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Assessment of irrigation water quality of Turkey using multivariate statistical techniques and water quality index: Sıddıklı Dam Lake

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ABSTRACT

This study was done in order to evaluate the status of the water quality of Sıddıklı Dam Lake as well as its suitability for irrigated agriculture. Sıddıklı Dam Lake is one of the major irrigation dam lakes flowing into Hirfanli Dam Lake. Throughout the first report on this study, surface water samples were taken monitoring 25 physicochemical variables at 4 different sites at every month between September 2015 and August 2016. In the present study, multivariate statistical techniques (hierarchical cluster analysis (HCA), principal component analysis (PCA)), the Pearson correlation, the Surface Water Quality Index, and Carlson's Trophic State Index were applied to the physicochemical variables on the water quality of the dam lake. Thus, we aim to determine the main pollution factors as well as the same time risky polluted areas. Sıddıklı Dam Lake was found eutrophic with a mean TSI value of 57. Moreover, the surface water quality index value was 67, inferring that it is of "medium quality". According to the results of HCA, four surface water sampling zones were grouped into two clusters. Upon looking at the PCA results, on can estimate that the lake dame pollution is mainly from agricultural run-off and soil erosion. Additionally, the water of Sıdıklı Dam Lake is not suitable for drinking, however it is fit for other purposes such as aquaculture, livestock drinking, and agricultural activities. Consequently, Sıddıklı Dam Lake has a satisfying level of water quality according to the overall quality variable permissible limits, however it has been strongly affected by agricultural use.

Keywords: Water quality; Multivariate statistical techniques; Water quality index (WQI); Carlson trophic state index (TSI)

1. Introduction

Clean freshwater resources are the primary source of water for domestic, agricultural, and industrial purposes in many countries. Unfortunately, a lot of negative conditions are observed in such resources, such as anthropogenic influences that impair their use for drinking, alongside industry, agriculture, and recreation purposes [1,2]. The pollution of freshwater resources with inorganic pollutants and an excess of certain nutrients has become a worldwide environmental concern. Nutrients such as phosphorus and nitrogen are known as the source of eutrophication and are known to negatively affect aquatic ecosystems [3].

Water quality for irrigation depends on the surrounding domestic and agricultural activities. Poor quality irrigation water poses many hazards to agricultural production [4]. The quality of these resources may affect both crop yields and soil physical conditions, even if all other conditions are optimal. Therefore, it is necessary to ensure the continuous monitoring of water resources, or else it can lead to large losses both in terms of water resources as well as in terms of agricultural products. The periodic monitoring the water

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Fig. 1. Map of study area with sampling point locations (changed from Google earth).

body quality will help protect our waterways from pollution, and will allow for sustainable use [5]. Recently, water quality index and multivariate statistical techniques have been widely used in order to gain a better understanding of the water quality during monitoring research activity. Additionally, these analyzes allow for the determination of possible pollutants that affect water sources [6–10]. Şener et al. [11] used GIS and the Water Quality Index (WQI) in order assess the suitability of river water from Aksu River, which is the main source of the Karacaören-1 Lake Dam, and is used for human consumption.

Kırşehir is one of the most important agricultural cities within Central Anatolia, it is used both for drinking and for irrigation water. It is undoubtedly of great importance to take precautions in order to determine and protect the quality of these resources. For this reason, the aim of the present study is/was:

1. To assess surface water quality used in agricultural and fishery activities,
2. To determine the relationship between stations,
3. To classify water quality variables for spatial differences, and
4. To clarify the impact of pollution sources on water quality variables for the lake dam.

Moreover, the results obtained from this study will provide baseline information for future studies.

