Environ Monit Assess (2009) 158:51–65
DOI 10.1007/s10661-008-0564-3

Assessment of seasonal variations of surface water quality characteristics for Porsuk Stream

Arzu Altın · Zeynep Filiz · Cansu Filik Iscen

Received: 10 April 2008 / Accepted: 11 September 2008 / Published online: 11 October 2008

Abstract In this study, the factor analysis technique is applied to surface water quality data sets obtained from Porsuk stream in Turkey, generated during 10 years (1995–2005) monitoring of 29 parameters at one site (Esenkara) for all four seasons. The varifactors obtained from factor analysis indicate that the parameters responsible for water quality variations are mainly related to mineral and inorganic nutrients, organic pollution, microbiological pollution in winter and spring; mineral and nutrients in summer; microbiological and nutrient pollution in fall. This study presents the necessity and usefulness of multivariate statistical assessment of large and complex databases in order to get better information about the quality of surface water.

A. Altın (✉) · Z. Filiz
Department of Statistics, Faculty of Arts and Science, Eskisehir Osmangazi University, Meşelik Campus, 26480 Eskisehir, Turkey
e-mail: aaltin@ogu.edu.tr

Z. Filiz
e-mail: zfiliz@ogu.edu.tr

C. F. Iscen
Department of Elementary Education, Faculty of Education, Eskisehir Osmangazi University, Meşelik Campus, 26480 Eskisehir, Turkey
e-mail: cfilik@ogu.edu.tr

Keywords Factor analysis · Porsuk stream · Seasonal variation · Surface water · Water pollution · Water quality

Introduction

A river is a system comprising both the main course and the tributaries, carrying the one-way flow of a significant load of matter in dissolved and particulate phases from both natural and anthropogenic sources. The quality of a river at any point reflects several major influences, including the lithology of the basin, atmospheric inputs, climatic conditions and anthropogenic inputs. On the other hand, rivers plays a major role in assimilation or transporting municipal and industrial wastewater and runoff from agricultural land. Municipal and industrial wastewater discharge constitutes a constant polluting sources, whereas surface runoff is a seasonal phenomenon, largely affected by climate within the basin (Shrestha and Kazama 2007).

The quality of water is identified in terms of its physical, chemical and biological parameters. Polluted surface waters cannot achieve a balanced ecosystem. A balanced ecosystem is one in which living things and the environment interact beneficially with one another. Water quality obviously plays a critical role in this relationship (Ntengwe

2006), as it is key to the maintenance of a well-balanced environment.

A variety of methods are being used to display the information which is concealed in the quality variables observed in a water quality monitoring network. A large portion of these approaches are statistical methods. When the number of variables is greater than two, employment of multivariate analysis techniques gives simpler and more easily interpretable results for the evaluation of observed quality data (Mazlum et al. 1999). The multivariate statistical techniques are the appropriate tool for a meaningful data reduction and interpretation of multi-constituent chemical and physical measurements (Massart et al. 1988). The multivariate statistical techniques are such as cluster analysis (CA), principal component analysis (PCA), factor analysis (FA), discriminant analysis (DA) and multidimensional scaling (MDS) have been successfully used as unbiased methods in analysis of water quality data for drawing meaningful conclusions (Vega et al. 1998; Helena et al. 2000; Wunderlin et al. 2001; Voncina et al. 2002; Simeonov et al. 2003, 2004; Simeonova et al. 2003; Ouyang 2005; Praus 2005; Panda et al. 2006; Ouyang et al. 2006; Kuppusamy and Giridhar 2006; Shrestha and Kazama 2007).

The purpose of this work is to obtain seasonal variations of monitored physico-chemical parameters in the Porsuk stream (Turkey), which was generated under a 10-years (1995–2005) monitoring program, and to obtain the more detailed information about water quality parameters for all four seasons by using the factor analysis method.

Study area

The Porsuk Stream (length of 460 km) is a tributary of the Sakarya River (length 824 km). It arises in the Murat Mountain to the south of the city of Kütahya, situated in Western Turkey. After taking up various creeks, it flows past Kütahya and enters the reservoir named after itself. Leaving the reservoir, the stream passes through the city of Eskisehir and flowing through a wide valley, again named after itself, it joins the Sakarya River. During its course, the Porsuk Stream travels a distance of 460 km and drains an area of 11 325 km^2 (SHW 1995; Albek 2003).

The stream is very important because it provides the two cities mentioned with drinkable water. The agricultural areas in the watershed, especially along the valley after Eskisehir, are irrigated with water supplied from the stream (Albek 2003).

Porsuk stream has been heavily polluted by domestic and industrial activities such as Nitrogen Fertilizer Factory, Sugar-beet Factory, and Magnesite Factory in Kütahya, Seyitomer Thermic Power Plant, which have no, or insufficient treatment plants. Figure 1 shows Porsuk stream and the locations of the main pollution sources.

Factor analysis

Factor Analysis is a multivariate statistical technique, which attempts to extract a lower dimensional linear structure from the data set. These factors can be interpreted in terms of new variables. Factor analysis aims to explain observed relation between numerous variables in terms of simpler relations (Cattel 1965). In FA, the basic concept is expressed in the following formula:

$$z_j = a_{j1} f_1 + a_{j2} f_2 + \ldots + a_{jm} f_m + e_{ij};\ j = 1, 2, \ldots, p \quad (1)$$

where, z is the measured value, f the factor score, a the factor loading, e the residual term accounting for errors or other sources of variation, i the sample number, j the variable number, and m is the total number of factors (Anazawa and Ohmori 2001).

Results and discussion

In this study, water quality data is obtained from the State Hydraulic Works (SHW) at Esenkara monitoring station. Esenkara monitoring station is one of the monitoring stations along the Porsuk Stream situated after the city of Kutahya. The data was observed at monthly intervals between the years 1995 and 2005. Data collection and analysis based on standard techniques have

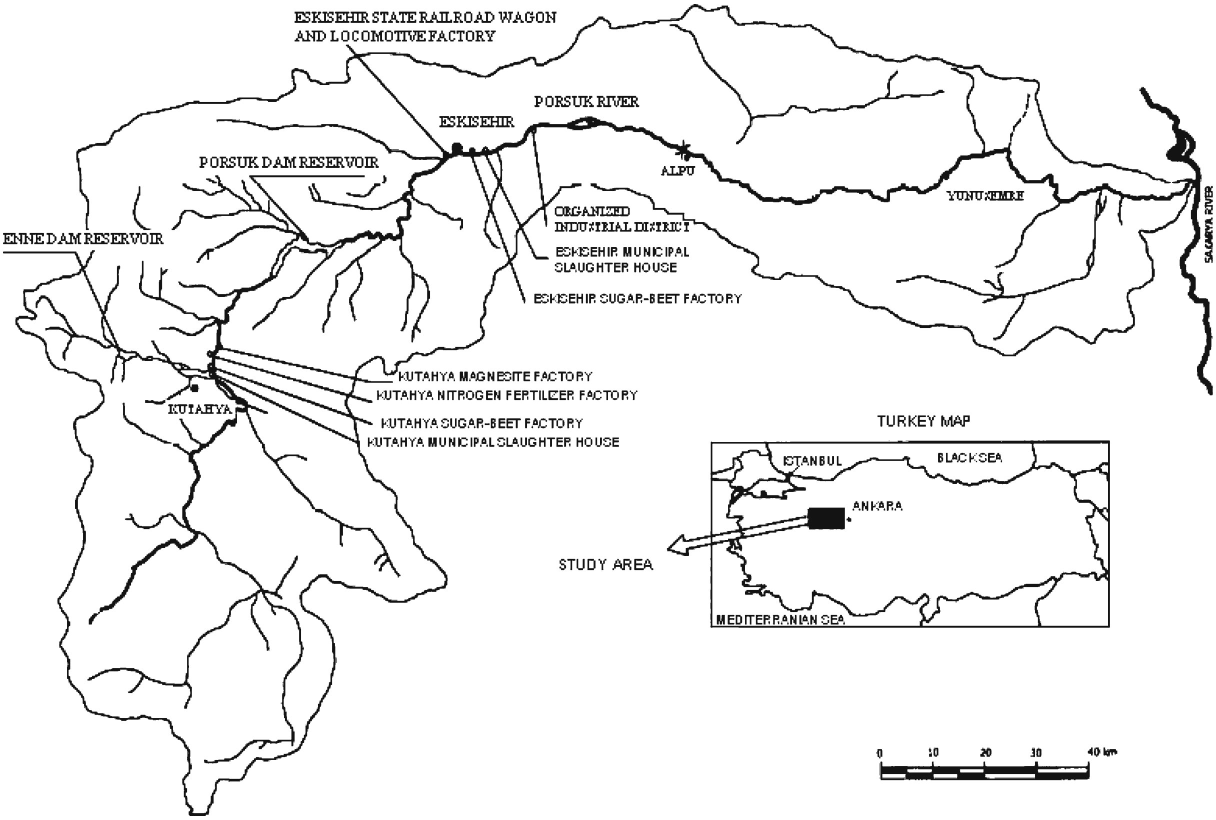

Fig. 1 Porsuk stream and locations of the main pollution sources (Source: Muhammetoglu et al. 2005)

been carried out by SHW within their long-term monitoring program.

