Original Research

Assessment of Water Quality of Yağlidere Stream (Turkey) Using Multivariate Statistical Techniquess

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Abstract

Yağlıdere Stream is one of the major waterways flowing into the eastern Black Sea. In this study, multivariate statistical techniques, hierarchical cluster analysis (HCA), and principal component analysis (PCA) were applied to data on Yağlıdere water quality. Thus, we aimed to determine main pollution factors and time risky polluted areas. During the study, water samples were taken by monitoring 23 physico-chemical parameters at five different sites every month between June 2013 and May 2014. In addition, Pearson correlation was used to determine the relationships of all physico-chemical parameters. According to the results of HCA, five sampling areas were grouped into two clusters. From the PCA results, it may be estimated that river pollution is mainly from agricultural runoff and soil weathering, soil erosion, hydroelectric power plant installation activities, domestic disposal, and leaching from solid waste disposal sites. Consequently, the Yağlıdere is of good quality according to the physico-chemical data by national and international permissible limits, but it is under pressure. These temporal and spatial scale effects indicate that water-monitoring schemes need to be scaled-sensitive to water management for coming years.

Keywords: water quality, fresh water, principal component analysis (PCA), hierarchical cluster analysis (HCA), Pearson's correlation

Introduction

The surface water quality in a region largely depends on the nature and extent of the industrial, agricultural, and other anthropogenic activities in the catchments. The quality of these resources is a very sensitive issue. Anthropogenic influences as well as natural processes degrade surface waters and impair their use for drinking, industry, agriculture, recreation, and other purposes [1-2]. Pollution of surface water bodies with toxic chemicals and excess nutrients, resulting from water runoff and groundwater discharges, has been an issue of worldwide environmental concern. Nutrients like phosphorus and nitrogen support the growth of algae and other plants. However, excessive levels of nutrients from sources such as fertilizer can cause eutrophication in an aquatic ecosystem.

In particular, it is necessary to ensure continuous monitoring of water for good water management and because fresh water will be a scarce source in the future. Monitoring the quality of surface water will help protect

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our waterways from pollution. In order to understand the process dynamics of a watershed, a well-designed water quality monitoring network identifies water quality problems while establishing baseline values for short- and long-term trend analysis. Generally, fresh water quality is affected by excess domestic and solid waste. And it even occurs when pollutants (particles, chemicals, or substances that contaminate water) are discharged directly or indirectly into water bodies without enough treatment to get rid of harmful compounds. Pollutants get into water mainly by human causes or factors. Water pollution is usually caused by human activities. Different human sources add to the pollution of water.

In addition to monitoring research in recent years, principal component analysis (PCA) and hierarchical cluster analysis (HCA) have been widely used as they help with the interpretation of monitoring a network's complex data arrays to gain a better understanding of water quality. This analyzes river hydrochemistry problems, and helps to evaluate chemical species and sources of pollution associated with hydrologic conditions [2-8]. Also, these techniques allow for the identification of possible sources that affect water systems and provide valuable tools for the safe management of water resources and the analysis of data from non-homogeneous variables [9-11]. And they are useful in verifying temporal and spatial variations caused by natural and anthropogenic factors and PCA and HCA groups, and sets of variables with similar properties [11-12].

Giresun has various sources of drinking water, but it is undoubtedly of great importance to take measures to determine and protect the quality of these resources. However, with the rapid increase in the population of the city and the need to meet the increasing demands of irrigation and human consumption, the available water resources are getting depleted and water quality has

deteriorated. In addition, the results of previous studies in this area also support our concerns about freshwater resources. The main source of livelihood for the people in question is agriculture and fishing. Especially Giresun hazelnut is an agricultural product known all over the world [13]. Chemical fertilizers and pesticides used unconsciously while hazelnut is grown are a great threat to water resources due to the frequent rainfall in the region. Since rivers constitute the main inland water sources for domestic and irrigation purposes, it is possible to ensure that river pollution is under control and that necessary precautions have been taken in advance in case of threats, but only by obtaining reliable information on water quality and pollution sources.

In this study, Yağlıdere water quality was primarily evaluated by a monitoring program. PCA and HCA multivariate techniques were applied to summarize the statistical correlation between the components in the water samples and to assess information about the similarity and dissimilarities among stations, to identify water quality variables for spatial differences, and also further to make sure of the impact of pollution sources on water quality parameters. It is also aimed at clarifying the impact of pollution sources on water quality parameters.