2. Material and methods

2.1. Sample location and sampling

Sıddıklı Dam Lake (or Sıddıklı Küçükboğaz Dam Lake, and originally known as Karababa Dam) is a zoned clay and rock-filled dam with a central core on Körpeli Boğaz creek at the border of the Province of Kırşehir Province in Turkey's Central Anatolian region. Construction of the dam began in 1991 and was completed in 2002. The lake dam is of the clay core-rock filling type. It has a surface area of 1.62 km^2, and an active water level of 25.3 hm^3. Built both for business rental as well as to irrigate the region's plains, it was renamed as Sıddıklı Küçük Boğaz Village, where its main crops are cereals. There are alluvial plains and erosion galleries in front of Pliocene fractals and lying mostly around the study area [12]. Generally, this area has a hard summer continental climate, including cold and snowy winters and hot and dry summers. Therefore, the water level fluctuates widely due to irrigation demands and seasonal rainfall levels.

The surface water samples were collected on a monthly bases between September 2015 and August 2016 from 4 different stations. Surface water samples (0–20 cm) were collected in triplicates at each sampling site using a Nansen bottle. Following collection, the samples were placed in coolers with ice boxes upon being transported to the laboratory, and were kept at about 4°C prior to analysis.

2.2. Determination of physicochemical variables

The water temperature, pH, dissolved oxygen, conductivity, total dissolved solid, salinity, and oxidoreduction potential were determined using with equipment of multi-parameter and turbid meter (YSI Pro Plus, WTW-Turb355). Also, nitrite nitrogen was determined using the YSI 9300 photometer, and secchi transparency was determined using a Secchi disc during the sampling period. Physicochemical variables including alkalinity, hardness, total suspended solids, sulphite, sulfate, silica, total phosphorus, orthophosphate phosphorus, total ammonia nitrogen, nitrate nitrogen, ammonium, ammonia, chlorophyll a, and BOD_5 were measured using standard methods [13]. Na and K were determined using flame photometers. The Water Research Center surface water quality index (NSF-WQI) was modified and used for seven parameters of the current situation analysis [14]. Also, the calculations of TSI were followed by calculated using the Carlson's Trophic State Index [15] for the three periods using the following three equations:

$$TSL_{CHL}\,\mu g/L = 10 * \left[6 - \left(2.04 - 0.68 ln(CHL)\right)/ln2\right]$$

$$TSI_{TP}\,\mu g/L = 10 * \left[6 - ln(48/TP)/ln2\right]$$

$$TSI_{SD}\,m = 10 * \left[6 - ln(SD)/ln2\right]$$

$$TSI_{AVG} = \left(TSI_{TP} + TSI_{CHL} + TSI_{SD}\right)/3$$

where TP = total phosphorus (µg/l); CHL = chlorophyll-a (µg/l); SD = Secchi depth (m); TSI-AVG = TSI averaged for all three parameters, and ln = natural logarithm.

2.3. Statistical analysis

Descriptive statistical analysis, including One-way ANOVA with Tukey's multiple range test was done, with a significance of ($p < 0.05$). Also, a nonparametric, one-way analysis of the variance, as well as the Kruskal-Wallis H-test were used to determine a seasonal difference. The relationships between the considered variables were tested using correlation analysis with Pearson's test. Multivariate statistical analysis of the overall water quality variables was performed using principal component and hierarchical cluster analysis (PCA-HCA) [16]. Statistical analysis of the results was carried out using SPSS 21.0.

3. Results and discussion

The annual mean values of physicochemical variables ranged between, for WT: 3.10 and 25.70°C, EC: 0.635 and 1.111 mS/cm, TDS: 0.42 and 1 g/L, pH: 7.35 and 8.52, DO: 4.75 and 15.39 mg/L, salinity: 0.31 and 0.79 ppt, , TAN: 0.110 and 1.408 mg/L, NO_3-N: 0.094 and 2 mg/L, NO_2-N: 0.0031 and 0.037 mg/L, NH_3: 0.001 and 0.102 mg/L, NH_4^+: 0.102 and 1.362 mg/L, silica: 1.3 and 75.5 mg/L, TP: 0.026 and 2.882 mg/L, O-PO_4: 0.033 and 3.710 mg/L, SO_3: 2 and 18 mg/L, SO_4: 25 and 106 mg/L, Na: 8.50 and 16.80 mg/L, K: 0.90 and 18.50 mg/L, alkalinity: 9 and 28.50 mg/L, hardness: 12 and 27.50°F, Chl_a: 0.818 and 4.235 µg/L, turbidity: 0.01 and 49.84 NTU, TSS: 0.42 and 2.16 g/L, BOD_5: 0.10 and 6.12 mg/L, and secchi disc depth: 97 and 275 cm. Spatial changes of all of the physiochemical variables in the surface water are shown in Table 1.