In our study, we selected 29 parameters for the estimation of surface water quality characteristics. The selected parameters are: Flow, water temperature, pH, electrical conductivity, total dissolved solids, suspended solids, total alkalinity, chloride, ammonical nitrogen, nitrite nitrogen, nitrate nitrogen, dissolved oxygen, organic matter, biochemical oxygen demand, chemical oxygen demand, total hardness, orto-phosphorus, sulphate, iron, manganese, sodium, potassium, calcium, magnesium, total coliforms, fecal streptococ, Escherichia coli, boron and fluoride. Because the measurement unit of the selected 29 variables are different, first, they are standardized. Next, Pearson correlation coefficient matrix are used for the determination of the correlation between the variables. Then, these correlation coefficients are examined to decide if factor analysis can be applied to the variables. As a result, factor analysis method was found to be applicable problem. Descriptive statistics results of water quality characteristics according to seasons are given in Table 1.

Seasonal correlation of water quality parameters

Data in Table 2 provide the seasonal correlation matrix of the water quality parameters obtained from the PCA. In general, the river water temperature had relatively weak to fair correlations, i.e., most of the correlation coefficients are less than 0.75 (absolute value) with other parameters for the entire four seasons. In spring, correlation coefficient between temperature and other parameters were less than or equal to 0.5. Such correlations had not changed in summer. These correlations had changed in fall with a positive increase in correlations with NH_3-N (0.593), $N0_2$-N (0.632) and o-PO_4^{3-} (0.502) as well as a negative increase

Table 1 Descriptive statistics of water quality data

Parameters	Abbreviation	Unit	Number	Winter		Spring		Summer		Fall	
				Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Flow	Q	m^3/sn	33	5.50	3.94	7.91	7.24	12.17	4.05	7.36	4.76
Temperature	T	°C	33	5.34	2.50	8.83	2.73	13.48	2.51	11.53	2.85
pH	pH	pH units	33	8.10	0.28	8.08	0.35	7.97	0.25	7.93	0.28
Electrical conductivity (25 °C)	EC	umho/cm	33	541.10	72.97	518.61	85.54	578.15	30.22	581.33	30.05
Total dissolved solids	TDS	mg/l	33	337.75	41.51	319.94	46.32	361.39	21.95	370.38	19.26
Suspended solids	SS	mg/l	33	34.72	104.55	23.42	14.88	17.76	8.95	20.76	15.39
Total alkalinity	M-Al	mg/l $CaCO_3$	33	242.09	32.75	231.11	40.36	248.68	15.53	264.73	13.42
Chloride	Cl^-	mg/l	33	12.54	2.70	11.59	2.80	13.89	2.12	13.23	1.26
Ammonical nitrogen	NH_3-N	mg/l	33	0.26	0.25	0.30	0.27	0.61	0.30	0.49	0.26
Nitrite nitrogen	NO_2-N	mg/l	33	0.02	0.01	0.02	0.01	0.06	0.03	0.05	0.03
Nitrate nitrogen	NO_3-N	mg/l	33	1.15	0.33	0.80	0.28	0.87	0.42	1.26	0.51
Dissolved oxygen	DO	mg/l	33	11.04	1.07	10.43	1.35	8.90	0.97	8.74	1.11
Organic matter	pV	mg/l	33	2.81	1.02	2.88	0.76	2.89	0.38	2.93	0.84
Biochemical oxygen demand	BOD_5	mg/l	33	3.04	0.88	3.01	1.03	3.39	0.89	3.36	1.09
Chemical oxygen demand	COD	mg/l	33	20.46	6.96	27.24	12.46	25.74	11.03	24.92	12.35
Total hardness	TH	mg/l $CaCO_3$	33	269.44	37.56	256.18	45.42	284.95	14.24	291.51	12.11
Orto-phosphorus	o-PO_4^{3-}	mg/l	33	0.38	0.21	0.37	0.27	0.84	0.25	0.86	0.23
Sulphate	SO_4^{3-}	mg/l	33	34.73	8.43	34.89	10.90	43.26	6.88	37.31	6.27
Iron	Fe	mg/l	33	0.35	0.34	0.35	0.27	0.27	0.14	0.33	0.23
Manganez	Mn	mg/l	33	0.11	0.11	0.08	0.04	0.09	0.04	0.11	0.06
Sodium	Na^+	mg/l	33	13.68	2.93	12.88	3.30	13.92	2.38	14.85	1.62
Potassium	K^+	mg/l	33	3.95	0.80	4.01	0.73	3.98	1.08	4.48	0.61
Calcium	Ca^{2+}	mg/l	33	46.93	5.32	46.50	8.15	48.31	6.78	52.63	5.79
Magnesium	Mg^{2+}	mg/l	33	36.96	7.47	34.00	8.46	39.89	3.47	38.93	3.74
Total coliforms	T. coli	MPN/100 ml	33	998.98	1,514.96	1,184.73	3,147.50	1,496.91	2,654.05	2,248.58	6,866.60
Fecal streptococ	F. strp.	MPN/100 ml	33	147.97	285.44	48.18	74.14	106.70	125.83	364.08	923.38
Escherichia coli	*E. coli*	MPN/100 ml	33	214.69	445.18	164.45	439.90	292.60	582.15	925.07	3,462.69
Boron	B	mg/l	33	0.16	0.08	0.14	0.09	0.16	0.15	0.17	0.10
Fluoride	F^-	mg/l	33	0.25	0.10	0.23	0.12	0.27	0.12	0.28	0.11

