Bray-Curtis distance as the similarity measure and Single Linkage Constrained (Fig. 2).

Based on the results of cluster analysis, it was concluded that:

Cluster 1 (Stations 1-2-3)

Sites mainly located at the entry and middle of the Atikhisar Reservoir were grouped under Cluster 1.

Cluster 2 (Stations 4)

These sites were located at the outflow of the reservoir and at the entry of the Creek. Therefore, similar water quality parameters were grouped under Cluster 2.

Cluster 3 (Stations 5)

This site was located at the beginning of Sarıçay Creek at the Atikhisar Reservoir and the water quality was with no pollution.. So, this station was designated as the reference station to compare with the other stations.

Cluster 4 (Stations 6-7)

This cluster included the stations located in the middle of the creek. Water quality variables were grouped together because of their similar physical conditions (e.g. depth, agricultural and settlement areas).

Cluster 5 (Station 8)

This site is located at the river mouth flowing into the Dardanelles. So, it is very different from the other sites.

This station is located at the end of the creek and links to the Dardanelles. So, the physico-chemical parameters of the water have been changing due to water currents and air conditions instantaneously in a day.

Results of Multi Dimensional Scaling (MDS) Analysis

MDS analysis was conducted for determining similar stations by taking 13 variables into account (Fig. 3). Figure 3 illustrates that 8 sites were divided into 5 groups. Station 1, 2, 3 were in group A and station 4 was in group B, station 5 was in group C, station 6 and 7 were in group D and station 8 was in group E.

Relationships among the 13 variables of water samples taken from the 8 sites were determined by MDS analysis (Fig. 4). Looking at figure 4 in detail, variables such as EC, Sal, OS, T and TN had affected the dissimilarities in the sites. The other variables group affecting the similarities of the sites were COD, BOD, TSS, AD, TP, pH, DO, and Chl-*a*

CONCLUSION

In this study, multivariate statistical methods including Principle Component, Cluster Analysis and Multidimensional Scaling Analysis were applied to a data set obtained from the Atikhisar Reservoir, which is the main drinking water source for Çanakkale and Sarıçay Creek which supplies irrigation water for the Sarıçay Basin. In addition, two-way ANOVA test was performed to determine the differences of season and station for the 13 variables.

Analysis of our results showed that the Sarıçay Creek was exposed to sewage and waste water from Çanakkale, Saraycık village, and agricultural runoff from the river basin.

Cluster analysis grouped 8 sampling sites into 5 clusters of similar water quality characteristics.

MDS analysis results revealed that the stations in Atikhisar Reservoir were grouped into 2 classes (stations 1, 2, 3 and stations 4), stations in Sarıçay Creek grouped into 3 classes (station 5, station 6, 7 and station 8), and the variables affecting the similarity of the sites were COD, BOD, TSS, AD, TP, pH, DO, Chl-*a* and variables in the dissimilarity of the sites were EC, Sal, OS, T and TN.

Based on the PCA analysis results, it may be concluded that 31.8% of the variances can be explained by six variables, and anionic detergent best explained the observed variances in the data (6.63%). The parameters in this PC1 include sal, pH, TP, TN, and T.

The two-way ANOVA results pointed out that the interaction of the station x season pH variable in Sarıçay Creek was significant.

Comparing water quality of the Atikhisar reservoir measured in this study to the inland water criteria of the Turkish Standard, determined that it was first class in terms of pH, T, TP, COD, BOD. A point about the dissolved oxygen was, although it was in the second class in the spring and summer seasons, it was in the first class in the winter and autumn. Fluctuations in dissolved oxygen according to seasons can be affected by different factors such as increases in temperature and oxygen consumption due to increasing biochemical reactions rises in

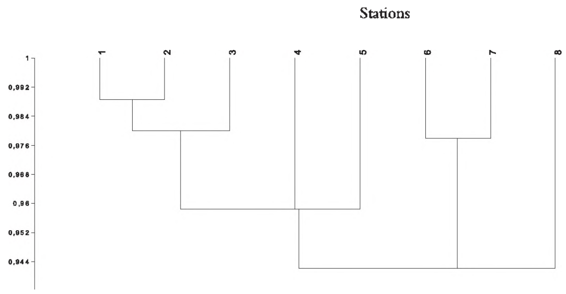

Fig 2. Bray-Curtis Similarity dendogram (Single Linkage-Constrained) of the sampling stations.