The highest and lowest values of the physicochemical variables were determined according station: WT, pH, alkalinity, hardness, NH_3, Chl_a, BOD_5 and WT, EC, TDS, salinity, TAN, NO_3, NH_3, NH_4, K, TP, O-PO_4, SO_4, alkalinity at Station 1; SD, SO_4, SO_3, O-PO_4 and TDS, salinity, NO_2, SO_3, SO_4, Na, Chl_a at Station 2; EC, TDS, salinity, TSS, TP and DO, SO_4, silica, TSS, NH_3 at Station 3; DO, turbidity, NO_3, NO_2, SO_3, silica, TAN, NH_4, Na, K and TDS, pH, turbidity, SD, hardness, K, BOD_5 at Station 4.

The Turkish surface water quality system is classified into four groups. Class I refers to very clean water, class II refers to less contaminated water, class III refers to considerably contaminated water, and class IV refers to extremely contaminated water [17]. The surface water of the dam lake is in good condition in terms of pH and NO_3-N values according to SWQR. DO and NH_4 and O-PO4 values are generally classified as Class I, however these values are sometimes classified as Class III, II, and IV, respectively. Moreover, the present results indicate that some water quality variables from previous studies which were used for irrigation water in Turkey are also suitable for Sıddıklı Lake Dam, and are demonstrated in Table 2. According to these studies on Turkish freshwater sources, TDS, TSS, turbidity and BOD_5 values were found to be lower compared to those in the present study (Table 2). DO measurement is especially vital for aquatic life. The optimum DO values for good water quality had ranged from 4 to 6 mg/L, which ensures healthy aquatic life in a water body [18]. In this study, minimum dissolved oxygen values were measured at 4.75 mg/L. The results that Kaplan et al. [19] had determined in terms of TDS concentrations (mg/L) in the Perisuyu River were lower than our results. Mutlu and Uncumusaoğlu [20] had found the pH values in the surface water of the Maruf Dam to be in range of 7.71–8.98. In another study, pH values of dam water were found to be in the range of 8.16–8.70 [21]. In similar Turkish studies, the geological structure is generally limy, and the measured pH values demonstrate the slightly alkali character of our lakes [22].

The analysis of Pearson correlation of the physiochemical variables had indicated the absence of positive and good correlation (above 0.7, Table 3). On the other hand, there was less of a significant correlation between some of the variables. The WT had shown significant and positive correlation between sulfate, TSS, and BOD_5 (r = 0.754, r = 0.714, r = 0.880), as well as a negative high correlation between TAN and NH_4 (r = –0.735, r = –0.767). The EC had shown a significant and positive high correlation between TDS and salinity (r = 0.808, r = 0.813). Also, the TDS had shown a significant and positive high correlation with regards to salinity (r = 0.997). The Turbidity had shown a significant and positive correlation between TSS and K (r = 0.885, r = 0.747). The sulfate had shown a significant and positive correlation with BOD_5 (r=0.816). The alkalinity had shown a significant and positive correlation with hardness (r = 0.831). The TAN had shown a significant and positive high correlation with NH_4 (r = 0.998), as well as negative correlation with BOD_5 (r = –0.827). Lastly, NH_4 had shown a significant and negative correlation with BOD_5 (r = –0.848).

Statistical analyzes of 48 samples taken monthly from the four stations were conducted. For the Anova and Kruskal-Wallis H-test analyses, seasonal mean levels (except for TP and SD) were significantly different ($p < 0.05$); however there were no significant differences between stations ($p > 0.05$).