Table 2 Correlation matrices

Winter	Q	T	pH	EC	TDS	SS	M-Al	Cl^-	NH_3-N	NO_2-N	NO_3-N	DO	pV	BOD_5	COD	TH	o-PO_4^{3-}	SO_4^{3-}	Fe	Mn	Na^+	K^+	Ca^{2+}	Mg^{2+}	T.coli	F.strp.	E.coli	B	F^-
Q	1.000
T	0.327	1.000
pH	-0.337	-0.400	1.000
EC	-0.169	0.438	0.249	1.000
TDS	-0.155	0.431	0.312	0.904	1.000
SS	0.207	-0.222	-0.373	-0.625	-0.673	1.000
M-Al	-0.180	0.376	0.196	0.908	0.841	-0.632	1.000
Cl^-	0.171	0.420	0.152	0.771	0.717	-0.427	0.670	1.000
NH_3-N	0.213	0.255	-0.222	-0.003	-0.122	0.099	-0.143	-0.123	1.000
NO_2-N	0.476	0.651	-0.347	0.274	0.198	-0.250	0.173	0.403	0.518	1.000
NO_3-N	-0.286	0.078	0.198	0.266	0.421	-0.274	0.331	0.007	-0.189	-0.116	1.000
DO	-0.148	-0.720	0.438	-0.308	-0.326	0.036	-0.274	-0.291	-0.228	-0.515	-0.284	1.000
pV	0.295	-0.187	-0.427	-0.827	-0.819	0.722	-0.782	-0.616	0.187	-0.115	-0.249	0.048	1.000
BOD_5	0.167	-0.040	-0.127	-0.265	-0.363	0.658	-0.390	-0.117	0.026	-0.010	-0.246	0.089	0.380	1.000
COD	0.163	0.382	-0.480	-0.248	-0.162	0.227	-0.259	-0.176	0.519	0.320	-0.011	-0.311	0.452	0.135	1.000
TH	-0.114	0.424	0.222	0.951	0.917	-0.657	0.972	0.754	-0.098	0.243	0.315	-0.290	-0.828	-0.373	-0.218	1.000
o-PO_4^{3-}	0.206	0.627	-0.213	0.372	0.413	-0.075	0.218	0.358	0.102	0.415	0.149	-0.445	-0.198	0.109	0.200	0.312	1.000
SO_4^{3-}	0.222	0.381	0.081	0.595	0.633	-0.437	0.419	0.649	-0.006	0.433	0.123	-0.250	-0.552	-0.024	-0.087	0.571	0.496	1.000
Fe	-0.145	-0.217	-0.164	-0.536	-0.519	0.544	-0.556	-0.568	0.031	-0.251	-0.089	0.031	0.499	0.587	0.190	-0.596	-0.201	-0.401	1.000
Mn	0.142	-0.263	-0.262	-0.628	-0.686	0.878	-0.655	-0.464	0.209	-0.199	-0.172	0.072	0.691	0.576	0.277	-0.673	-0.109	-0.454	0.470	1.000
Na^+	-0.166	0.318	0.341	0.767	0.793	-0.632	0.646	0.531	-0.096	0.164	0.344	-0.136	-0.704	-0.077	-0.148	0.724	0.388	0.719	-0.393	-0.593	1.000
K^+	0.144	0.134	-0.095	0.126	0.014	0.370	-0.032	0.135	0.482	0.153	-0.238	-0.135	0.041	0.385	0.273	0.014	0.131	0.059	0.095	0.340	0.067	1.000
Ca^{2+}	-0.215	0.370	-0.078	0.555	0.505	-0.511	0.729	0.223	-0.189	0.128	0.291	-0.292	-0.477	-0.385	-0.159	0.646	0.066	0.111	-0.231	-0.608	0.339	-0.301	1.000
Mg^{2+}	-0.045	0.360	0.303	0.924	0.903	-0.581	0.874	0.827	-0.037	0.244	0.259	-0.231	-0.805	-0.287	-0.197	0.944	0.355	0.652	-0.628	-0.560	0.740	0.148	0.358	1.000
T.coli	0.144	0.339	-0.290	0.085	-0.044	0.115	0.079	0.062	0.264	0.267	-0.266	-0.128	0.046	0.142	0.278	0.079	-0.085	0.045	0.000	0.124	-0.075	0.270	0.139	0.037	1.000
F.strp.	0.188	0.078	-0.427	-0.245	-0.425	0.526	-0.280	-0.261	0.596	0.278	-0.418	-0.146	0.384	0.385	0.322	-0.293	-0.181	-0.164	0.241	0.498	-0.323	0.533	-0.165	-0.286	0.610	1.000
E.coli	0.107	0.287	-0.201	-0.012	-0.124	0.163	-0.079	-0.120	0.545	0.347	-0.275	-0.202	0.139	0.230	0.279	-0.067	0.009	-0.048	0.122	0.169	-0.112	0.401	-0.031	-0.068	0.683	0.778	1.000
B	-0.052	0.093	0.026	0.354	0.319	-0.383	0.295	0.265	0.122	0.299	-0.010	-0.051	-0.285	-0.200	0.025	0.356	0.206	0.463	-0.278	-0.370	0.387	-0.068	0.246	0.329	-0.142	-0.045	-0.037	1.000
F^-	-0.202	0.003	0.417	0.328	0.335	-0.261	0.261	0.241	-0.090	-0.033	-0.018	-0.009	-0.478	-0.078	-0.303	0.300	0.338	0.344	-0.336	-0.246	0.419	0.020	0.039	0.349	-0.232	-0.150	-0.013	0.208	1.000
Spring
Q	1.000
T	0.103	1.000
pH	-0.279	-0.109	1.000
EC	0.317	0.336	0.111	1.000
TDS	0.361	0.317	0.140	0.960	1.000
SS	0.416	0.233	-0.299	-0.150	-0.122	1.000
M-Al	0.244	0.325	0.212	0.946	0.891	-0.201	1.000
Cl^-	0.226	0.310	-0.108	0.759	0.697	-0.027	0.680	1.000
NH_3-N	0.694	0.235	-0.290	0.549	0.545	0.095	0.399	0.440	1.000
NO_2-N	0.400	0.404	-0.141	0.560	0.574	-0.182	0.443	0.395	0.755	1.000
NO_3-N	-0.126	0.194	0.363	0.317	0.371	-0.194	0.381	0.298	0.059	0.167	1.000
DO	-0.403	-0.456	0.507	-0.122	-0.202	-0.103	-0.011	-0.019	-0.469	-0.447	0.065	1.000
pV	-0.045	-0.100	-0.414	-0.657	-0.585	0.229	-0.745	-0.512	-0.107	-0.085	-0.341	-0.223	1.000
BOD_5	-0.301	-0.107	0.207	0.269	0.289	-0.016	0.131	0.199	-0.089	-0.094	0.106	0.314	-0.192	1.000
COD	-0.287	-0.099	-0.068	-0.079	-0.062	0.031	-0.081	-0.149	-0.128	-0.119	0.140	0.023	0.139	0.147	1.000
TH	0.265	0.340	0.197	0.971	0.949	-0.174	0.978	0.727	0.424	0.489	0.393	-0.070	-0.725	0.217	-0.090	1.000
o-PO_4^{3-}	0.615	0.327	-0.226	0.578	0.601	0.026	0.392	0.437	0.882	0.851	0.075	-0.504	-0.039	-0.031	-0.121	0.457	1.000
SO_4^{3-}	0.241	0.225	0.071	0.608	0.699	-0.156	0.435	0.430	0.469	0.615	0.028	-0.430	-0.192	0.260	-0.038	0.555	0.632	1.000
Fe	0.073	-0.107	-0.033	-0.550	-0.541	0.676	-0.587	-0.380	-0.192	-0.357	-0.264	0.205	0.521	0.028	0.087	-0.573	-0.180	-0.414	1.000
Mn	-0.223	-0.103	-0.191	-0.102	-0.041	0.047	-0.134	0.059	-0.266	-0.202	0.008	-0.042	0.203	0.288	0.418	-0.092	-0.253	0.037	0.072	1.000
Na^+	0.152	0.155	0.174	0.867	0.823	-0.218	0.773	0.700	0.466	0.584	0.269	-0.010	-0.611	0.389	-0.095	0.827	0.532	0.637	-0.427	0.019	1.000
K^+	0.137	0.124	-0.202	0.526	0.492	-0.186	0.386	0.437	0.489	0.513	-0.017	-0.120	-0.271	0.386	-0.112	0.425	0.519	0.442	-0.313	0.168	0.664	1.000
Ca^{2+}	0.168	0.386	0.182	0.614	0.565	-0.137	0.716	0.334	0.214	0.246	0.398	-0.128	-0.567	0.038	-0.192	0.685	0.196	0.137	-0.446	-0.328	0.395	-0.033	1.000
Mg^{2+}	0.248	0.217	0.150	0.909	0.908	-0.147	0.857	0.754	0.429	0.494	0.280	-0.016	-0.614	0.261	-0.004	0.904	0.482	0.645	-0.486	0.070	0.848	0.574	0.308	1.000
T.coli	0.039	0.388	0.043	0.066	0.101	0.419	0.020	0.074	0.043	0.058	-0.016	-0.040	0.129	0.276	0.123	0.074	0.127	0.154	0.360	0.093	0.008	0.065	0.027	0.081	1.000
F.strp.	0.060	0.359	-0.037	-0.099	-0.061	0.482	-0.178	-0.053	0.007	0.028	-0.091	-0.050	0.345	0.224	0.225	-0.120	0.116	0.063	0.536	0.184	-0.119	0.009	-0.196	-0.042	0.900	1.000

Table 2 (continued)