Material and Methods

Sample Location and Sampling

Yağlıdere Stream is formed by small streams joining together after originating from the Çakrak Mountains in the southeast border of Giresun Province, and the length of its main branch is 70 km. After it is formed, the Yağlıdere passes through towns and cities and pours into the southeastern Black Sea in the town of Espiye. This study
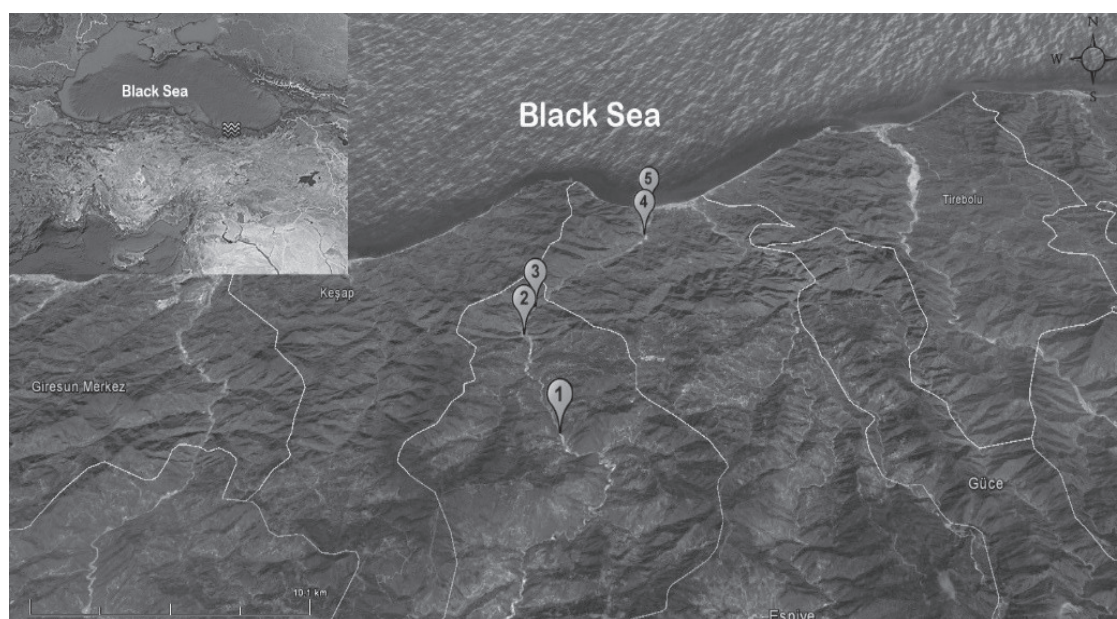

Fig. 1. Map of study area with sampling point locations (adapted from Google Earth).

was conducted along the Yağlıdere in the city of Giresun. Replicate samples for each location along the stream were collected monthly in June 2013 and May 2014 from five stations (Fig. 1).

Samples for water quality studies were collected in 2.5 L plastic bottles that had been previously soaked in 5% nitric acid for 24 h and rinsed with distilled water. Moreover, water samples were collected in 1-liter pre cleaned (with 50% HNO_3 and then thrice with deionized water) polyethylene bottles and acidified with 10 mL concentrated HNO_3 per liter of wastewater for the analysis of heavy metals. After collection, the samples were placed in coolers with ice bags while being transported to the laboratory and kept at about 4ºC until analysis.

Determination of Physico-Chemical Parameters

Water temperature, conductivity, dissolved oxygen, pH, total dissolved solid, salinity, and oxidoreduction potential were determined using a YSI 556 MPS meter, and turbidity was measured with Turb 355 T/IR turbid meter (WTW) after calibration with standard buffer solutions.

Routine laboratory analysis, such as total ammonia nitrogen, nitrite nitrogen, nitrate nitrogen, ammonium, ammonia, silica, total phosphorus, orthophosphate phosphorus, alkalinity, hardness, suspended solids, chlorophyll a and BOD_5 were measured by standard methods [14]. To assess the precision and accuracy of results, replicate analysis of blank, standard, and samples were done.

