Original Research

Groundwater Quality of Türkmen Mountain, Turkey

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Received: 27 November 2012
Accepted: 19 February 2013

Abstract

This study was carried out to determine the groundwater quality of Türkmen Mountain, which provides drinking water to about 250,000 people, and to evaluate the water quality by using some multivariate statistical techniques. In this study, groundwater samples were collected from 18 stations on Türkmen Mountain in summer 2011. Some lymnological parameters and element levels in groundwater of the mountain were determined. Factor analysis (FA), cluster analysis (CA), and Pearson Correlation Index were applied to the results in order to estimate the data properly. The ArcGIS package program was used to make distribution maps of arsenic, boron, and total phosphorus (which were detected as the most critical parameters of the mountain) in order to provide visual summaries of element accumulations. Also, water samples were evaluated according to the criteria of SKKY (water pollution control regulation in Turkey) and evaluated as drinking water according to the criteria of TS266 (Turkish Standards Institute), the EC (European Communities), and WHO (World Health Organization). It was determined that arsenic accumulations of some stations exceeded the limit values specified by TS266, WHO, and the EC. Significant positive correlations were determined between arsenic and boron levels ($p<0.01$), and according to the FA results, the "Boron Works Factor," which was strongly positive related to the variables of arsenic and boron, was identified as the most effective component for Türkmen Mountain (25.88% of total variance). As a result, in addition to the geological structure of the mountain, mining activities and mineral recovery processes are significant effective factors of groundwater quality of Türkmen Mountain.

Keywords: Türkmen Mountain, groundwater quality, multivariate statistical techniques, ArcGIS

Introduction

Only 2.8 percent of earth's water is fresh and suitable for human consumption, and 30.1% percent of the world's freshwater is groundwater. It was estimated that 50% of total groundwater withdrawals were allocated to drinking water, 20% to industrial supplies, 15% to agriculture, 10% to municipal supplies, and 5% to other uses [1]. Groundwater is an important source of drinking water for many people. Even for many rural and small communities (for almost all the villages and some towns, briefly except for the urban life), groundwater is the only source of drinking water [2].

Rapid growth of the world's population, extreme developments of industry and technology, and lack of environmental awareness in society have caused significant

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decreases of limited freshwater potential of the world [3]. Since the rehabilitation and cleaning of the contaminated water supply is harder and more expensive than protection [4], monitoring of groundwater quality is a necessity both for human and ecosystem health.

Türkmen Mountain is one of Turkey's most important mountain ecosystems. It is located in the eastern part of Kütahya and the southwestern Eskişehir and bordering the Aegean and Central Anatolian Regions. In addition to possessing a high biological diversity, Türkmen also provides the drinking water for Kütahya and Eskişehir provinces. Although Türkmen is situated away from many pollutant factors, mining and agricultural activities adversely affect the groundwater quality of Türkmen.

The aim of this study is to determine the groundwater quality of Türkmen Mountain using some statistical techniques to evaluate the water quality as drinking water.

Material and Method

Study Area and Collection of Samples

Türkmen Mountain is located between the Aegean and Central Anatolian regions of Turkey, and the borders of regions were identified according to varied climatic conditions. Therefore, different climatic conditions are dominant on two slopes of the mountain, and the Aegean region is significantly wetter than the Central Anatolian region. One of the most important boron deposits in Turkey is located on the southeastern part of the mountain. Also, agricultural activities on the suitable topographic areas of the mountain play a significant role on the groundwater quality.

In the present study, groundwater samples were collected in summer season 2011 from 18 stations from the drill fountains of the villages and plateaus (thought to be the most representative regions) located on Türkmen. Altitude and coordinate information and station sites are given in Table 1, and a map of the study area is in Fig. 1.

Groundwater with a volume of three wells was purged before sampling. Groundwater samples were then collected at the outflow of each drillpump in polyethylene bottles.

Table 1. Altitudes and location properties of stations.

Station	Altitude (m)	Coordinates		Location
		latitude	longitude	
T 1	1270	39 30 60 N	30 41 60 E	İkizoluk Village
T 2	1276	39 20 39 N	30 25 18 E	Çürüttüm Village
T 3	1368	39 23 13 N	30 25 06 E	İdris Plateau
T 4	1494	39 23 44 N	30 23 01 E	İkizçeşmeler Fountain
T 5	1323	39 23 16 N	30 21 34 E	Sandıközü Village
T 6	1277	39 20 40 N	30 22 16 E	Göcenoluk Village
T 7	1287	39 18 06 N	30 22 02 E	Makasalanı Village
T 8	1330	39 24 19 N	30 20 46 E	Lütfiye Village
T 9	1430	39 26 59 N	30 20 35 E	Çobanlar Plateau
T 10	1576	39 27 45 N	30 20 01 E	İnli Plateau
T 11	1615	39 26 21 N	30 22 33 E	Gölcük Plateau
T 12	1756	39 26 07 N	30 23 01 E	Türkmenbaba Fountain
T 13	1400	39 24 42 N	30 22 12 E	Güllüdere Village
T 14	1364	39 24 49 N	30 17 31 E	Yumaklı Village
T 15	1224	39 26 18 N	30 12 31 E	Kozluca Village
T 16	1134	39 28 27 N	30 13 03 E	İnli Village
T 17	1195	39 28 01 N	30 14 06 E	Çobanlar Village
T 18	1198	39 28 19 N	30 15 16 E	Bayat Village

Chemical and Physicochemical Analysis

Temperature, conductivity, salinity, TDS (total dissolved solid), pH, ORP (oxidation-reduction potential), chloride, chlorophyll-*a*, percent oxygen saturation, and dissolved oxygen parameters were determined using a Hach Lange Hydrolab DS5 Multiparameter Sonde device during the field studies. Nitrate, nitrite, orthophosphate, sulphate, and COD (chemical oxygen demand) parameters were determined using Hach Lange DR 890 Colorimeter and Hach Lange DR 2800 Spectrophotometer devices.