In a PCA analysis comprised of 25 physicochemical variables, seven components were included. These

Table 1
The Sıddıklı Dam Lake water quality variables

Stations	1				2				3				4			
	Mean	SE±	Min.	Max.	Mean	SE±	Min.	Max.	Mean	SE±	Min.	Max.	Mean	SE±	Min.	Max.
WT (°C)	14.60	2.278	3.10	25.70	14.64	2.246	3.10	25.40	14.41	2.179	3.10	23.70	14.16	2.150	3.10	23.10
EC (mS/cm)	0.770	0.039	0.635	1.090	0.792	0.039	0.636	1.093	0.797	0.041	0.660	1.111	0.799	0.038	0.652	1.095
TDS	0.567	0.053	0.416	1.001	0.579	0.052	0.416	0.988	0.582	0.052	0.429	1.001	0.585	0.050	0.423	0.988
Salinity(ppt)	0.43	0.043	0.31	0.77	0.44	0.042	0.31	0.77	0.44	0.042	0.32	0.79	0.44	0.040	0.32	0.77
DO (mg/L)	8.98	0.780	5.76	14.79	9.59	0.770	6.82	14.58	8.75	0.875	4.75	14.83	9.37	0.833	5.80	15.39
pH	8.25	0.080	7.46	8.52	8.28	0.055	7.82	8.50	8.22	0.079	7.40	8.42	8.16	0.082	7.35	8.41
TAN (mg/L)	0.685	0.120	0.110	1.335	0.710	0.103	0.116	1.182	0.667	0.110	0.114	1.207	0.758	0.099	0.347	1.408
NO_3-N (mg/L)	0.273	0.039	0.094	0.605	0.280	0.041	0.139	0.640	0.298	0.055	0.109	0.650	0.433	0.153	0.101	2.000
NO_2-N (mg/L)	0.007	0.001	0.004	0.013	0.008	0.001	0.003	0.015	0.010	0.002	0.004	0.019	0.013	0.003	0.004	0.037
NH_3 (mg/L)	0.037	0.008	0.001	0.102	0.038	0.008	0.002	0.081	0.032	0.005	0.001	0.068	0.030	0.005	0.003	0.064
NH_4 (mg/L)	0.648	0.119	0.102	1.307	0.672	0.103	0.114	1.153	0.635	0.108	0.106	1.160	0.728	0.098	0.323	1.362
Silica (mg/L)	13.55	5.370	1.95	62.50	12.75	4.798	1.45	55.50	13.45	4.966	1.25	57.50	15.36	6.346	1.70	75.50
SO_4 (mg/L)	63.00	6.499	25.00	84.00	69.92	6.642	25.00	106.00	65.17	5.863	25.00	89.00	65.42	5.220	33.00	84.00
SO_3 (mg/L)	11.00	1.022	6.00	17.00	10.42	1.264	2.00	18.00	10.00	1.087	4.00	16.00	10.25	1.426	3.00	18.00
TP (mg/L)	0.170	0.044	0.026	0.467	0.155	0.037	0.048	0.459	0.400	0.234	0.029	2.882	0.234	0.088	0.028	1.112
O-PO_4 (mg/L)	0.752	0.253	0.033	2.573	0.957	0.334	0.055	3.710	0.920	0.294	0.068	3.519	0.833	0.244	0.076	2.849
Alk. (mg/L)	15.45	1.462	9.00	28.50	15.18	1.277	11.50	26.50	15.48	1.336	12.50	28.00	15.68	1.380	11.50	27.50
Hard. (°F)	18.44	1.302	13.80	27.50	17.33	1.021	14.00	24.00	17.90	0.883	14.00	23.50	17.78	1.095	12.00	26.00
Chl_a (µg/L)	2.394	0.248	1.286	4.235	2.396	0.273	0.818	3.998	2.240	0.272	0.883	3.617	2.234	0.251	1.135	3.964
TSS (g/L)	1.04	0.140	0.54	1.68	1.06	0.170	0.44	2.00	0.98	0.158	0.42	2.16	1.01	0.146	0.44	1.60
Na (mg/L)	13.20	0.383	10.90	16.30	13.05	0.585	8.50	16.20	13.55	0.352	11.30	15.30	14.06	0.423	11.30	16.80
K (mg/L)	5.65	1.692	0.90	17.40	3.76	0.790	1.30	10.40	4.46	1.242	1.00	16.60	5.63	1.848	0.90	18.50
Turb. (NTU)	13.70	4.429	0.77	38.75	12.96	4.298	0.10	46.90	13.18	4.297	0.62	44.53	16.04	5.326	0.01	49.84
BOD_5 (mg/L)	3.38	0.567	0.50	6.12	3.38	0.558	0.45	6.10	3.36	0.544	0.44	6.09	3.07	0.543	0.10	5.05
SD (cm)	174.7	15.3	110.0	268.0	171.9	13.1	128.0	275.0	171.6	13.9	118.0	251.3	152.7	14.5	97.0	259.0