Statistical Analysis

Statistical analysis of data was carried out using SPSS statistical package programs. Descriptive statistical analysis, including one-way ANOVA and significance (0.01 and 0.05) was done. Important differences in the mean values were tested with Tukey's multiple range test. Moreover, relationships among the considered variables were tested using Pearson's correlation. Multivariate analysis of the stream water quality data set was performed through principal component and hierarchical cluster analysis (PCA-HCA) techniques [23]. The water quality data had been initially standardized by z-scale transformation because the water quality variables were measured in different units [15-16]. All statistical calculations were performed with SPSS 17.0 for Windows.

Result and Discussion

The annual mean values of physico-chemical parameters ranged between, for WT: 7.02 and 24.41ºC, EC: 175 and 428 mS/cm, TDS: 0.11 and 0.28 g/L, pH: 6.96 and 8.57, DO: 7.04 and 15.52 mg/L, salinity: 0.01 and 0.21 ppt, ORP: -77 and 133.20 mV, TAN: 0.106 and 5.577 mg/L, NO_3-N: 0.311 and 2.100 mg/L, NO_2-N: 0.001

and 0.038 mg/L, NH_3: 0.001 and 0.081 mg/L, NH_4^+: 0.102 and 5.542 mg/L, silica: 6.6 and 18 mg/L, TP: 0.011 and 0.915 mg/L, O-PO_4: 0.008 and 0.354 mg/L, Na: 1.30 and 9.70 mg/L, K: 0.30 and 10 mg/L, alkalinity: 56 and 174 mg/L, hardness: 9 and 23.70ºF, Chl-a: 0.019 and 5.558 µg/L, turbidity: 1.920 and 74.540 NTU, TSS: 0.264 and 2 g/L and BOD_5: 0.51 and 11.72 mg/L.

The lowest and highest values of physico-chemical parameters were determined as a station, respectively: TDS, ORP, K, alkalinity, hardness, TSS and EC, DO, salinity, TAN, NO_2, NH_4, silica, TP, O-PO_4, alkalinity, hardness at Station 1; WT, EC, TDS, NO_3, NH_4, and pH, ORP, Chl-a at Station 2; DO, TAN, Chl-a and NO_3, NH_3, BOD_5 at Station 3; salinity, TP, Na and WT, NO_2, Na, TSS at Station 4; pH, TAN, silica, O-PO_4, turbidity, BOD_5, and K, turbidity at Station 5. In addition, the mean values of physiochemical parameters at different stations are demonstrated in Table 1. Moreover, the results indicate that some water quality parameters in Yağlıdere surface water are suitable for similar previous studies in Table 2 [28-32].

According to Turkish legislation, it is very important to define and elaborate upon the quality of water before use for various purposes in light of physico-chemical parameters [17-18]. Water quality of surface water is classified into four groups. Yağlıdere surface water is in good condition in terms of WT and NO_3-N values according to RSWQM. All parameters based on average values were found to be Class I water quality except for NO_2-N, TP, and BOD_5. Nitrate nitrogen concentrations did not exceed water standards (>5 ppm) [17-19] and were generally well below this level, but sometimes TP and NH_4 were Class IV. The use of agricultural fertilizers and urban sewage are believed to increase the ammonia nitrogen, nitrate, phosphate, and nitrite concentrations because the absence of freshwater plants might affect the increase in nitrogen ion concentrations in the stream. Moreover, a comparison of our data with the WHO [20] acceptable limits showed that our values for turbidity are higher than, and hardness, pH, sodium, and TDS lower than international guidelines.

We conducted statistical analyses of 60 samples taken monthly from five stations. For the Anova analyses seasonal mean levels at each of the stations except TP were significantly different (P<0.05), but between the stations there were no significant differences throughout the sampling period (P>0.05) (Table 1).

The Pearson correlation analysis of the water quality parameters listed in Table 3 indicated the absence of a positive and good correlation (above 0.7), although there was less significant correlation between some parameters. The TDS showed significant and positive high correlation with EC (r = 0.965, P >0.01). Salinity showed significant and positive high correlation with EC and TDS (r = 0.970, r = 0.936, P >0.01), which are responsible for water mineralization. pH showed significant and positive correlation with WT (r = 0.857, P >0.01). NH_3 showed significant and positive correlation with pH (r = 0.742, P >0.01). NH_4 showed significant and positive max correlation with TAN (r = 1.000, P>0.01). NO_3 was

Table 1. Stations' mean, standard error (SE), and range (minimum–maximum) of water quality parameters.