For determining element levels in groundwater, water samples of one liter that were taken at each sampling point were adjusted to pH 2 by adding 2 ml of HNO_3 into each for determination of all elements except chromium (potassium, sodium, sulfur, magnesium, zinc, arsenic, boron, cadmium, copper, manganese, lead, nickel, and total phosphorus). For determination of total chromium in groundwater, 100 ml samples were transferred to a 250-ml beaker, and 2 ml (1+1) of nitric acid and 1 ml (1+1) of hydrochloric acid were added. Then they put on a hot plate for evaporation to near dryness, making certain that the samples did not boil at 85ºC. Sample volume came down to approximately 20 ml. Afterward, all the samples were filtered (cellulose nitrate, 0.45 μm) in such a way as to make their volumes 50 ml with ultra-pure water.

All the element accumulations in groundwater samples were determined by an ICP-OES (Varian 720 ES) device. Element analysis in water samples was recorded as means triplicate measurements [5, 6]. In the ICP-OES analysis, the following wavelength lines were used; K 766,491 nm, Na 588,491 nm, S 181,973 nm, Mg 383,829 nm, Zn 213,856 nm, As 193,759 nm, B 249,678 nm, Cd 226,502 nm, Cu 324,754 nm, Mn 257,610 nm, Pb 220,353 nm, Cr 205,552 nm, Ni 231,604 nm, and P 214,914 nm.

Statistical Analysis and ArcGIS

Cluster analysis (CA), whose primary purpose is to assemble objects based on the characteristics they possess, is an important group of multivariate techniques. CA classifies objects so that each object is similar to the others in the cluster with respect to a predetermined selection criterion. Hierarchical agglomerative clustering is the most common approach and it provides intuitive similarity relationships between any one sample and the entire data set, and is typically illustrated by a dendrogram that provides a visual summary of the clustering processes [7, 8].

Principal component analysis (PCA) that attempts to explain the variance of a large dataset of intercorrelated variables with a smaller set of independent variables is a powerful pattern recognition tool [16]. Factor analysis (FA) reduces the contribution of less significant variables obtained from PCA and the new group of variables obtained from PCA, and the new group of variables known as varifactors is extracted by rotating the axis defined by PCA. A varifactor can include unobservable, hypothetical, latent variables; while a principle component is a linear combination of observable water-quality variables [9, 10].

ArcGIS is a geographic information system (GIS) for working with maps and geographic information. It is used for developing and using maps, compiling geographic data, analyzing mapped information, sharing and discovering geographic information, and using maps and geographic information in a range of applications and managing geographical information in a database [11].

CA was applied to the results using the "Past" package program. Pearson correlation index and FA were applied to the results using the "SPSS 17" package program. The distribution maps of parameters were made by using the "ArcGIS" package program.

Results

Results of physicochemical parameters, and results of mean element concentration levels and some limit values were given in Tables 2 and 3. Distribution maps made using arsenic, boron, and total phosphorus accumulations of groundwater on the mountain were given in Fig. 2.

According to the criteria of SKKY identified for Turkey (water pollution control regulation in Turkey), Türkmen Mountain has I.-II. class water quality in terms of all physiochemical parameters except dissolved oxygen and pH parameters. T1, T7, T8, and T9 stations have III. class (limit value for III. class is "3-6 mg·L^{-1}"); T3 and T6 stations have IV. class (limit value for IV. class is "<3 mg·L^{-1}") water quality in terms of dissolved oxygen parameter. T10 and T14 stations have III. class (limit value for III. class is "<6.5 and >8.5"); and T9 and T11 have IV. class (limit value for IV. class is "<6 and >9") water quality in terms of pH parameter [12]. According to the limit values specified by TS266 (Turkish Standards Institute), EC (European