	Q	T	pH	EC	TDS	SS	M-Al	Cl^-	NH_3-N	NO_2-N	NO_3-N	DO	pV	BOD_5	COD	TH	o-PO_4^{3-}	SO_4^{3-}	Fe	Mn	Na^+	K^+	Ca^{2+}	Mg^{2+}	T.coli	F.strp.	E.coli	B	F^-
E.coli	0.011	0.443	0.036	0.040	0.084	0.489	-0.004	0.044	-0.008	0.035	0.017	-0.022	0.146	0.309	0.188	0.053	0.093	0.107	0.436	0.189	0.015	0.099	-0.045	0.095	0.952	0.945	1.000		
B	0.284	0.354	-0.043	0.520	0.466	0.340	0.524	0.505	0.145	0.260	0.069	0.027	-0.215	0.050	-0.060	0.536	0.173	0.269	0.004	-0.027	0.386	-0.004	0.340	0.501	0.284	0.180	0.256	1.000	
F^-	0.242	0.280	-0.007	0.320	0.348	0.115	0.291	0.125	0.200	0.239	0.015	-0.183	-0.246	-0.063	-0.183	0.292	0.311	0.160	-0.193	-0.295	0.248	0.131	0.214	0.255	0.044	-0.072	0.026	0.104	1.000
Summer																													
Q	1.000																												
T	-0.086	1.000																											
pH	-0.220	-0.114	1.000																										
EC	-0.062	-0.372	0.228	1.000																									
TDS	-0.054	-0.069	0.032	0.566	1.000																								
SS	0.050	0.087	-0.292	-0.038	-0.042	1.000																							
M-Al	0.125	-0.291	0.166	0.668	0.647	0.049	1.000																						
Cl^-	0.183	-0.024	-0.111	0.156	0.249	0.139	0.260	1.000																					
NH_3-N	0.040	-0.057	0.084	0.238	0.239	-0.054	0.245	0.099	1.000																				
NO_2-N	-0.065	0.463	-0.027	0.163	0.577	-0.196	0.387	0.192	0.117	1.000																			
NO_3-N	0.086	-0.480	0.045	0.297	0.205	0.117	0.287	-0.012	0.083	-0.286	1.000																		
DO	0.042	-0.245	-0.022	-0.048	0.057	0.334	0.223	-0.127	-0.148	-0.067	0.194	1.000																	
pV	0.334	0.054	-0.106	-0.017	-0.295	0.027	-0.064	-0.079	-0.257	-0.044	-0.148	0.325	1.000																
BOD_5	-0.031	0.135	0.042	0.120	0.013	0.187	0.120	0.019	0.294	0.120	-0.163	0.073	0.012	1.000															
COD	0.056	0.037	-0.146	-0.108	-0.019	0.126	-0.078	-0.165	-0.305	-0.097	-0.132	0.035	-0.055	0.195	1.000														
TH	0.096	-0.283	0.089	0.542	0.673	0.084	0.831	0.325	0.303	0.391	0.164	0.228	-0.159	0.154	-0.219	1.000													
o-PO_4^{3-}	0.065	-0.075	-0.230	0.399	0.416	0.071	0.389	0.273	0.346	0.234	0.506	-0.240	-0.310	0.266	-0.174	0.374	1.000												
SO_4^{3-}	0.247	-0.276	0.343	0.189	-0.016	-0.184	0.097	-0.017	0.362	-0.118	-0.165	-0.348	-0.236	0.269	-0.021	0.211	0.012	1.000											
Fe	-0.214	0.384	-0.110	-0.172	0.010	0.578	-0.135	0.013	-0.109	0.032	-0.060	-0.033	-0.219	0.194	-0.040	-0.091	0.185	-0.262	1.000										
Mn	-0.004	0.076	0.171	0.124	-0.026	0.116	0.076	-0.235	-0.067	0.089	-0.252	0.185	0.193	0.240	0.226	0.021	-0.180	0.065	-0.087	1.000									
Na^+	-0.151	-0.083	0.294	0.228	0.026	-0.042	0.131	0.047	0.168	0.102	-0.012	-0.223	-0.136	0.348	-0.272	0.068	0.166	0.412	0.052	0.199	1.000								
K^+	-0.011	0.082	0.056	-0.088	0.051	0.204	0.030	-0.086	0.277	0.004	0.061	0.202	-0.035	0.186	-0.165	0.080	-0.011	0.075	0.218	-0.032	0.256	1.000							
Ca^{2+}	0.001	-0.462	0.167	0.234	0.310	-0.211	0.422	0.126	0.215	0.139	0.075	0.214	0.079	0.078	-0.225	0.588	0.078	0.164	-0.270	-0.087	-0.048	-0.118	1.000						
Mg^{2+}	0.092	0.265	-0.111	0.259	0.299	0.331	0.324	0.172	0.045	0.222	0.073	-0.027	-0.250	0.060	0.049	0.297	0.279	0.016	0.227	0.124	0.123	0.217	-0.598	1.000					
T.coli	0.126	-0.125	-0.348	0.020	0.022	0.028	-0.108	-0.013	-0.123	-0.228	-0.036	-0.062	-0.101	-0.135	0.489	-0.012	0.065	-0.059	-0.048	0.046	-0.511	-0.481	-0.027	0.021	1.000				
F.strp.	0.004	0.038	-0.007	-0.004	0.158	0.255	-0.021	0.084	0.051	0.006	0.024	0.109	0.045	0.182	-0.058	0.322	0.152	-0.014	0.202	-0.077	-0.131	-0.004	0.140	0.155	0.341	1.000			
E.coli	-0.066	-0.087	-0.010	0.021	0.160	0.102	0.072	0.204	-0.123	-0.024	0.163	-0.182	-0.166	-0.213	-0.071	0.152	0.255	-0.062	0.106	-0.122	-0.066	-0.563	-0.055	0.218	0.339	0.494	1.000		
B	-0.053	0.249	-0.065	-0.089	0.130	-0.153	0.134	0.112	0.209	0.278	0.102	-0.079	-0.396	0.018	-0.175	0.198	0.300	0.045	-0.109	-0.117	0.034	-0.280	-0.067	0.276	0.057	-0.015	0.224	1.000	
F^-	-0.113	-0.072	0.098	0.143	0.367	-0.213	0.102	-0.050	0.176	0.021	0.352	0.050	-0.281	-0.214	-0.330	0.191	0.326	-0.106	0.011	-0.051	0.056	0.038	0.003	0.187	0.012	0.261	0.263	0.264	1.000
Fall																													
Q	1.000																												
T	0.456	1.000																											
pH	-0.338	-0.138	1.000																										
EC	-0.373	0.081	0.210	1.000																									
TDS	-0.310	0.143	0.067	0.491	1.000																								
SS	-0.120	0.289	0.128	0.193	0.309	1.000																							
M-Al	-0.271	-0.226	0.340	0.457	0.373	0.033	1.000																						
Cl^-	0.144	0.192	-0.163	0.043	-0.242	-0.061	-0.407	1.000																					
NH_3-N	0.493	0.593	-0.185	-0.125	0.037	0.016	-0.305	-0.017	1.000																				
NO_2-N	0.356	0.632	-0.135	-0.031	-0.040	-0.182	-0.252	0.078	0.574	1.000																			
NO_3-N	-0.616	-0.295	0.215	0.510	0.467	0.065	0.618	-0.349	-0.383	-0.012	1.000																		
DO	-0.240	-0.751	0.309	-0.268	-0.250	-0.196	0.129	-0.195	-0.364	-0.555	0.029	1.000																	
pV	0.127	0.018	-0.367	-0.044	-0.043	0.075	-0.100	0.434	-0.077	-0.233	-0.261	0.154	1.000																
BOD_5	0.174	0.311	-0.043	-0.198	0.028	0.392	-0.422	0.106	0.434	0.262	-0.305	-0.304	0.045	1.000															
COD	0.064	0.022	-0.560	-0.109	-0.192	0.060	-0.562	0.343	0.107	-0.007	-0.247	-0.096	0.390	0.235	1.000														
TH	-0.106	0.060	0.367	0.435	0.431	0.136	0.702	-0.337	-0.108	-0.042	0.489	-0.144	-0.285	-0.154	-0.379	1.000													
o-PO_4^{3-}	0.241	0.502	0.040	0.069	0.310	0.105	-0.165	0.019	0.446	0.708	0.002	-0.449	-0.156	0.436	-0.051	0.088	1.000												
SO_4^{3-}	0.231	0.255	-0.021	-0.107	-0.135	-0.111	-0.488	0.396	0.338	0.255	-0.381	-0.234	-0.070	0.343	0.388	0.058	0.201	1.000											
Fe	-0.120	0.299	-0.072	0.187	0.290	0.820	-0.015	0.035	-0.075	-0.227	0.060	-0.211	0.080	0.148	0.120	0.113	-0.109	-0.137	1.000										
Mn	0.008	-0.058	0.232	0.240	0.365	-0.054	0.336	-0.154	0.102	-0.074	0.177	-0.104	-0.127	0.039	-0.270	0.347	0.210	-0.175	-0.195	1.000									
Na^+	-0.088	-0.124	-0.310	0.049	0.068	-0.153	0.094	0.338	0.060	0.180	0.210	-0.040	0.302	-0.099	0.108	-0.205	0.032	-0.089	-0.194	-0.149	1.000								