	Stations																					P Value
	1				2				3				4				5				
	Mean	SE±	Min.	Max.	Mean	SE±	Min.	Max.	Mean	SE±	Min.	Max.	Mean	SE±	Min.	Max.	Mean	SE±	Min.	Max.	
WT	12.674	1.361	7.24	19.96	13.598	1.543	7.02	22.16	13.756	1.536	7.18	22.6	14.562	1.632	7.06	24.41	14.471	1.619	7.23	24.01	0.911
EC	292.08	25.781	185	428	288	23.84	175	415	292.66	22.73	187	410	275.41	20.838	177	385	274.91	19.713	180	380	0.962
TDS	0.199	0.016	0.12	0.28	0.187	0.016	0.11	0.27	0.190	0.015	0.12	0.27	0.18	0.013	0.12	0.25	0.177	0.013	0.11	0.25	0.838
Salinity	0.139	0.013	0.09	0.21	0.138	0.012	0.08	0.2	0.141	0.012	0.09	0.2	0.125	0.014	0.01	0.19	0.132	0.009	0.09	0.18	0.882
DO	11.421	0.727	7.3	15.52	11.334	0.61	7.56	14.84	11.517	0.627	7.04	14.64	11.178	0.599	7.42	14.8	11.468	0.632	8	14.9	0.996
pH	7.801	0.121	7.15	8.42	7.903	0.151	7.03	8.57	7.851	0.134	7.02	8.56	7.877	0.14	7.11	8.56	7.731	0.116	6.96	8.44	0.901
ORP	-4.542	11.421	-77	50	15.45	17.974	-73.9	133.2	20.917	17.50	-60.3	124.6	22.692	17.29	-65.7	105.4	30.858	19.27	-69.6	123.6	0.652
TAN	0.944	0.471	0.108	5.577	0.436	0.113	0.108	1.583	0.564	0.173	0.106	2.244	0.385	0.08	0.107	1.189	0.367	0.066	0.106	1.009	0.396
NO_3-N	0.833	0.096	0.356	1.29	0.785	0.126	0.311	1.96	0.807	0.144	0.382	2.1	0.749	0.108	0.325	1.57	0.716	0.084	0.339	1.13	0.955
NO_2-N	0.010	0.003	0.001	0.038	0.011	0.003	0.001	0.037	0.013	0.003	0.001	0.035	0.011	0.003	0.001	0.038	0.012	0.002	0.001	0.027	0.965
NH_3	0.014	0.004	0.001	0.035	0.015	0.004	0.001	0.039	0.019	0.007	0.001	0.081	0.015	0.005	0.001	0.049	0.009	0.003	0.001	0.031	0.735
NH_4	0.930	0.469	0.105	5.542	0.421	0.113	0.102	1.571	0.545	0.172	0.103	2.228	0.369	0.08	0.103	1.18	0.358	0.065	0.103	1.002	0.394
Silica	12.333	0.705	9	18	11.125	0.457	9	14.5	10.992	0.467	7.8	13.5	10.992	0.389	8.2	12.5	11.192	0.524	6.6	14	0.321
TP	0.254	0.093	0.025	0.915	0.178	0.064	0.022	0.803	0.203	0.068	0.02	0.858	0.207	0.076	0.011	0.841	0.172	0.071	0.013	0.853	0.944
O-PO_4	0.094	0.028	0.011	0.354	0.075	0.026	0.015	0.299	0.089	0.021	0.013	0.277	0.088	0.026	0.009	0.264	0.064	0.017	0.008	0.17	0.896
Alk.	95.583	9.047	56	174	87.917	4.862	68	118	93.25	5.397	71	122	86.75	5.221	63	122	88.5	5.44	58	120	0.823
Hard.	15.25	1.315	9	23.7	14.742	1.095	10	21.4	14.692	1.087	9.6	21	13.575	0.944	9.6	19.6	13.858	0.926	10.1	19.7	0.805
Chl.	0.751	0.238	0.08	2.466	1.209	0.424	0.068	5.558	1.295	0.37	0.019	4.208	1.322	0.341	0.171	4.291	1.623	0.393	0.215	4.106	0.549
TSS	0.693	0.054	0.264	0.98	0.665	0.054	0.314	1	0.688	0.037	0.494	0.844	0.774	0.116	0.454	2	0.692	0.036	0.508	0.826	0.81
Na	5.842	0.588	3.4	9.5	5.058	0.564	2	9.1	5.717	0.584	3.5	9.3	5.642	0.626	1.3	9.7	6.325	0.685	2.5	9.6	0.698
K	1.892	0.781	0.3	9.8	2.25	0.936	0.4	9.8	2.6	0.969	0.6	9.9	2.708	0.993	0.5	9.9	2.525	0.912	0.4	10	0.972
Turb.	12.498	2.102	3.1	28.89	13.65	3.018	4.67	39.2	17.559	4.372	3.56	50.05	12.069	2.21	3.34	29.24	22.264	5.361	1.92	74.54	0.247
BOD_5	4.846	0.488	2.14	7.54	4.694	0.752	1.46	9.71	4.987	0.884	1.42	11.72	4.494	0.899	0.62	10.18	5.238	0.933	0.51	10.37	0.974