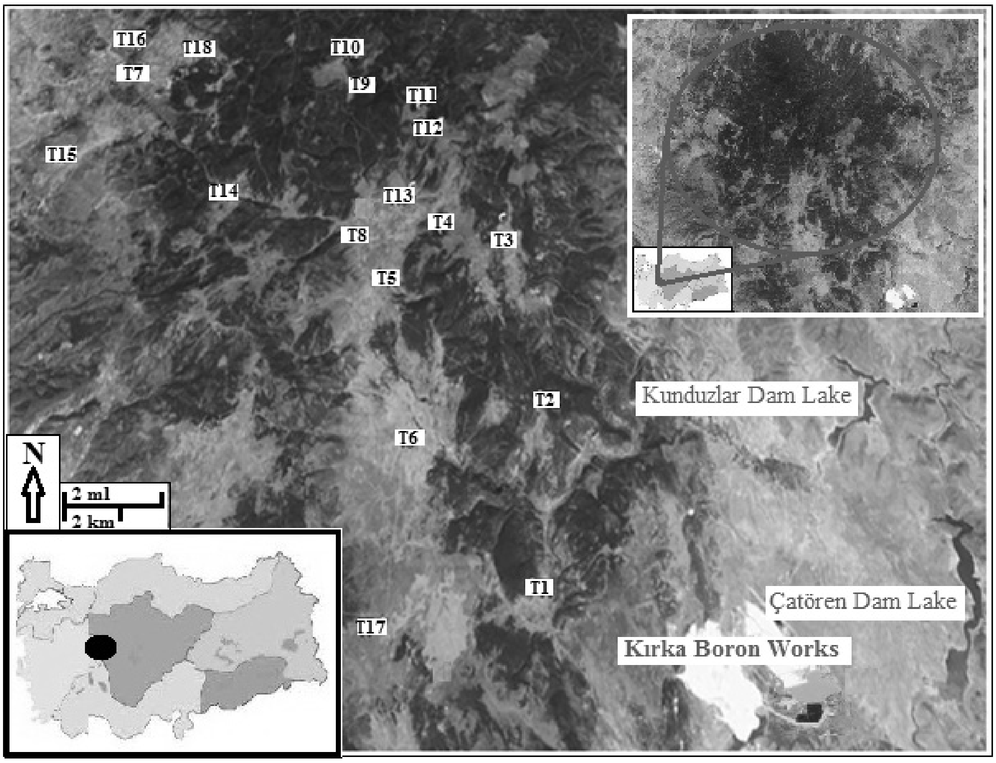

Fig. 1. Türkmen Mountain and sampling points.

Table 2. Results of physiochemical parameters and limit values.

	Temp. (ºC)	Cond. (mS/cm)	Salinity 0%	TDS	pH	ORP	Cl ($mg\cdot L^{-1}$)	NO_3 ($mg\cdot L^{-1}$)	NO_2 ($mg\cdot L^{-1}$)	PO_4 ($mg\cdot L^{-1}$)	SO_4 ($mg\cdot L^{-1}$)	Chl-*a*	COD ($mg\cdot L^{-1}$)	% O_2	O_2 ($mg\cdot L^{-1}$)
T 1	14.54	571	0.29	0.4	6.89	323	39	2.48	0.002	0.32	Nd	0.1	2.42	69.3	5.81
T 2	12.33	637	0.33	0.4	6.76	330	98	3.6	0.004	0.43	Nd	0.16	1.45	76.7	6.76
T 3	12.72	630	0.32	0.4	6.92	322	94	4.37	0.008	0.93	Nd	0.37	2.23	16.8	1.47
T 4	10.52	475	0.24	0.3	7.28	321	94	0.78	0.001	0.37	Nd	0.04	2.46	85.7	7.88
T 5	13.88	531	0.27	0.3	7.53	320	92	5.03	0.005	0.77	Nd	0.36	5.12	82.8	7.04
T 6	12.72	611	0.31	0.4	7.11	322	95	2.4	0.001	0.57	Nd	0.29	3.21	15	1.31
T 7	15.84	546	0.28	0.3	7.03	330	62	1.63	0.004	0.73	Nd	0.07	4.45	65	5.3
T 8	22.45	393	0.2	0.3	7	326	60	0.05	0.005	0.92	Nd	0	6.95	79.8	5.68
T 9	9.21	136	0.06	0.1	5.98	318	398	0.06	0.007	0.9	Nd	0.23	6.8	86.7	8.23
T 10	14.35	79	0.03	0.1	6.43	299	143	0.05	0.004	0.38	Nd	0.13	3.41	86.9	7.33
T 11	11.05	137	0.06	0.1	5.91	324	105	0.16	0.002	0.93	Nd	0.52	9.69	59.4	5.4
T 12	9.44	79	0.03	0.1	6.56	309	65	0.18	0.004	0.51	Nd	0.27	3.4	78.1	7.37
T 13	13.74	145	0.06	0.1	6.74	314	56	0.09	0.006	0.52	Nd	0.27	3.58	88.1	7.53
T 14	13.81	122	0.05	0.1	6.13	331	50	0.06	0.007	0.79	Nd	0.19	3.95	91.9	7.85
T 15	20.12	658	0.34	0.4	7.7	324	64	2.46	0.006	1.36	Nd	0.76	3.05	89	6.63
T 16	14.48	163	0.07	0.1	6.83	315	175	0.14	0.012	0.51	Nd	0.25	5.55	92.2	7.75
T 17	14.77	153	0.07	0.1	7.2	322	65	0.47	Nd	0.2	Nd	0.85	2.1	94.5	7.9
T 18	16.04	580	0.3	0.4	8.06	326	76	0.43	0.002	0.78	Nd	1.81	1.98	91.5	7.43
Limit Values for SKKY Standarts															
I. Class	25				6.5-8.5		25	5	0.002		200		25	90	8
II. Class	25				6.5-8.5		200	10	0.01		200		50	70	6
III. Class	30				6.0-9.0		400	20	0.05		400		70	40	3
IV. Class	>30				<6.0-9.0<		>400	>20	>0.05		>400		>70	<40	<3
Limit Values for Drinking Water Standarts															
TS266		2500			<6.5-9.5<			50	0.5		250				
EC		2500			<6.5-9.5<			50	0.5		250				
WHO								50	0.2						

Nd – not detected, Temp. – temperature, Cond. – conductivity, Chl-*a* – chlorophyll-*a*, SKKY – Water Pollution Control Regulation in Turkey, TS266 – Turkish Standards Institute, EC – European Communities, WHO – World Health Organization

Table 3. Results of element accumulations and limit values.