Table 2
Comparison of water quality variables in the similar previous studies

	Kralkizi Dam reservoirs, [21]	Groundwater in the Bafra Plain, [23]	Eğirdir Lake, [24]	Küçüksu Pond, [25]	Maruf Dam, [20]	This study
WT (°C)	4.4–27.2		20.8–27.7		14.17–20.8	3.10–25.70
pH	8.16–8.70			7.71–8.98	7.9–8.42	7.35–8.52
DO (mg/L)	6.84–11.40		3.1–11.98	9.30–12.24	9–12	4.75–15.39
Salinity (ppt)				0.040– 0.140		0.31–0.79
TDS (mg/L)		1.342–8.132				420–1001
TSS (mg/L)	0.8–8.6			1.02–9.50	1.2–9.62	420–2160
Hardness (mg/L)	138–200				25.49*	12–27.5
Alkalinity (mg/L)	94–150					9–28.5
Na (mg/L)	2–7.11	257–2514	4.52–13.47	36.42–74.40	37.24–53.88	8.5–16.8
K (mg/L)			0.87–59.13	5.76–18.220	2.473*	0.9–18.5
Turb. (NTU)			0.37–14.2			0.01–49.84
NH_4 (mg/L)			0–1.89	0.0001–0.004		0.102–1.362
NO_2-N (mg/L)	0–0.014		0.019–0.08	0.0005–0.0081		0.003–0.037
NO_3-N (mg/L)	0.002–0.483		0.72–4.23	2.40–13.86	4.21*	0.094–2
O-PO_4 (mg/L)					0.33*	0.033–3.710
BOD_5 (mg/L)				0.360–2.180	2.19*	0.10–6.12

*: mean value.

components were acquired with eigenvalues >1 summing up 84.52% of the total variance in the surface water results. (Table 4, Figs. 2 and 3). The first PC, which accounts for 31.61% of the total variance has a strong positive loadings on WT, SO_4, and BOD_5, a moderate positive loading on Chl_a, and a strong negative loadings on TAN and NH_4. This first factor, which is also known as the "organic pollutant factor", can be based on domestic waste as well as seasonal changes [26].

The second or "ionic" factor, which accounts for 19.18% of the total variance, has a strong positive loading on EC, TDS, and salinity, as well as moderate positive loadings on SD. Soil erosion and precipitation are the natural source of these variables in this region. The third or "pH Factor", in accounting for 10.65% of the total variance, has a strong positive loading on pH and NH_3, as well as strong negative loadings on DO. Seasonal changes are the natural source of these variables within this region. The fourth or the "geological" factor, in accounting for 7.86% of the total variance, has a strong positive loadings on alkalinity and hardness. This situation corrleates with carbonate, bicarbonate and lime deposits in the lake dam bed. The fifth or "agricultural" factor, PC accounting for 6.60% of the total variance, has a strong positive loading on NO_3-N, and moderate positive loadings on NO_2-N, K, and turbidity. This factor represents fertilizer pollution sources, and can explain the high levels of organic nitrogen compounds consuming large amounts of oxygen, which undergoes aerobic processes leading to formation of ammonia and nitrate nitrogen. The sixth or "pesticides" factor, which accounts for 4.58% of the total variance, has a moderate positive loading on sulfide, and strong negative loading on Na. This factor is due to the discharge of pesticides carried by a feeder stream into the dam lake water and, and is a harmful towards certain bacteria. The seventh or "fertilizer" factor, whih accounts for 4.05% of the total variance, has a strong positive loading on TP, and moderate positive loading on silica. The phosphate has its origin in lake dam waters due to the use of phosphatic fertilizers, and because it feeds into a stream that is contaminated with domestic wastewater.