Table 2. Comparison of water quality parameters in previous studies.

	Gökpınar and Çürüksu Creek [28]	Kürk Stream [29]	Beydilli River [30]	Horohon Creek [31]	This Study
WT (ºC)	10-28.4	3.5-25.5	3.8-26.4	6-16	7.02-24.41
pH	6.50-11.15	7.1-8.9	7.26-7.82	8.11-8.47	6.96-8.57
DO (mg/L)	4.5-8.2	6.8-10.1	10.29-14.90	7.84-13.90	7.04-15.52
Salinity (ppt)			0.01-0.08	0.01-0.19	0.01-0.21
TDS (mg/L)	295-3286				110-280
TSS (mg/L)			0.1-4.9	0.03-4.12	264-2000
Hardness (mg/L)		9.4-51	99.42-155.26		9-23.7
Alk. (mg/L)		89-689		137-250	56-174
Na (mg/L)			12.48-46.12	7-77	1.3-9.7
K (mg/L)			1.27-3.06	2-5.3	0.3-10
Turb. (NTU)		1-339			1.92-74.54
NH_4 (mg/L)			Nd-0.0013	Nd-0.025	0.102-5.542
NO_2-N (mg/L)			Nd-0.013	Nd-0.009	0.001-0.038
NO_3-N (mg/L)			Nd-0.95	Nd-4.20	0.311-2.100
O-PO_4 (mg/L)					0.008-0.354
BOD_5 (mg/L)	0.53-166		0.1-7.1		0.51-11.72

positively correlated with all parameters except Na and turbidity, which was a negative correlation – indicating that these variables are derived from similar sources and also moving together. The alkalinity showed significant and positive correlation with EC, TDS, and salinity (r = 0.829, r = 0.780, r = 0.795, P >0.01). NH_4 showed significant and positive max correlation with TAN (r = 1.000, P>0.01). Hardness showed significant and positive correlation with alkalinity (r = 08.10, P>0.01) and high positive correlation with EC, TDS, and salinity (r = 0.940, r = 0.902, r = 0.901, P>0.01). BOD showed significant and positive correlation with WT (r = 0.718, P >0.01). As expected, the negative relationship of DO with other parameters reveals the organic pollution that can be considered one of the causes of water ecological changes in the environment (Table 3).

Due to the complexity of the relationship between numerous water quality parameters, confidential information was extracted using principal component analysis (PCA) and revealed detailed data structure. PCA analysis was combined to help eliminate the redundant data and choose responsible environmental factors [21-22]. PCAs classified the factor loadings as 'strong,' 'moderate,' and 'weak,' corresponding to absolute loading values of >0.75, 0.75-0.50, and 0.50-0.30, respectively [23]. The results of calculations are shown in Table 4.

A PCA analysis included seven components, and 23 physico-chemical parameters were classified. These components were acquired with eigenvalues >1 summing 83.53% of the total variance in the surface water dataset (Table 4 and Figs 2-3, respectively). The first

PC, explaining 33.62% of the total variance, has a strong positive loading on EC, hardness, TDS, salinity, alkalinity, and moderate positive loadings on BOD_5 and WT. This natural source of these parameters in catchments from soil weathering and flowing run-off. This factor can be based on seasonal changes [24].