	K	Na	S	Mg	Zn	As	B	Cd	Cu	Mn	Pb	Cr	Ni	P
	(mg·L^{-1})													
T 1	1.0055	3.5622	1.1865	7.2134	0.0037	Nd	0.0265	Nd	0.0014	0.0003	0.0078	Nd	Nd	0.0669
T 2	5.4014	5.3854	1.9733	7.2134	0.0021	Nd	0.0889	Nd	0.0006	0.0039	0.0075	Nd	Nd	0.1127
T 3	9.3418	8.4815	2.9451	8.9016	0.0017	0.0307	0.0777	Nd	0.0003	0.0059	0.0038	Nd	Nd	0.3007
T 4	0.8568	1.9004	1.7334	10.65	0.0005	0.0039	0.0339	Nd	Nd	0.0002	0.0032	Nd	Nd	0.0632
T 5	3.9107	2.1172	4.7853	16.17	0.0012	0.0312	0.1353	Nd	0.0006	0.0002	0.0014	Nd	Nd	0.1689
T 6	2.3649	4.73	7.6352	15.465	0.0016	0.04	0.1067	Nd	0.0008	0.0007	0.0033	Nd	Nd	0.0551
T 7	3.0701	2.6795	1.856	4.119	0.0019	Nd	0.0324	Nd	0.0004	0.0022	0.0014	Nd	Nd	0.1289
T 8	2.2613	12.217	0.9872	3.3445	0.0027	0.0025	0.0347	Nd	0.0002	0.0056	0.0033	Nd	Nd	0.1744
T 9	7.309	2.4662	4.1512	1.0913	0.0048	Nd	0.0285	Nd	0.001	0.0059	0.0035	Nd	Nd	0.209
T 10	2.1955	2.891	1.679	0.8896	0.0023	Nd	0.0261	Nd	0.0003	0.0011	0.0065	Nd	Nd	0.2654
T 11	2.1419	3.2357	6.8182	1.7835	0.0039	Nd	0.0182	Nd	0.0005	0.0062	0.0047	Nd	Nd	0.0406
T 12	2.1218	2.333	2.5121	1.2165	0.0055	Nd	0.0659	Nd	0.0005	0.0022	0.0044	Nd	Nd	0.1606
T 13	6.9907	3.0698	3.8414	1.8644	0.0043	Nd	0.0113	Nd	0.0002	0.0024	0.0013	Nd	Nd	0.1429
T 14	2.606	4.0979	3.9742	1.5142	0.0038	Nd	0.0321	Nd	0.0004	0.001	0.001	Nd	Nd	0.2192
T 15	2.5789	2.4567	33.502	35.611	0.0041	0.0034	0.0297	Nd	0.0005	0.0037	0.001	Nd	Nd	0.2611
T 16	6.7145	4.0528	5.5672	0.6944	0.0033	Nd	0.0188	Nd	0.0006	0.0016	0.0017	Nd	Nd	0.1252
T 17	1.902	4.0234	3.4368	3.9913	0.0065	Nd	0.0179	Nd	0.0006	0.0011	0.0008	Nd	Nd	0.1889
T 18	6.4216	4.3239	4.5027	32.641	0.0039	0.0168	0.034	Nd	0.0007	0.0013	0.0025	Nd	Nd	0.0353
Limit Values for SKKY Standarts														
I. Class		125			0.2	0.02	1	0.003	0.02	0.1	0.01	0.02	0.02	0.02
II. Class		125			0.5	0.05	1	0.005	0.05	0.5	0.02	0.05	0.05	0.16
III. Class		250			2	0.1	1	0.01	0.2	3	0.05	0.2	0.2	0.65
IV. Class		>250			>2	>0.1	1	>0.01	>0.2	>3	>0.05	>0.2	>0.2	>0.65
Limit Values for Drinking Water Standarts														
TS266		200				0.01	1	0.005	2	0.05	0.01	0.05	0.02	
EC		200				0.01	1	0.005	2	0.05	0.025	0.05	0.02	
WHO						0.01	0.5	0.003	2	0.4	0.01	0.05	0.07	

Nd – not detected, SKKY – Water Pollution Control Regulation in Turkey, TS266 – Turkish Standards Institute, EC – European Communities, WHO – World Health Organization

Communities), and WHO (World Health Organization) for drinking water, all physiochemical parameters detected in Türkmen were suitable for drinking except pH parameter. T9, T10, T11, and T14 stations have acidic character and pH values detected in these stations were outside the range of drinking water limits (limit value for drinking water is "<6.5 and >9.5") [13-15].

According to the criteria of SKKY identified for Turkey, Türkmen has I. class water quality in terms of all inorganic parameters except arsenic and total phosphorus parameters. T3, T5, and T6 stations have II. class (limit value for II. class is "0.02-0.05 mg·L^{-1}") water quality in terms of arsenic accumulations, and T3, T5, T8, T9, T10, T12, and T17 stations have III. class (limit value for III. class is "0.16-0.65 mg·L^{-1}") water quality in terms of total phosphorus accumulations [12]. According to the limit values specified by TS266, the EC, and WHO for drinking water, Türkmen groundwater quality was suitable to use as drinking water in term of all inorganic parameters except arsenic accumulations detected in T3, T5, and T6 stations (limit value for drinking water is "0.01 mg·L^{-1}") [13-15].

Cluster Analysis

Cluster analysis (CA) is a group of multivariate techniques whose primary purpose is to assemble objects based on the characteristics they possess. CA classifies objects so that each object is similar to the others in the cluster with respect to a predetermined selection criterion [8]. CA was applied to the results to classify the stations according to physicochemical status and element contents.

According to the first cluster analysis (CA1) determined by using physiochemical parameters (temperature, conductivity, salinity, TDS, pH, ORP, chloride, nitrate, nitrite, orthophosphate, sulphate, chlorophyll-*a*, COD, % oxygen saturation, and dissolved oxygen); maximum similarity was observed between T3 and T6 stations (99%) and minimum similarities were observed between T3 and T9 stations (57%), and between T6 and T9 stations (%57) (Table 4, Fig. 3).