	Q	T	pH	EC	TDS	SS	M-Al	Cl^-	NH_3-N	NO_2-N	NO_3-N	DO	pV	BOD_5	COD
K^+	-0.255	0.020	-0.125	0.156	0.051	0.184	0.135	0.092	-0.065	-0.194	-0.047	-0.003	0.217	0.017	-0.011
Ca^{2+}	-0.125	0.074	0.073	0.114	0.344	0.219	0.258	-0.322	0.098	0.157	0.330	-0.142	-0.281	0.025	-0.315
Mg^{2+}	0.010	-0.025	0.231	0.232	0.017	-0.108	0.307	0.053	-0.206	-0.205	0.069	0.031	0.045	-0.169	-0.005
T.coli	-0.222	0.204	-0.029	0.127	0.232	0.878	-0.063	0.037	-0.096	-0.201	0.062	-0.233	0.120	0.389	0.151
F.strp.	-0.304	0.047	-0.138	0.033	0.185	0.763	-0.048	0.031	-0.177	-0.303	0.046	-0.125	0.173	0.306	0.132
E.coli	-0.233	0.190	-0.042	0.115	0.232	0.876	-0.067	0.024	-0.100	-0.209	0.066	-0.225	0.137	0.389	0.164
B	0.164	-0.031	-0.259	-0.024	0.020	-0.019	-0.037	0.108	0.067	-0.033	-0.161	0.018	0.208	0.187	0.109
F^-	-0.127	0.111	0.280	0.200	0.316	0.169	0.417	-0.539	-0.071	-0.002	0.242	-0.096	-0.455	-0.198	-0.282

	TH	o-PO_4^{3-}	SO_4^{3-}	Fe	Mn	Na^+	K^+	Ca^{2+}	Mg^{2+}	T.coli	F.strp.	E.coli	B	F^-
K^+	-0.197	-0.297	-0.244	0.256	-0.322	0.102	1.000							
Ca^{2+}	0.327	0.267	-0.251	0.189	0.204	0.161	-0.106	1.000						
Mg^{2+}	0.445	-0.210	0.263	-0.082	0.072	-0.332	-0.008	-0.696	1.000					
T.coli	0.092	-0.049	0.037	0.806	-0.198	-0.089	0.239	0.244	-0.161	1.000				
F.strp.	-0.016	-0.188	-0.040	0.747	-0.223	0.020	0.293	0.178	-0.181	0.940	1.000			
E.coli	0.067	-0.057	0.009	0.807	-0.202	-0.080	0.245	0.247	-0.182	0.998	0.944	1.000		
B	-0.106	-0.025	-0.058	0.025	0.244	-0.031	0.145	-0.282	0.175	0.029	0.120	0.022	1.000	
F^-	0.489	-0.051	-0.192	0.281	0.063	-0.285	0.035	0.170	0.230	0.025	-0.011	0.018	-0.050	1.000

in correlations with DO (−0.751). The correlation coefficients between temperature and parameters fell below the absolute value of 0.72 in winter, indicating relatively fair correlations. It should be noted that few efforts have been devoted to investigating the correlations among the variables used in this study. Ouyang et al. (2006) investigated the seasonal physical and chemical characteristic changes of 22 monitoring stations located in the main stem of the LSJR during March 1998–March 2001. These authors found that the water temperature had very weak correlations with other water quality parameters such as turbidity, TKN, TOC, DOC, EC, alkalinity, salinity, and BOD_5, which were, in general, similar to our findings.

Very strong correlations between EC and other parameters (TDS, M-Al, PV, TH and Mg) were also found in winter and spring, but such correlations were not found in summer and fall. That is, the correlation coefficients between EC and TDS, EC and M-Al, EC and PV, EC and TH and EC and Mg^{2+} were respectively 0.904, 0.908, 0.827, 0.951 and 0.924 in winter, 0.960, 0.946, 0.657, 0.971 and 0.909 in spring, 0.566, 0.668, −0.017, 0.542 and 0.259 in summer, and 0.491, 0.457, −0.268, 0.435 and 0.232 in fall.

Very strong correlations between DO and other parameters were not found in four seasons.

Results from the PCA showed that large seasonal variations in correlation coefficients between BOD_5 and other parameters were not found. The correlation coefficients between BOD_5 and other parameters were less than or equal to 0.587.

Very strong correlations between TDS and other parameters (i.e., M-Al, TH and Mg) were found in spring, but the correlations were moderately reduced in summer and profoundly in fall, and finally recovered in winter. That is, the correlation coefficients between TDS and M-Al, TDS and TH and TDS and Mg were respectively 0.891, 0.949 and 0.908 in spring, 0.647, 0.673 and 0.299 in summer, 0.373, 0.431 and 0.017 in fall and 0.841, 0.917 and 0.903 in winter. These data imply that TDS was not always highly correlated with M-Al, TH and Mg in Porsuk.

The M-Al had strong correlations with TH (0.972) and Mg (0.874) in winter, TH (0.978) and Mg (0.857) in spring and TH (0.831) and Mg

(0.324) in summer. Such correlations became very poor in fall (TH (−0.106) and Mg (0.010)).

Very strong correlations between SS and other parameters (i.e., Fe, *T-coli* and *E-coli*) were found in fall, but the correlations were moderately reduced spring and profoundly in summer, and finally recovered in winter. That is, the correlation coefficients between SS and Fe, SS and *T-coli* and SS, and SS and E-coli were respectively 0.820, 0.878 and 0.876 in fall, 0.676, 0.419 and 0.489 in spring, 0.578, 0.028 and 0.102 in summer and 0.878, 0.115 and 0.163 in winter. These data imply that SS was not always highly correlated with Fe, *T-coli* and *E-coli* in Porsuk.

The Cl^- had strong correlations with Mg (0.827) in winter and Mg (0.754) in spring, such correlations became very poor in summer and fall. The NH_3-N had strong correlations with NO_2-N (0.755) and o-PO_4^{3-} (0.882) in spring, such correlations became very poor in winter, summer and fall. The NO_2-N had strong correlations with o-PO_4^3 (0.851) in spring and o-PO_4^3 (0.708) in fall, such correlation very poor in winter and summer. The NO_3-N and COD had not correlations with other parameters in four seasons. The PV had negative correlations with TH (−0.828), Mg (−0.805), EC (−0.827) and TDS (−0.819) in winter, TH (−0.725), Mg (−0.614), EC (−0.657) and TDS (−0.585) in spring but such correlations were not found in summer and fall. The TH had strong correlations with Mg (0.944) in winter Mg (0.904) in spring, such correlations were not found in summer and fall. The SO_4^{3-} had good correlations with Na (0.719) in winter but such correlations were not in spring, summer and fall. The F.strp had correlation E-coli (0.778) in winter, E-coli (0.945) in spring and E-coli (0.944) in fall, such correlation was not found in summer. The *T-coli* had good correlations F.strp (0.900) and E-coli (0.952) in spring and F.strp (0.940) and *E-coli* (0.998) in fall and such correlations were not found in winter and summer.

Temporal variations of water quality parameters

Eigenvalues are normally used to determine the number of principal components that can be retained for further study. First four principal components have eigenvalues greater than or close to unity and explain 80.859%, 81.543%, 81.839% and 82.433% of the total variances of information contained in the original dataset for winter, spring, summer and fall, respectively (Table 3).

The component loadings are the linear combinations for each principal component, and express the correlation between the original variables and the newly formed components. The component loadings can be used to determine the relative importance of a variable as compared to other variables in a principal component and do not reflect the importance of the component itself.

Component loadings of principal components for each season are presented in Fig. 2.

In winter, Factor 1(F1) explained 35.619% of the total variance and was strong positive loading EC, TDS, M-Al, Cl^-, TH, Mg; moderate positive loading SO_4^{3-} and strong negative loading on PV; and moderate negative loading SS, Fe and Mn. This factor seems to measure the preponderance of mineral and inorganic nutrient-related water quality parameters over the organic-related water quality parameters (Table 4).