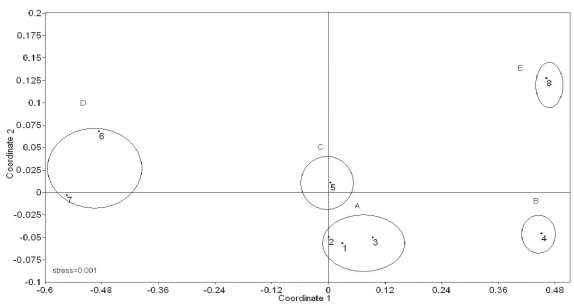

Fig 3. MDS plot of the sampling stations in terms of the 13 water quality variables (Euclidean distance measure).

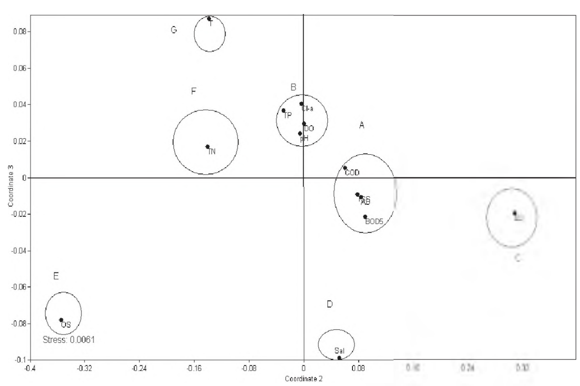

Fig 4. MDS plot of the 13 variables effecting the classification of the stations (Euclidean distance measure).

respiration of aquatic organisms, decaying of organic materials etc. When evaluating the water quality of the Atikhisar reservoir in light of the measured data, it was concluded that the reservoir wasnt exposed to any serious pollution.

Similarly, comparing the water quality of Sarıçay Creek to the inland water criteria of the Turkish Standards, it was ascertained that it was first class in terms of T, TP, pH and COD. In the point of dissolved oxygen, although the fifth and eighth stations had first class water, the sixth and seventh stations were in the second class in the spring and summer seasons. In terms of BOD, the fifth station was in the first class; sixth station was in the third class, the seventh and eighth stations were in the second class. In conclusion, it was determined that the water of Sarıcay Creek was subjected to various domestic wastewaters especially in the sixth, seventh and eighth stations in the spring and summer seasons.

In a study done between the dates of May 2002 and September 2003 in Sarıçay Creek, on the water quality parameters, the creek was illustrated to have first class water quality for pH and temperature. Its salinity values ranged between%0.2181 and 0.233% at the creek mouth. The salinity values ranged between%0.615 and 0.757% at the 7 stations mentioned in this study (Odabaşı and Büyükateş 2009). In terms of pH and temperature, the two studies had the same results, but the salinity results were different. Odabaşı and Büyükateş (2009) recorded Saricay Creek, second class in terms of TP, but our investigation indicated that it was first class. Both investigations showed an increase in the TP during the spring and autumn seasons. This may be due to agricultural manure and domestic sewage mixing with the creek's water after the rains.

Yüksek (2003) ran a research on Sarıçay Creek water quality and reported that stations near the downtown area had more pollution while those close to Atikhisar reservoir had less pollution. These results are in agreement with our findings.

This study shows that multivariate statistical techniques such as MDS, PCA and CA can successfully be used to derive information from the data set about the possible influences of different environmental factors on surface water quality. In water pollution prevention actions, these statistical methods can help authorities assess water quality.

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