According to the second cluster analysis (CA2) determined by using element accumulations (potassium, sodium, sulfur, magnesium, zinc, arsenic, boron, cadmium, copper, manganese, lead, chromium, nickel, and total phosphorus), maximum similarity was observed between T9 and T13 stations (93%) and minimum similarity was observed between T10 and T15 stations (18%) (Table 4, Fig. 3).

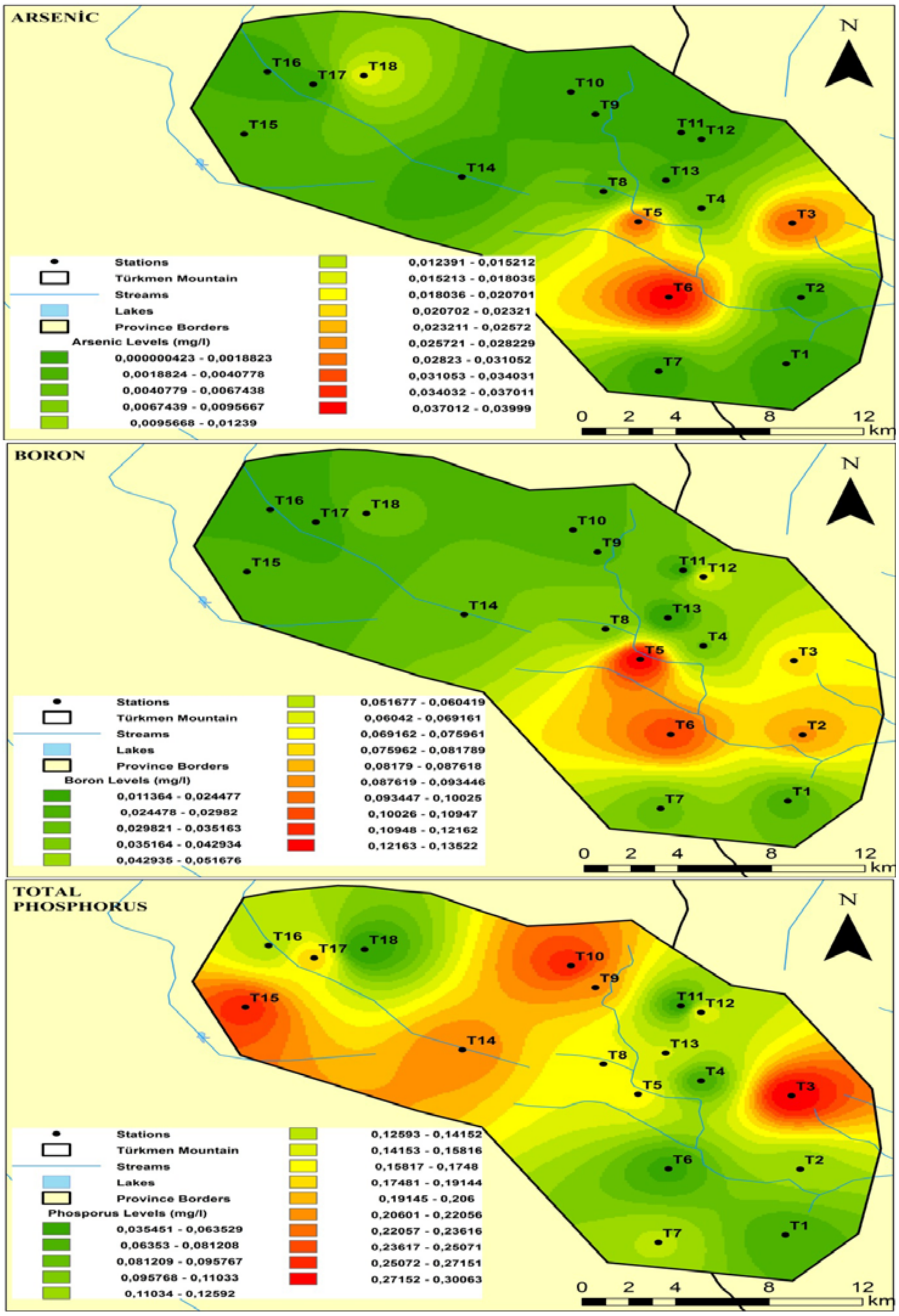

Fig. 2. As, B, and total P distributions in groundwater of Türkmen Mountain.

Table 4. Similarity coefficients (italic numbers for CA1, underlined numbers for CA2).