Factor-2 (F2) explained 16.751% of the total variance and was positively and largely contributed to by T, COD, NO_2-N, and o-PO_4^{3-} and was negatively and largely due to pH and DO. This organic factor can be interpreted as representing influences from point sources, such as of discharges from wastewater treatment plants and industrial effluents.

Factor-3 (F3) explained 7.643% of the total variance and is related to the three bacteriological contamination parameters (loading 0.859, 0.853 and 0.794 for E.coli, F.strp *T. coli* respectively). This factor assigned as the "microbiological factor". F3 may involve an urban origin, where waste disposal from populated areas increases fecal contents in the affected waters.

Factor-4 (F4) is named organic factors, account for 6.932% of the total variance and was strong positive loading for BOD_5. This factor represents pollution from domestic waste. Factor-5 (F5) explained 5.672% of the total variance and was positively and largely contributed to by B, and F^-. Factor-6 (F6) explained 4.615% of the total variance and was positively due to Q and was negatively due to NO_3-N. Factor-7 (F7) explained

Table 3 Total variance explained before and after Varimax rotation for seasons

Component	Initial Eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
Winter	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	10.329	35.619	35.619	10.329	35.619	35.619	8.817	30.402	30.402
2	4.858	16.751	52.370	4.858	16.751	52.370	3.477	11.991	42.393
3	2.216	7.643	60.012	2.216	7.643	60.012	3.257	11.230	53.623
4	2.010	6.932	66.944	2.010	6.932	66.944	2.295	7.915	61.539
5	1.645	5.672	72.616	1.645	5.672	72.616	1.947	6.714	68.253
6	1.338	4.615	77.231	1.338	4.615	77.231	1.856	6.401	74.655
7	10.329	3.628	80.859	1.052	3.628	80.859	1.799	6.205	80.859
8	0.925	3.191	84.050						
Spring									
1	9.885	34.087	34.087	9.885	34.087	34.087	8.236	28.400	28.400
2	4.221	14.557	48.644	4.221	14.557	48.644	4.018	13.856	42.256
3	3.326	11.471	60.114	3.326	11.471	60.114	3.702	12.765	55.022
4	2.251	7.763	67.878	2.251	7.763	67.878	2.044	7.047	62.069
5	1.522	5.248	73.125	1.522	5.248	73.125	1.941	6.692	68.761
6	1.396	4.813	77.938	1.396	4.813	77.938	1.927	6.643	75.404
7	1.045	3.604	81.543	1.045	3.604	81.543	1.780	6.138	81.543
8	0.870	3.001	84.544						
Summer									
1	4.759	16.412	16.412	4.759	16.412	16.412	4.023	13.873	13.873
2	3.038	10.477	26.889	3.038	10.477	26.889	2.287	7.886	21.759
3	2.821	9.727	36.616	2.821	9.727	36.616	2.201	7.590	29.349
4	2.417	8.335	44.951	2.417	8.335	44.951	2.158	7.442	36.791
5	2.063	7.115	52.066	2.063	7.115	52.066	2.099	7.238	44.029
6	1.875	6.464	58.530	1.875	6.464	58.530	2.090	7.205	51.234
7	1.627	5.610	64.140	1.627	5.610	64.140	1.867	6.437	57.671
8	1.537	5.301	69.441	1.537	5.301	69.441	1.805	6.225	63.897
9	1.306	4.502	73.944	1.306	4.502	73.944	1.804	6.222	70.118
10	1.248	4.304	78.248	1.248	4.304	78.248	1.728	5.959	76.077
11	1.041	3.591	81.839	1.041	3.591	81.839	1.671	5.762	81.839
12	0.976	3.366	85.205						

Table 3 (continued)

Component	Initial Eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
Winter	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
Fall									
1	5.355	18.464	18.464	5.355	18.464	18.464	5.015	17.293	17.293
2	5.121	17.658	36.122	5.121	17.658	36.122	4.001	13.798	31.091
3	3.917	13.507	49.629	3.917	13.507	49.629	3.528	12.164	43.255
4	2.315	7.984	57.612	2.315	7.984	57.612	2.473	8.527	51.782
5	2.044	7.050	64.662	2.044	7.050	64.662	2.326	8.020	59.802
6	1.546	5.331	69.994	1.546	5.331	69.994	1.972	6.801	66.603
7	1.470	5.069	75.063	1.470	5.069	75.063	1.571	5.417	72.019
8	1.105	3.812	78.874	1.105	3.812	78.874	1.535	5.292	77.312
9	1.032	3.559	82.433	1.032	3.559	82.433	1.485	5.121	82.433
10	0.790	2.724	85.157						

3.628% of the total variance and was positively contributed to by NH_3-N and K^+ and was negatively due to Ca^{++}.

In spring F1 explained 34.087% of the total variance and was strong positively loaded by mineral-related parameters (i.e TH, EC, M-Al, Mg^{2+}, Na^+, TDS and Cl^-); moderate positive loadings, B, Ca^{2+} and strongly negative loadings on PV; moderately negative loadings on Fe. This component seems to measure the preponderance of mineral and inorganic nutrient-related water quality parametres.

The second factor F2 (which explained 14.557% of the total variance) was positively and largely due to parameters (i.e, o-PO_4^{3-}, NH_3-N and NO_2-N). This "nutrient" factor represents influences from nonpoint sources such as agricultural runoff and atmospheric deposition.

The third factor, F3 explained 11.471% of the total variance and is related to the three bacteriological contamination parameters (loading 0.975, 0.939 and 0.935 for E.coli, T. coli, F.strp., respectively). This factor assigned as the "microbiological factor". Coliform bacteria are excreted in large numbers in the faeces of humans and other warm-blooded animals. Consequently, water contaminated by faecal matter is identified as being potentially dangerous due to the indicator organisms co-existing with E. coli, which causes cholera (Hammer 1986). Some examples of diseases caused by drinking or swimming in faecal contaminated water are diarrhea, cholera, dysentery and skin, eye, ear, nose and throat infections (WHO 1993). The fourth factor F4 explained 7.763% of the total variance and was positively due to Q and SS. This factor explains the erosion from upland areas during rainfall events. The fifth factor F5 explained 5.248% of the total variance and was positively contributed to by COD and Mn and was negatively due to F. COD is a parameter in the amount of organic material observable in the water. F6 explained 4.813% of the total variance and was positively due to T and was negatively contributed to by DO and BOD_5. The inverse relationship between temperature and dissolved oxygen is a natural process because warmer water becomes saturated more easily with oxygen and it can hold less dissolved oxygen. F7 explained 3.604% of the total variance and was positively contributed to by pH and NO_3-N and was negatively due to K^+.

In summer, F1, which accounted for 16.412% of the total variance, was positively influenced by M-Al, TH, TDS, EC parameters; moderate positive loadings NO_2-N. This factor assigned as the "mineral and inorganic nutrient factor". In summer, while F2, which accounted for 10.477% of the total variance, was positively influenced by Mg^{2+} parameter and was negatively due to Ca^{2+}.

F3 explained 9.727% of the total variance and was positively contributed to by NO_3-N and was negatively due to T and NO_2-N. This factor assigned as the "nutrient" factor. As long as nitrification is occurring in the water, an increase in NO_3-N and a reduction in NO_2-N is a normal event. Accordingly in the nitrification process, NO_2-N is an unstable intermediary which is inclined to transform to NO_3-N (Filik Iscen et al. 2008).

F4 explained 8.335% of the total variance and was positively contributed to by SO_4^{3-} and was negatively due to DO. Sulphate is considered to be a permanent solute of water that reacts with organic matter, producing sulphur (S), H_2O and CO_2. The majority of sulphates are soluble in water. The quality of lake water is affected by sulphates. In most natural surface waters, sulphate levels in Turkey range from 200 to over 400 mg/l (Turkish Standards 2004).