The HCA classifies the four sampling stations into two major clusters (Fig. 4). The first cluster corresponds to station 4. This station is located at the entrance to the river points that feed into the lake dam. The second cluster corresponds to Stations 2, 1, and 3. These sampling stations are situated on the other side of sampling location in this lake dam, and receives its pollution mainly from agricultural run-off and soil erosion.

We should note that the NSF-WQI had been applied in many studies involving fresh water systems [6,9,27]. The NSF-WQI was used to aggregate seven parameters and their dimensions into a single score, in turn showing a picture of the water quality. This index had shown that, according to pH, BOD_5, WT, TP, NO_3-N, turbidity and total solids values, the water quality score was 67 and was deemed as being medium quality water. Lumb et al. [28] had reported that the NSF-WQI index results for seven parameters scenarios at the Don River (Canada) had ranged from 59–78. In another study on NSF-WQI, researchers had revealed that water quality of Golgol river had good or average conditions at all stations at different months [29].

Table 3
Pearson correlations of the physicochemical variables

		WT	EC	TDS	Sal.	DO	pH	Turb.	SD	NO_2–N	NO_3–N	SO_4	SO_3	Silica	Alk.
								$p < 0.01$							
WT		1		–0.422	–0.436	–0.549		0.633		0.553		0.754	–0.219		
EC		–0.285	1	0.808	0.813			–0.603		–0.449	–0.407		–0.465		
TDS				1	0.997			–0.573	0.493	–0.451	–0.392		–0.415		0.255
Sal.					1			–0.582	0.496	–0.454	–0.394		–0.393		
DO			0.302	0.271	0.284	1	–0.702	–0.597		–0.552	–0.351	–0.472			
pH							1		0.465						
Turb.								1		0.633	0.602	0.346			–0.438
SD									1						
NO_2-N										1	0.492	0.371			
NO_3-N		0.295									1				
SO_4												1			
SO_3	$p < 0.05$							0.240					1		
Silica		0.332										0.333		1	
Alk.		–0.283	0.297	0.255	0.274										1
Hard.				0.317						–0.263	–0.259				
TSS															
TP															
O-PO_4							0.330								
TAN							0.312	–0.298		–0.245					
NH_3															–0.273
NH_4							0.274	–0.330		–0.271					
Na						0.247		–0.296	–0.282						0.241
K													0.257		
Chl_a				–0.243	–0.240		–0.322	0.277	–0.269						
BOD_5						–0.319							–0.259	0.242	

Table 3 (Continued)