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	T18
T1	**1.00**	0.79	0.61	0.79	0.58	0.60	0.73	0.56	0.41	0.58	0.54	0.54	0.50	0.58	0.27	0.43	0.74	0.43
T2	0.93	**1.00**	0.80	0.67	0.65	0.65	0.74	0.62	0.63	0.55	0.54	0.55	0.69	0.63	0.30	0.66	0.71	0.56
T3	0.92	0.96	**1.00**	0.60	0.63	0.63	0.57	0.62	0.62	0.42	0.46	0.44	0.65	0.54	0.33	0.62	0.60	0.58
T4	0.91	0.91	0.89	**1.00**	0.72	0.67	0.64	0.42	0.37	0.47	0.43	0.49	0.41	0.44	0.34	0.33	0.59	0.48
T5	0.94	0.94	0.92	0.96	**1.00**	0.86	0.58	0.38	0.54	0.40	0.53	0.46	0.55	0.52	0.51	0.52	0.57	0.71
T6	0.92	0.95	**0.99**	0.89	0.92	**1.00**	0.53	0.46	0.45	0.40	0.63	0.43	0.48	0.56	0.53	0.54	0.61	0.68
T7	0.97	0.93	0.91	0.93	0.96	0.92	**1.00**	0.61	0.64	0.77	0.66	0.76	0.69	0.72	0.26	0.58	0.83	0.39
T8	0.88	0.85	0.82	0.92	0.90	0.83	0.90	**1.00**	0.41	0.53	0.50	0.50	0.48	0.58	0.20	0.45	0.64	0.33
T9	0.58	0.61	**0.57**	0.67	0.65	**0.57**	0.60	0.66	**1.00**	0.64	0.68	0.70	**0.93**	0.75	0.23	0.87	0.63	0.45
T10	0.62	0.64	0.59	0.71	0.68	0.60	0.64	0.71	0.79	**1.00**	0.70	0.88	0.65	0.77	**0.18**	0.61	0.70	0.28
T11	0.69	0.70	0.68	0.76	0.74	0.68	0.72	0.78	0.79	0.88	**1.00**	0.73	0.73	0.82	0.30	0.75	0.75	0.38
T12	0.65	0.64	0.59	0.71	0.69	0.60	0.68	0.76	0.73	0.91	0.88	**1.00**	0.69	0.80	0.20	0.61	0.74	0.29
T13	0.71	0.69	0.64	0.77	0.74	0.65	0.73	0.81	0.77	0.87	0.92	0.92	**1.00**	0.79	0.24	0.87	0.71	0.48
T14	0.70	0.67	0.62	0.74	0.72	0.63	0.72	0.80	0.76	0.86	0.91	0.92	0.96	**1.00**	0.25	0.77	0.85	0.41
T15	0.94	0.96	0.93	0.89	0.92	0.92	0.93	0.86	0.59	0.62	0.67	0.64	0.70	0.68	**1.00**	0.25	0.27	0.69
T16	0.68	0.70	0.65	0.77	0.74	0.66	0.70	0.77	0.85	0.90	0.90	0.83	0.90	0.87	0.68	**1.00**	0.66	0.48
T17	0.72	0.70	0.66	0.78	0.75	0.67	0.74	0.82	0.77	0.86	0.92	0.91	0.97	0.95	0.72	0.91	**1.00**	0.44
T18	0.96	0.95	0.93	0.93	0.96	0.93	0.96	0.89	0.62	0.65	0.70	0.67	0.73	0.71	0.95	0.72	0.75	**1.00**

Correlations

Pearson Correlation Index was applied to the results to determine the relationships between all detected parameters (n=18 for all parameters), and all significant relations are given in Table 5. It was determined that the relations between conductivity-salinity, TDS and NO_3, salinity-TDS, pH-Mg, NO_3-B, % O_2 saturation-dissolved O_2, and As-B in groundwater of Türkmen were directly proportional ($p<0.01$; $r^2>0.75$). Significant negative correlations were determined between altitude of the stations and values of temperature, conductivity, salinity, pH and ORP ($p<0.05$), and dissolved oxygen and As ($p<0.01$). Also, significant positive correlations between nitrate and levels of As and B ($p<0.01$), chlorophyll-*a*, and values of pH ($p<0.05$) and Mg ($p<0.01$) were determined.

Factor Analysis

Factor analysis (FA) is a powerful pattern recognition tool that attempts to explain the variance of a large dataset of inter correlated variables with a smaller set of indepen-

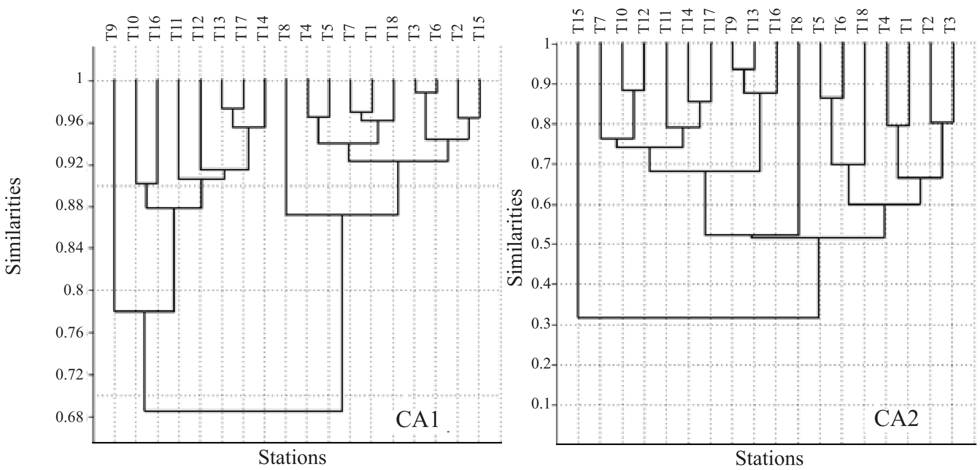

Fig. 3. Diagrams of CA.

Table 5. Statistically significant Pearson Correlation Index coefficients.