F5 explained 7.115% of the total variance and was positively due to B and F^-. F6 explained

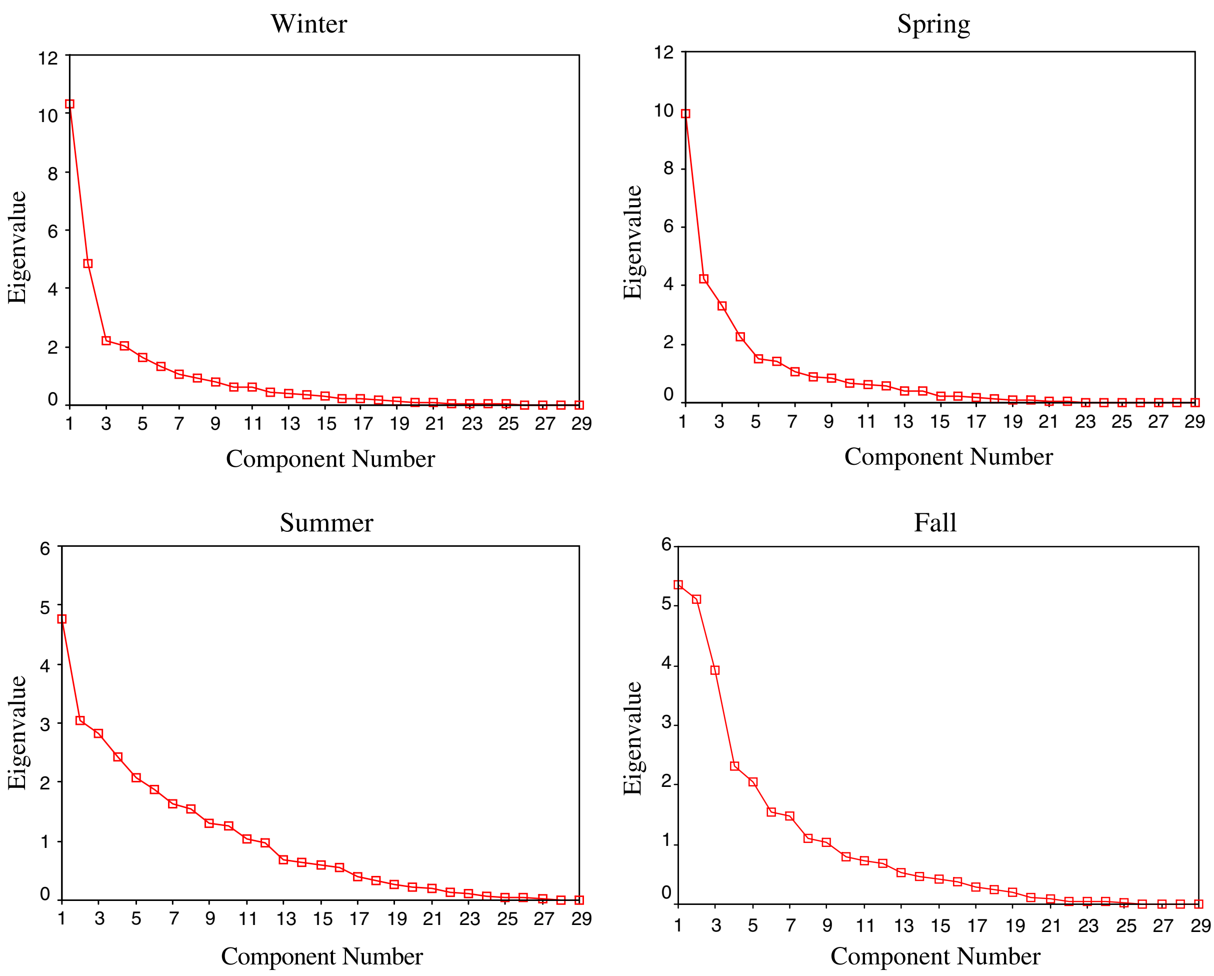

Fig. 2 Screen plot of the eigenvalues of principal components for all four seasons

Table 4 Factor loadings (Varimax rotation) rotated component matrices for all seasons

Variable	WINTER							SPRING							SUMMER											FALL								
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6	7	8	9
Q						0.804			0.588		0.626														0.852			-0.572						
T		0.797											0.662				-0.764										0.887							
pH		-0.657											-0.540	0.556				0.413													0.866			
EC	0.945							0.925							0.750													0.790						
TDS	0.906							0.878							0.844													0.687						
SS	-0.564			0.604							0.739					0.440										0.915								
M-Al	0.892							0.923							0.911													0.628						
Cl^-	0.823							0.800														0.079	-0.591						0.827					
NH_3-N			0.536				0.593		0.864										0.425								0.734							
NO_2-N		0.606							0.800						0.522		-0.695										0.828							
NO_3-N						-0.579								0.684			0.814											0.828						
DO		-0.809							-0.502				-0.756					-0.571									-0.786							
pV	-0.847							-0.756																	0.598				0.696					
BOD_5				0.869									-0.525											0.849										-0.538
COD		0.629										0.745								-0.771											-0.752			
TH	0.942							0.946							0.863													0.579						
o-PO_4^{3-}		0.604							0.903										0.481								0.722							
SO_4^{3-}	0.610								0.565									0.905												0.492				
Fe	-0.583			0.502				-0.534														0.311			-0.450	0.880								
Mn	-0.574											0.746											0.778										0.630	
Na^+	0.752							0.836												0.630									0.532					
K^+							0.631							-0.506							0.873											-0.868		
Ca^{2+}							-0.644	0.571							0.432	-0.843														-0.762				
Mg^{2+}	0.957							0.900								0.865														0.902				
T.coli			0.794							0.939										-0.814						0.974								
F.strp.			0.853							0.935												0.907				0.910								
E.coli			0.859							0.975					0.084						-0.690	0.520				0.974								
B					0.714			0.590			0.531								0.776														0.787	
F^-					0.565							-0.579							0.605										-0.766					

Loadings with magnitudes greater then |0.4| shown

6.464% of the total variance and was positively influenced by Na and was negatively influenced by COD and *T-coli*. F7 explained 5.610% of the total variance and was positively due to K^+ and was negatively due to E-coli. F8 explained 5.301% of the total variance and was positively and largely contributed to F. strp. F9 explained 4.502% of the total variance and was positively influenced by Mn and was negatively influenced by Cl^-. F10 explained 4.304% of the total variance and was positively and largely contributed to by BOD_5. This factor represents pollution from domestic waste, so F10 represents the "organic pollution" factor. F11 explained 3.591% of the total variance was positively due to Q and PV.

The F1 in fall, which explained 18.464% of the total variance, was positively and largely influenced by parameters (i.e, *T-coli*, E-coli, F.strp, SS and Fe). The highest burden in this factor was revealed by T-coli, E-coli and F. strp. It revealed that intensive discharge had occurred into the river from sewage.

F2, which explained 17.658% of the total variance, was positively participated by parameters (i.e, T, NO_2-N NH_3-N, and o-PO_4^{3-}) and was negatively due to DO. This factor can be attributed to a seasonal changes.

F3 (which explained 13.507% of the total variance) was positively affected due to NO_3-N, TDS, EC, M-Al, and TH. This factor assigned as the "mineral and inorganic nutrient factor". F4 (which explained 7.984% of the total variance) was positively affected due to Cl^-, PV and Na^+ and was negatively affected due to F. F5 explained 7.050% of the total variance and was positively contributed to by SO_4^{3-} and Mg and was negatively due to Ca. F5 is strongly correlated with Mg which is mainly originated from agricultural uses. F6, which explained 5.331% of the total variance, was positively participated by pH and was negatively participated by COD. F7 explained 5.069% of the total variance and was negatively contributed by K. F8, which explained 3.812% of the total variance, was positively due to Mn and B. F9 explained 3.559% of the total variance and was negatively influenced by BOD_5.

Vega et al. (1998) investigated the seasonal and polluting effects on water quality of the Pisuerga River (Spain) using exploratory data analysis. The first factor in this study was mostly contributed by mineral and inorganic nutrient-related water quality parameters. Also, Ouyang et al. (2006) investigated the seasonal variations on water quality of the St. Johns River, Florida using principal factor analysis technique. However, in their study, the first factor was mostly contributed by organic-related parameters and physical parameters. We attribute the discrepancies to the different river environments and different water quality parameters as well as to the different time periods used in each study. In our work, we found similar results with Vega et al. (1998) for all seasons except the fall.