The second PC, accounting for 14.86% of the total variance, has a strong positive loading on pH. NH_3 has strong negative loadings on dissolved oxygen and moderate positive loadings on WT. This factor represents the contribution of non-point source pollution from hazelnut trees. In these areas, farmers use nitrogenous fertilizer, which undergoes nitrification processes and the rivers receive nitrate nitrogen by groundwater leaching [4]. In addition, this factor represents loadings on a moderate negative temperature and dissolved oxygen [25-26].

The third PC, accounting for 10.28% of the total variance, has a strong positive loading on TAN and NH_4, and moderate positive loadings on K. This shows the influence of agricultural runoff from the soil as nitrogenous fertilizers are extensively used in this region – indicating the influence of domestic waste.

The fourth PC was explaining the lowest variance (8.18%), which has strong positive loadings on NO_3-N and moderate positive loadings on NO_2-N, and weak negative loadings on Na. Thus it shows the nutrient group of pollutants, which points to some source of wastewater and runoff. This organic factor can be interpreted as representing influences from point sources, such as discharges from domestic wastewater and industrial effluents.

Table 3. Pearson correlations for the elemental composition of Yağldere Stream water.

	WT	EC	TDS	Sa.	DO	pH	ORP	TAN	NO_3	NO_2	NH_3	NH_4	Sil	TP	PO_4	Alk.	Hard.	Chl.	TSS	Na	K	Turb.	BOD_5
WT	1																						
EC	0.594**	1																					
TDS	0.542**	**0.965****	1																				
Sal.	0.550**	**0.970****	**0.936****	1																			
DO	-0.576**	-0.125	-0.040	-0.109	1																		
pH	**0.857****	0.416**	0.377**	0.375**	**-0.666****	1																	
ORP	0.414**	0.591**	0.594**	0.581**	-0.050	0.207	1																
TAN	-0.257	0.121	0.133	0.138	0.225	-0.123	-0.003	1															
NO_3-	0.052	0.266*	0.330*	0.310*	0.024	0.094	0.128	0.122	1														
NO_2-	0.015	-0.229	-0.252	-0.200	-0.244	0.166	-0.092	0.101	0.378**	1													
NH_3	**0.655****	**0.534****	**0.516****	**0.501****	-0.405**	**0.742****	0.518**	0.251	0.127	0.150	1												
NH_4	-0.272*	0.111	0.123	0.128	0.235	-0.139	-0.014	**1.000****	0.120	0.099	0.232	1											
Sil.	0.148	0.453**	0.454**	0.447**	0.032	0.087	0.371**	0.281*	0.204	-0.199	0.290*	0.276*	1										
TP	0.187	0.143	0.113	0.148	-0.121	0.227	-0.010	-0.192	0.134	-0.236	0.062	-0.194	-0.049	1									
PO_4	0.557**	0.636**	0.604**	0.598**	-0.144	0.480**	0.076	-0.033	0.072	-0.269*	0.390**	-0.041	0.244	0.199	1								
Alk.	0.428**	**0.829****	**0.780****	**0.795****	0.014	0.200	0.409**	-0.017	0.154	-0.173	0.294*	-0.023	0.220	0.100	0.473**	1							
Hard.	0.654**	**0.940****	**0.902****	**0.901****	-0.145	0.520**	0.435**	0.055	0.224	-0.213	0.518**	0.045	0.382**	0.243	**0.699****	**0.810****	1						
Chl.	0.516**	0.418**	0.381**	0.397**	-0.421**	0.413**	0.220	-0.136	0.264*	0.056	0.208	-0.141	0.294*	-0.034	0.344**	0.226	0.343**	1					
TSS	-0.471**	-0.317*	-0.298*	-0.268*	0.245	-0.439**	-0.248	0.085	0.228	-0.021	-0.335*	0.092	-0.046	0.223	-0.320*	-0.279*	-0.387**	-0.156	1				
Na	-0.230	-0.248	-0.203	-0.230	0.168	-0.216	0.289*	0.054	-0.421**	-0.220	0.071	0.053	-0.010	-0.094	-0.330*	-0.246	-0.348**	-0.438**	0.007	1			
K	-0.275*	0.069	0.072	0.107	0.149	-0.138	0.039	**0.602****	0.357**	0.280*	0.031	**0.604****	0.168	-0.270*	-0.101	-0.097	-0.043	0.016	0.071	-0.075	1		
Turb.	-0.037	-0.125	-0.194	-0.114	-0.203	-0.008	-0.272*	0.050	-0.200	0.158	-0.095	0.053	-0.023	-0.251	-0.013	-0.163	-0.185	0.233	0.032	0.098	0.164	1	
BOD_5	**0.718****	0.510**	0.492**	0.460**	-0.086	0.544**	0.165	-0.317*	0.018	-0.145	0.342*	-0.326*	0.060	0.149	**0.537****	**0.537****	**0.621****	0.388**	-0.384**	-0.351**	-0.501**	-0.061	1

** $p < 0.01$ * $p < 0.05$

Table 4. Varimax rotated factor matrix for the whole data set.