		Hard.	TSS	TP	O–PO_4	TAN	NH_3	NH_4	Na	K	Chl_a	BOD_5
	$p < 0.05$						$p < 0.01$					
WT			0.714		0.422	−0.735	0.426	−0.767		0.381	0.512	0.880
EC		0.396	−0.575		−0.403		−0.554		0.336	−0.482		
TDS			−0.583		−0.405		−0.382			−0.447		
Sal.		0.338	−0.590		−0.417		−0.411			−0.438		
DO			−0.571		−0.548		−0.668			−0.393		
pH							0.635		−0.367			
Turb.		−0.460	0.885		0.458		0.480	−0.330		0.747		0.416
SD												
NO_2-N			0.616		0.403		0.369			0.523		0.377
NO_3-N			0.521							0.371		
SO_4		0.364	0.401			−0.675		−0.695			0.421	0.816
SO_3						0.362		0.361	−0.512			
Silica				0.357		−0.494	−0.353	−0.476			0.529	
Alk.		0.831	−0.509							−0.418		
Hard.		1	−0.452				−0.361			−0.397		
TSS			1		0.529	−0.450	0.490	−0.484	−0.367	0.650	0.358	0.498
TP				1								
O-PO_4		−0.277			1		0.501			0.362		
TAN						1		0.998			−0.582	−0.827
NH_3							1					
NH_4								1			−0.576	−0.848
Na		0.251							1			
K							.261*		−0.327	1		
Chl_a											1	0.552
BOD_5					0.278							1

Table 4
Varimax rotated factor matrix for the whole data set

Variable	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7
Eigenvalues	7.904	4.794	2.663	1.966	1.649	1.144	1.012
Percentage of variance	31.614	19.175	10.650	7.864	6.596	4.576	4.048
Accumulative %	31.614	50.789	61.439	69.303	75.899	80.475	84.523
	Factor loadings (varimax normalized)						
WT	0.831	–0.301	0.310	–0.134	0.196	–0.153	0.025
EC	0.050	0.770	–0.256	0.193	–0.234	–0.217	0.059
TDS	–0.069	0.916	–0.088	0.139	–0.199	–0.114	–0.073
Salinity	–0.074	0.920	–0.107	0.158	–0.194	–0.086	–0.059
DO	–0.245	0.107	–0.806	–0.070	–0.379	–0.122	0.032
pH	–0.248	0.124	0.860	–0.049	0.045	0.192	0.080
Turbidity	0.348	–0.413	0.285	–0.295	0.615	0.204	–0.081
SD	–0.011	0.662	0.482	–0.177	–0.097	0.239	0.084
NO_2-N	0.247	–0.322	0.392	–0.111	0.585	–0.149	0.172
NO_3-N	0.098	–0.179	–0.024	–0.084	0.871	0.043	–0.041
SO_4	0.782	–0.018	0.316	0.381	0.152	–0.139	0.036
SO_3	–0.306	–0.452	0.019	0.312	0.129	0.654	–0.007
Silica	0.465	0.118	–0.209	0.052	0.087	0.063	0.614
Alkalinity	–0.110	0.083	–0.041	0.951	–0.120	–0.045	0.029
Hardness	0.185	0.203	–0.150	0.865	–0.196	–0.032	0.034
TSS	0.486	–0.392	0.339	–0.381	0.427	0.247	0.117
TP	0.008	–0.103	0.013	0.009	–0.039	0.017	0.917
O-PO_4	0.293	–0.371	0.481	–0.173	–0.014	0.224	–0.297
TAN	–0.936	–0.163	0.120	0.072	–0.137	0.026	–0.103
NH3	0.024	–0.342	0.823	–0.204	0.026	–0.076	–0.230
NH4	–0.944	–0.142	0.069	0.085	–0.140	0.031	–0.089
Na	0.079	0.051	–0.199	0.196	–0.070	–0.877	–0.046
K	0.192	–0.299	0.142	–0.341	0.508	0.327	0.023
Chlorophyll a	0.706	–0.253	–0.284	0.021	–0.003	0.227	0.148
BOD_5	0.920	–0.138	0.129	0.036	0.051	–0.174	–0.110

Extraction method: Principal component analysis.
Rotation method: Varimax with Kaiser normalization.
[a] Rotation converged in 8 iterations.
The factor loadings were classified according to loading values as; "strong (>0.75)," "moderate (0.75–0.50)," and "weak (0.50–0.30)".

4. Conclusion

The use of agricultural fertilizers is believed to increase the nitrogen and phosphorus compound concentrations due to the absence of freshwater plants that might affect the increase in these ion concentrations in the dam lake zone.