Conclusion

1. In this study, surface water quality data for 29 parameters collected from Esenkara monitoring station along the Porsuk Stream in Eskisehir, Turkey from 1995–2005 were analyzed, using the factor analysis. Results from the factor analysis show that river water temperature had relatively weak to fair correlations with other parameters for the entire for seasons except for DO in fall, which had a correlation coefficient of −0.751.
2. Very strong correlations between EC and other parameters (TDS, M-Al, PV, TH and Mg) were also found in winter and spring, but such correlations were not found in summer and fall.
3. Ouyang et al. (2006), found strong correlation between the DO and the organic-related parameters (TKN, TOC and DOC) in spring, but the correlations were reduced moderately in summer and sharply in fall and finally recovered in winter. In this study, strong correlations between DO and other parameters were not found in four seasons. In addition, large seasonal variations in correlation coefficients between BOD_5 and other parameters were not found in this study. But, Ouyang et al. (2006) found large seasonal variation in correlations between BOD_5 and organic-relation parameters in LSJR. These discrepancies might be due to climate differences

because Turkey is cold area as compared to Florida.

4. Very strong correlations between TDS and other parameters (M-Al, TH and Mg) were found in spring, but the correlations were moderately reduced in summer and profoundly in fall, and finally recovered in winter. That is, the correlation coefficient between TDS and M-Al, TDS and TH and TDS and Mg were respectively 0.891, 0.949 and 0.908 in spring, 0.647, 0.673 and 0.299 in summer, 0.373, 0.431 and 0.017 in fall and 0.841, 0.917 and 0.903 in winter. These data imply that TDS was not always highly correlated with M-Al, TH and Mg in the Porsuk stream.
5. Large seasonal variation in correlations between SS and other parameters (Fe, *T-coli* and *E-coli*) were found in fall, but the correlations were moderately reduced spring and profoundly in summer, and finally recovered in winter. That is, the correlation coefficients between SS and Fe, SS and *T-coli* and SS and *E-coli* were respectively 0.820, 0.878 and 0.876 in fall, 0.676, 0.419 and 0.489 in spring, 0.578, 0.028 and 0.102 in summer and 0.878, 0.115 and 0.163 in winter. These data imply that SS was not always highly correlated with Fe, T-coli and E-coli in Porsuk stream.
6. The results of present study point to the existence of three main types of contamination of Porsuk Stream: mineral and inorganic nutrients, organic pollution, microbiological pollution each respectively of agricultural, domestic-industrial effluents and urban origin. These forms of contamination are in turn related to different terrestrial features including rivers and urban feature and so on.
7. Selection of correct parameters in water quality monitoring studies is an important point for technique and financial feasibility of monitoring programmes (Champman 1992). That's why, to continue the water monitoring studies of Porsuk stream at Esenkara station by using the parameters reduced from the factor analysis may result in technically and economically feasible outcome. In addition, these parameters can also be used in environmental studies to prevent the pollution.

References

Albek, E. (2003). Estimation of point and diffuse contaminant loads to streams by non-parametric regression analysis of monitoring data. *Water, Air, and Soil Pollution, 147*, 229–243. doi:10.1023/A:1024592815576.

Anazawa, K., & Ohmori, H. (2001). Chemistry of surface water at a volcanic summit area, Norikura, Central Japan: Multivariate statistical approach. *Chemosphere, 45*, 807–816. doi:10.1016/S0045-6535(01)00104-7.

Cattel, R. B. (1965). Factor analysis: Introduction to essentials. *Biometrics, 21*, 190–215. doi:10.2307/2528364.

Champman, J. S. (1992). *Water quality assessments* (pp. 38–39). London: Champman and Hall.

Filik Iscen, C., Emiroglu, O., Ilhan, S., Arslan, N., Yilmaz, V., & Ahiska, S. (2008). Application of multivariate statistical techniques in the assessment of surface water quality in Uluabat Lake, Turkey. *Environmental Monitoring and Assessment, 144*, 269–276. doi:10.1007/s10661-007-9989-3.

Hammer, J. M. (1986). *Water and Wastewater Technology* 3rd ed., (pp. 473–477). New Delhi, India: Prentice Hall.

Helena, B., Pardo, R., Vega, M., Barrado, E., Fernandez, J. M., & Fernandez, L. (2000). Temporal evolution of groundwater composition in an alluvial (Pisuerga river, Spain) by principal component analysis. *Water Research, 34*, 807–816. doi:10.1016/S0043-1354(99)00225-0.

Kuppusamy, M. R., & Giridhar, V. V. (2006). Factor analysis of water quality characteristics including trace metal speciation in the coastal environmental system of Chennai Ennore. *Environment International, 32*, 174–179. doi:10.1016/j.envint.2005.08.008.

Massart, D. L., Vandeginste, B. G. M., Deming, S. N., Michotte, Y., & Kaufman, L. (1988). *Chemometrices: A textbook*. Amsterdam: Elsevier.

Mazlum, N., Ozer, A., & Mazlum, S. (1999). Interpretation of water quality data by principal components analysis. *Turkish Journal Of Engineering and Environmental Science, 23*, 19–26.

Muhammetoglu, A., Muhammetoglu, H., Oktas, S., Ozgokcen, L., & Soyupak, S. (2005). Impact assessment of different management scenarios on water quality of porsuk river and dam system-Turkey. *Water Resources Management, 19*, 199–210, doi:10.1007/s11269-005-3473-z.

Ntengwe, F. W. (2006). Pollutant loads and water quality in streams of heavily populated and industrialised towns. *Physics and Chemistry of the Earth, 31*, 832–839.

Panda, U. C., Sundaray, S. K., Rath, P., Nayak, B. B., & Bhatta, D. (2006). Application of factor and cluster analysis for characterization of river and estuarine water systems—A case study: Mahanadi River (India). *Journal of Hydrology* (*Amsterdam*), *331*(3–4), 434–445. doi:10.1016/j.jhydrol.2006.05.029.

Praus, P. (2005). Water quality assessment using SDV-based principal component analysis of hydrological data. *Water South Africa 31*(4), 417–422.

Ouyang, Y. (2005). Evaluation of river water quality monitoring stations by principal component analysis. *Water Research, 39*, 2621–2635. doi:10.1016/j.watres.2005.04.024.

Ouyang, Y., Nkedi-Kizza, P., Wu, Q. T., Shinde, D., & Huang, C. H. (2006). Assessment of seasonal variations in surface water quality. *Water Research, 40*, 3800–3810. doi:10.1016/j.watres.2006.08.030.

Shrestha, S., & Kazama, F. (2007). Assessment of surface water quality using multivariate statistical techniques: A case study of the Fuji river basin; Japan. *Environmental Modelling & Software, 22*, 464–475. doi:10.1016/j.envsoft.2006.02.001.

SHW (1995). *Water quality assessment in the Porsuk watershed for the year 1994* (p. 75). Ankara: Department of Technical Research and Quality Control (in Turkish).

Simeonova, P., Simeonov, V., & Andreev, G. (2003). Analysis of the struma river water quality. *Central European Journal of Chemistry, 2*, 121–126. doi:10.2478/BF02479264.

Simeonov, V., Stratis, J. A., Samara, C., Zachariadis, G., Voutsa, D., Anthemidis, A., et al. (2003). Assessment of the surface water quality in Northern Greece. *Water Research, 37*, 4119–4124. doi:10.1016/S0043-1354(03)00398-1.

Simeonov, V., Simeonova, P., & Tsitouridou, R. (2004). Chemometric quality assessment of surface waters two case studies. *Chemical and Engineering Ecology, 11*(6), 449–469.

Turkish Standards (2004). *Su kirliligi yönetmeligi, 25687 sayılı resmi gazete*.

Vega, M., Pardo, R., Barrado, E., & Deban, L. (1998). Assessment of seasonal and polluting effects on the quality of river water by exploratory data analysis. *Water Research, 32*, 3581–3592. doi:10.1016/S0043-1354(98)00138-9.

Voncina, D. B., Dobcnik, D., Novic, M., & Zupan, J. (2002). Chemometric characterization of the quality of river water. *Analytica Chimica Acta, 462*, 87–100. doi:10.1016/S0003-2670(02)00298-2.

World Health Organization (WHO) (1993). *Guidelines for drinking water quality* (2nd ed., Vol. 1, pp. 13). Geneva: Recommendations.

Wunderlin, D. A., Diaz, M. P., Ame, M. V., Pesce, S. F., Hued, A. C., & Bistoni, M. A. (2001). Pattern recognition techniques for the evaluation of spatial and temporal variations in water quality. A case study: Suquia river basin (Cordoba-Argentina). *Water Research, 35*, 2881–2894. doi:10.1016/S0043-1354(00)00592-3.