	Temp.	Cond.	Sal.	TDS	pH	ORP	NO_3	NO_2	PO_4	Chl. a	O_2 Sat.	O_2	S	Zn	As
Sal.		0.999**													
TDS		0.983**	0.984**												
pH	0.497*	0.676**	0.679**	0.659**											
ORP		0.539*	0.542*	0.496*											
NO_3		0.755**	0.750**	0.697**											
Chl-*a*					0.541*										
O_2 Sat.							-0.485*								
O_2		-0.522*	-0.515*	-0.538*			-0.502*				0.970**				
K								0.622**							
S									0.639**						
Mg		0.681**	0.684**	0.678**	0.801**					0.674**			0.666**		
Zn		-0.560*	-0.556*	-0.528*			-0.519*								
As		0.537*	0.530*	0.528*			0.633**				-0.678**	-0.686**		-0.486*	
B		0.491*	0.488*				0.773**				-0.483*			-0.507*	0.765**
Mn									0.596**						
P								0.500*							
Alt.	-0.534*	-0.499*	-0.497*		-0.564*	-0.506*									

Temp. – temperature, Cond. – conductivity, Sal. – salinity, Chl-*a* – chlorophyll-*a*, Sat. – saturation, Alt. – altitude
*Correlation is significant at the 0.05 level
**Correlation is significant at the 0.01 level

Table 6. Extracted values of various FA parameters.

Component	Extraction sums of squared loadings (unrotated)			Rotation sums of squared loadings (rotated)		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.754	41.096	41.096	3.623	25.880	25.880
2	2.218	15.843	56.939	3.333	23.810	49.690
3	1.953	13.951	70.890	2.170	15.502	65.192
4	1.171	8.366	79.256	1.969	14.064	79.256

dent variables [16]. FA was applied to the results to classify the affected significant factors on the groundwater quality of Türkmen by using correlated variables. Uncorrelated variables were removed to increase the reliability of FA, and a total of 14 variables (altitude, dissolved oxygen, temperature, salinity, conductivity, TDS, pH, NO_2, PO_4, chlorophyll-*a*, As, B, Mg, and total P) were used to determine the varifactors. The results of KMO (Kaiser-Meyer-Olkin) measuring of sampling adequacy test was 0.464, and this value means that the sampling adequacy was enough. Eigenvalues greater than one were taken as criterion for evaluate the principal components required to explain the sources of variance in the data (Fig. 4).

The percentage variance counted, cumulative percentage variance, and component loadings (unrotated and rotated) are given in Table 6. According to rotated cumulative percentage variance, four factors explain 79.25% of the total variance.

The parameter loadings (>0.5) for four components before and after rotation are given in Table 7. According to loading values, Liu et al. [17] classified the factor loadings as: strong (>0.75), moderate (0.75-0.50), and weak (0.50-0.30).

First factor (F1), named as "Boron Works Factor" explains 25.88% of total variance and it is related to the variables of As, B, dissolved O_2, salinity, conductivity, and TDS. As and B were strong positively and dissolved O_2 was strong negatively loaded with this factor, and also parameters of salinity, conductivity and TDS were moderate positively loaded with this factor.

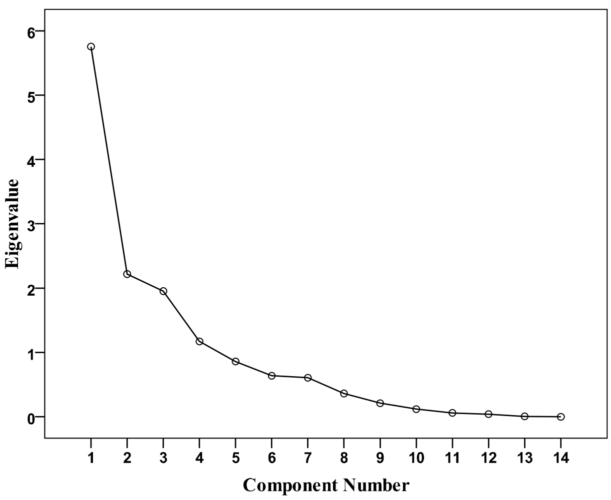

Fig. 4. Scree plot.

The second factor (F2), named "Geographic Factor," explains 23.81% of total variance and is related to the variables of altitude, temperature, salinity, conductivity, TDS, and pH. Altitude was strong negatively and temperature was strong positively loaded with this factor. Also, parameters of salinity, conductivity, TDS, and pH were moderate positively loaded with this factor.

The third factor (F3), named "pH Factor," explains 15.50% of total variance and is related to the variables of chlorophyll-*a*, Mg, and pH. Chlorophyll-*a* and Mg were strong and pH was moderate positively loaded with this factor.

The fourth factor (F4), named "Agricultural Factor," explains 14.06% of total variance and is related to the variables of total P, NO_2, and PO_4. Total P and NO_2 were strong, and PO_4 was moderately positively loaded with this factor.

Disscusion

Dissolved oxygen is one of the most important parameter for monitoring the exchange of the water quality in surface water [18]. The amount of dissolved oxygen in water depends on current temperature, the density of dissolved salt, and biological processes. Solubility of oxygen in water increases with decreasing temperature and salt concentration [19]. Determining significant negative correlations between dissolved oxygen values – salinity, conductivity and TDS values – confirms this information ($p<0.05$) (Table 5). But as it is known, photosynthetic activity limited in groundwater is one of the most effective factors on the dissolved oxygen parameter [20]. So detected low oxygen levels in almost all stations were an expected situation and not a limiting factor for using the groundwater as drinking water.

Geological structure and organic matter of soils are the most important factors effective on pH parameter. Organic matter in soils is degraded by microorganisms, producing high concentrations of dissolved carbon dioxide. This process lowers the pH values by increasing the carbonic acid concentration [21]. In the present study, total phosphorus concentrations detected in T9, T10, and T14 stations, where the groundwater had acidic characteristics, were significantly higher than other stations (Fig. 2). These results

Table 7. Values of component matrix and rotated component matrix.