Eigenvalues	7.735	3.418	2.365	1.882	1.426	1.249	1.139
Percentage of variance	33.629	14.860	10.284	8.181	6.200	5.429	4.950
Accumulative %	33.629	48.489	58.773	66.954	73.154	78.583	83.533
	Factor loadings (varimax normalized)						
EC	**0.94**	0.183	0.086	0.077	0.178	0.051	0.019
Hardness	**0.931**	0.264	0.024	0.034	-0.023	-0.059	0.043
TDS	**0.926**	0.128	0.094	0.098	0.213	-0.007	0.022
Salinity	**0.909**	0.151	0.108	0.117	0.199	0.056	0.042
Alkalinity	**0.858**	-0.029	-0.089	0.052	0.022	-0.117	-0.121
O-PO$_4$	**0.705**	0.283	0	-0.161	-0.32	0.125	0.117
BOD	**0.631**	0.308	-0.417	-0.081	-0.278	-0.039	-0.115
Silica	0.435	-0.027	0.288	0.012	0.41	0.349	0.185
pH	0.297	**0.908**	-0.089	0.05	-0.079	0.024	0.015
DO	0.08	**-0.783**	0.186	-0.106	-0.014	-0.314	-0.048
NH$_3$	0.364	**0.757**	0.27	-0.009	0.282	-0.132	-0.041
WT	**0.52**	**0.744**	-0.283	0.012	0.026	0.071	-0.053
TAN	0.061	-0.039	**0.968**	-0.011	-0.005	-0.036	-0.021
NH$_4$	0.054	-0.055	0.967	-0.011	-0.011	-0.034	-0.021
K	-0.039	-0.134	0.711	0.384	0.095	0.166	-0.142
NO$_3$-N	0.219	-0.021	0.136	**0.85**	0.047	-0.048	0.217
NO$_2$-N	-0.359	0.316	0.139	**0.655**	-0.088	-0.047	-0.365
ORP	0.449	0.17	-0.05	0.072	**0.803**	-0.127	-0.111
Na	-0.334	-0.043	0.084	**-0.557**	0.628	-0.129	-0.057
Turbidity	-0.197	0.065	0.113	-0.166	-0.143	**0.764**	-0.191
Chlorophyll a	0.374	0.283	-0.192	0.331	0.012	**0.649**	-0.002
TP	0.128	0.204	-0.184	-0.03	-0.106	-0.255	**0.803**
TSS	-0.331	-0.392	0.092	0.224	0.027	0.092	**0.628**

Extraction Method: Principal Component Analysis.   Rotation Method: Varimax with Kaiser Normalization.
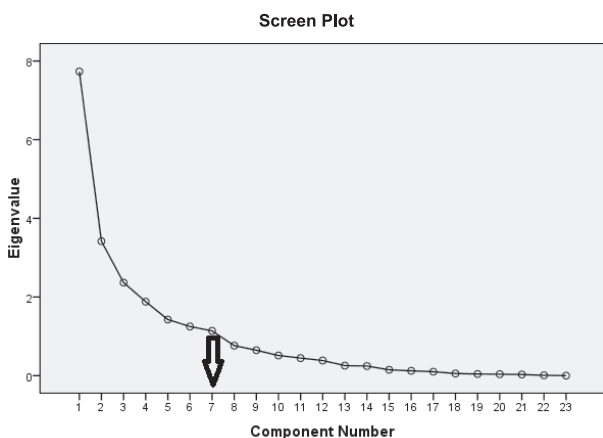a. Rotation converged in 8 iterations.