In the present study, the surface water quality of the Sıddıklı Lake Dam was analyzed using multivariate statistical analysis, the water quality index, and Carlson's Trophic State Index. The result of cluster analysis was grouped, whereby four sampling sites into two clusters according to similar features. Considering the increase of NH_4, O-PO_4, decrease of DO concentrations were evaluated according to SWQR as a Classes 3–4. Also, the Water Research Center Water Quality Index had shown that the water quality class is medium quality qater. Moreover, Sıddıklı Dam Lake is in a hypereutrophic state as based on the TP, in a hypolimnic state as based on the Chl_a, and in an eutrophic state as based on the SD and mean TSI.

According to the PCA, the nutrient variable, organic pollution, and solid groups are the dominant determinants

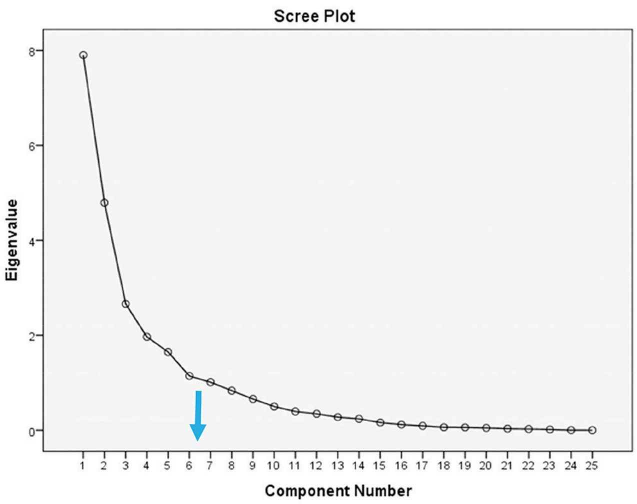

Fig. 2. Scree-plot for the principal component model of the monitoring data.

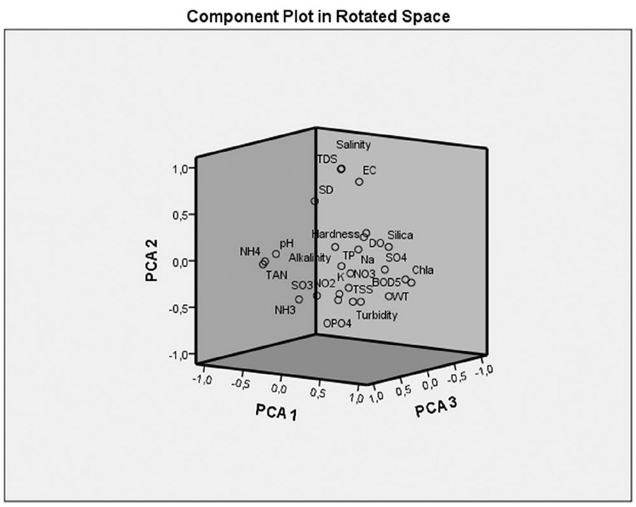

Fig. 3. Component plot.

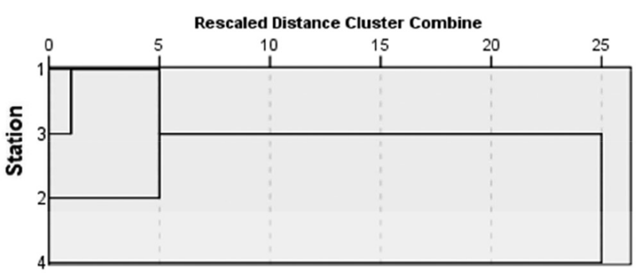

Fig. 4. Dendogram (using Ward Method) shows clusters of variables.

of surface water quality in water bodies. Moreover, a dangerous level of reduction has been observed on the water bodies due to irrigation. It is evident that the anticipatory measures taken by the local governments still remain inadequate. In conclusion, all of our analysis indicate that these important sources need to be monitored regularly. If not, these pollutants can be hazardous both for human health for aquatic organisms in the Sıddıklı Dam Lake, and for agricultural products in irrigated areas.

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