Parameters	Component matrix				Rotated component matrix			
	F1	F2	F3	F4	F1	F2	F3	F4
As	0.672				**0.861**			
B	0.508	-0.642			**0.852**			
O_2	-0.514	0.553			**-0.793**			
Altitude	-0.563					**-0.801**		
Temperature		0.632				**0.769**		
Salinity	0.940				**0.653**	**0.685**		
Conductivity	0.940				**0.659**	**0.683**		
TDS	0.931				**0.652**	**0.670**		
pH	0.807					**0.653**	**0.550**	
Chlorophyll-*a*				0.596			**0.920**	
Mg	0.821						**0.773**	
P			0.759					**0.796**
NO_2			0.763					**0.784**
PO_4			0.618					**0.716**

reflect that geological structure and organic matter of soil have a combined effect on pH levels of groundwater in Türkmen Mountain.

Mining activities and pesticide applications have an important place for the release of arsenic to the environment from anthropogenic sources [22]. As a result of agricultural activities carried out on the mountain, pesticide applications could be one of the most important factors on arsenic accumulations in groundwater of Türkmen Mountain. Determined significant positive correlations between nitrate and arsenic levels ($p<0.01$) proves this prediction. Arsenic and boron are often correlated as they are both soluble minerals found in hydrothermal-volcanic deposits, and it is known that boron contents of geological structure significantly affect arsenic levels [23]. Determining the highest arsenic accumulations in the stations that were closer to the Kırka Boron Works (Fig. 2), significant positive correlations between arsenic-boron levels and similarity of the distribution of arsenic and boron concentrations on the mountain (Fig. 2) reflect that a prime source of arsenic in the mountain could be mining activities.

The geochemical environment of mountains is quite diverse because of the effects of highly variable climate and many different rock and soil types. Also, the hydrology of mountainous terrain is characterized by highly variable precipitation [21]. As stated before, Türkmen is located in the middle of two different geographical regions and the statistical data observed clearly show the geographic and climatic differences of two slopes of mountain. According to data of cluster analysis, significant distances were determined between the stations, which were located in different regions, especially in terms of element accumulations of groundwater (CA2). Also, the effect of precipitation could clearly be seen from the distribution of total phosphorus across the mountain (Fig. 2).

Detected nutrient levels in mountain groundwater were under the limit values specified by TS266, WHO, and EC [13-15]. As presented in results of factor analysis, agricultural activities carried out on the mountain, given as "Agricultural Factor" in F4, explains 14.06% of total variance, not a very effective component for Türkmen Mountain.

Chlorophyll-*a* (chl-*a*), which can be found in very small quantities in the green sulfur bacteria and anaerobic photoautotroph, is essential for photosynthesis in eukaryotes and cyanobacteria. The molecular formula of chl-*a* is $C_{55}H_{72}MgN_4O_5$ [24] and determined high positive correlation between chl-*a* – Mg ($p<0.01$) in this study was an expected situation. Probably the organisms containing chl-*a* could have passed to the groundwater by interactions with surface water or by precipitation from soil. According to the results of factor analysis, pH could be the limiting factor for chl-*a*-containing organisms on Türkmen (F3).

"Geographic Factor," which explains 23.81% of total variance, also was an effective component for the mountain and it is strongly negative related to the variable of altitude and positive related to the variable of temperature. The hydrology of mountainous terrain also is characterized by water movement over and through steep land slopes. In addition, macropores created by burrowing organisms and by decay of plant roots have the capacity to transmit subsurface flow downslope quickly, and some rock types underlying soils may be highly weathered or fractured and may transmit significant additional amounts of flow through the subsurface. In some settings this rapid flow and movement of water results in many hillside springs in the lower parts of the mountain. The altitude of the water table in the vicinity of these streams at the lower sides of the mountain could be lower than the altitude of the stream water surfaces [21]. Surface water could seep to groundwater at these sides and temperature of groundwater at the lower altitudes of mountain could be affected by the interactions of groundwater and surface water. Solubility of salts in water often is increasing in parallel with the increase of temperature [3]. Determined moderate positive loadings of salinity, conductivity, and TDS with "Geographic Factor" were parallel with this information.

According to the results of factor analysis, the "Boron Works Factor," which explains 25.88% of total variance, was determined as the most effective component for Türkmen Mountain. It is strongly positive related to the variables of As and B and negative related to the variable of dissolved O_2. Turkey has 70% of the total boron reserve of the world, and the most important borat deposits are located in the Kırka county of Eskişehir Province [25], and Kırka Boron Works is located quite closed to the mountain (Fig. 1). As can be understood from the distribution maps of As and B (Fig. 2), in addition to the geological structure of mountain, mining activities and mineral recovery processes are significant effective factors on groundwater quality.

Conclusion

According to data observed and statistical assessments, although Türkmen Mountain seems to have high groundwater quality in terms of almost all physiochemical, chemical, and inorganic parameters, arsenic concentrations of some stations have exceeded the limit values an average of 3-4 times and it was clearly identified that arsenic is the limiting factor to use the groundwater for drinking. Significant positive correlations were observed between arsenic and boron concentrations ($p<0.01$). As can be seen in ArcGIS distribution maps, the boron facility is an effective factor on distribution of boron and arsenic levels in groundwater, and agricultural activities carried out on the mountain affects the total phosphorus accumulations in groundwater. Also, this study presents the necessity and utility of multivariate statistical techniques to assess large and complex databases in order to obtain better information concerning the quality of groundwater and the utility of geographic information systems (GIS) in order to provide visual summaries of data obtained for water quality studies.

Acknowledgements

The authors would like to thank Anadolu University, Turkey for financial and technical support. This investigation was supported by project No. 1101F011 as accepted by Anadolu University, Commission of Scientific Research Projects.

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