Fig. 2. Screen- plot for the principal component model of the monitoring data.
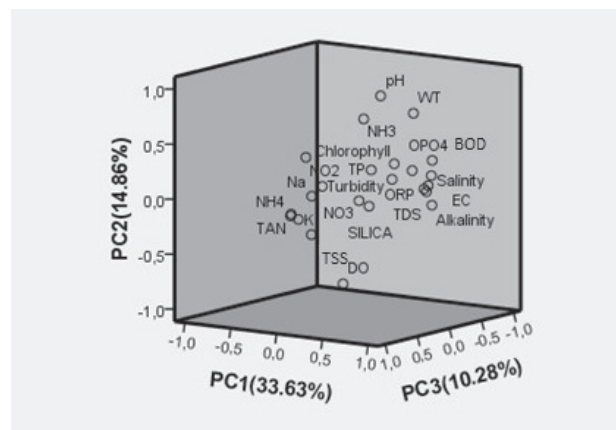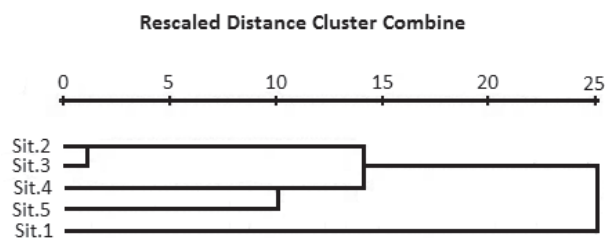

Fig. 3 Component plot.

Fig. 4. Dendogram (using Ward Method) showing clusters of variables.

The fifth PC accounting for 6.20% of the total variance has a strong positive loading on ORP. This factor represents anthropogenic pollution sources and can explain the high levels of dissolved organic matter that consume large amounts of oxygen and that undergoe anaerobic fermentation processes leading to the formation of ammonia and organic acids.

The sixth PC accounts for 5.42% of the total variance and has a strong positive loading on turbidity and moderate positive loading on chlorophyll a due to the erosion and hydroelectric power plant installation activities in this region.

The seventh PC accounts for 4.95% of the total variance has a strong positive loading on TP and moderate positive loading on the suspended solid matter. The phosphate has its origin in soils due to use of phosphatic fertilizers in this region.

In this study, hierarchical cluster analysis (HCA) was used to show sampling stations with similar characteristics in the river basin. When HCA was applied for five stations and the dendogram (Fig. 4), hierarchical cluster analysis grouped five sampling sites into two clusters. The first cluster corresponds to station 1, situated at the most upstream site of the stream. This group makes understanding the self-purification and assimilative capacity of the stream because it almost does not receive pollution. This station is the nearest water source in order that it differs from other stations in terms of water quality.

Cluster 2 corresponds to (5 and 4, 2, 3). These stations are situated at the most downstream sampling location in this river so receive pollution mostly from domestic wastewater. These stations receive pollution from non-point sources, but mostly from agricultural runoff and soil weathering, soil erosion, hydroelectric power plant installation activities, domestic disposal, and leaching from solid waste disposal sites. They have similar characteristics with wastes showing that these systems are highly affected by these pollution sources.

Conclusion

In this study the water quality level of Yağlıdere Stream was analyzed and distributed pollution degrees using statistical analysis. Considering the increase of NH_4 (at stations 1 and 3) and TP (at all stations), concentrations were evaluated by RSWQM as Class IV. Cluster analysis

grouped five sampling sites into two clusters according to similar water quality characteristics.

From the PCA loadings it is evident that for this region major groups of parameter (strong loadings) that emerged are nutrient parameter group (representing influences from non-point sources such as atmospheric deposition and agricultural runoff) and organic pollution group (representing influences from point sources such as village and districts), and solid group (soil erosion and hydroelectric power plant installation activities by runoff process). PCA results were confirmed with HCA. It has emerged that these important pollutants in pollution sources have to be monitored regularly. From the PCA results, it may be persuasively estimated that the river pollution is mainly from agricultural runoff and soil weathering, soil erosion, hydroelectric power plant installation activities, domestic disposal, and leaching from solid waste disposal sites. In many countries an increasing proportion of water pollution originates from diffuse sources such as agricultural use of fertilizers, which cannot be controlled. Instead, the principle of "best environmental practice" should be applied to minimize non-point source pollution [27].

By this investigation we also suggest that precautions be taken in order to prevent future surface water pollution. Otherwise, such pollution can be dangerous for human health.

Acknowledgements

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