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A quality assessment of public water fountains and relation to human health: a case study from Yozgat, Turkey

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Abstract

Public fountains are very common and everyday people appreciate the benefits a water fountain can bring. However, consumption of public fountain water in some country has decreased because of growing concerns that constituents in fountain water may have adverse effects on health. A few studies have examined the safety of public fountains, proposing only limited evidence of fountain-related health issues in Turkey. Most of these public fountains are sourced from natural springs in Turkey. In this study, a 177 fountain water and 32 rock samples were analysed for source and quality of water. The geology of the region has the direct impact on the quality of the public fountain water. The results indicate that the level of some elements exceeded the limit values determined by WHO and US.EPA. The most striking high values were observed for iron (Fe), nickel (Ni), aluminum (Al), arsenic (As) and bromine (Br) concentrations.

Introduction

Drinking water fountains provide free access to high-quality water for the public. Fountains are known to have existed since the early Bronze Age (Juuti *et al*., 2015). They were originally connected to springs or aqueducts to provide drinking water and other human requirements. Advanced hydro technologies, including fountains, were first developed in Crete by the Minoans, in the centre of Europe's first advanced civilization (Mays *et al*., 2007). Later, they were improved and exported to other European and Mediterranean regions by the Mycenaeans, Etruscans, Classical and Hellenistic Greeks, Romans, Venetians and Ottomans (Angelakis and Spyridakis, 2013). As modern municipal water systems developed globally, public water fountains became a fixture of the urban landscape. In the past few decades, however, they have been disappearing from public spaces for a number of reasons, including concern over the health risks of the fountains (Gleick, 2010; Stoner, 2012). A small number of studies have examined the safety of water fountains offering only limited evidence of fountain-related health issues over the past 25 years. In such cases, contamination was traced to microorganisms and heavy metals (Phurisamban and Gleick, 2017).

It is generally recognized that in addition to the major elements such as calcium (Ca), potassium (K), magnesium (Mg), sodium (Na), phosphorus (P) and sulfur (S), there are a number of elements including Co, Cr, Cu, Fe, I, Mn, Mo, Se, V and Zn that are essential for many vital functions (Edmunds and Smedley, 1996). Drinking water is an important source for the daily intake of many essential elements (Baba *et al*., 2008). Trace elements are present in living organisms at very low levels but some of them play key roles in many different biochemical reactions that occur in the human body. A number of such elements are found in fountain water. Certain constituents of the drinking water may have adverse health effects. Epidemiological studies have examined the relationship between the exposure to trace elements and minerals and the occurrence of disease, including reproductive outcomes (Aschengrau *et al*., 1989), certain forms of cancer (Shy and Stroba 1982), rare congenital malformations of the central nervous system (Morton *et al*., 1976; St Leger and Elwood, 1980; Arbuckle *et al*., 1988), cardiovascular disease (Morris *et al*., 1961; Schroeder, 1966; Crawford and Gardner, 1968; Anderson and LeRiche, 1971; Schroeder and Kraemer, 1974) and sudden death (Eisenberg, 1992). Due to the ionic form of waterborne minerals and easy absorption by the gastrointestinal tract, it has been suggested that drinking water may be an important source of mineral intake (Neri *et al*., 1985; Gibson *et al*., 1987; Heany and Dowell, 1994). Industrial activities, including welding, mining, smelting are the other sources of toxic metal exposure (Karakulak *et al*., 2016; Çetintepe *et al*., 2017).

The aim of this study is to determine the quality of public fountain water and its relationship to human health in the Yozgat region which is located in central Turkey. A total of 177 water and 32 rock samples, collected from different parts of Yozgat, were analysed for 55 variables in order to compare their ingredients with the existing national and international standards.

General characteristics of the study area

The study area, where is one of Anatolia's oldest sites of inhabitance, is located in the centre of Turkey (Fig. 1). The local economy is mostly dependent on agricultural and animal husbandry. A limited amount of mining is performed in the region. The morphology of the project area represents general characteristics of mountainous topography. The Yozgat centre is located on the slopes of the Yozgat Creek valley. The average altitude of the Yozgat city is 1070 m amsl.

Yozgat is located in the continental Mediterranean region, where annual precipitation is 538 mm. It is an area of extreme heat, and virtually no rainfall is observed in summer; the Anatolian plateau continental climate is cold in winter and receives heavy, lasting snows. The hottest month averages at 26°C during the day. Winter temperatures can drop as low as −20°C at the height of the season.

Geological and hydrogeological properties of the study area

The geology and mining characteristics of Yozgat region and its environs have been studied by numerous researchers (Paoulo, 1911; Arni, 1936; Pilz, 1936; Lahn, 1939; Baykal, 1943). 1/100.000 scale geology map and a generalized stratigraphic section of the region were prepared by the General Directorate of Mineral Research and Exploration (MTA). Magmatic and sedimentary rocks outcrop in the study area (Fig. 2). The basement of the study area includes gabbro and granite. Gabbro consists of dark green, black coloured, coarse in the lower parts, and micro-grained gabbro in the upper parts. In general, plagioclase and mafic mineral composition is seen in gabbro. The plagioclases are in the form of self-shaped andesine [$(Ca, Na)(Al, Si)_4O_8$] and labradorite [$CaNa(Al, Si)AlSi_2O_8$]. Mafic minerals are self-formed pyroxene and slightly opaque formations can be seen in the south and east of Yozgat (Bilgin *et al*., 1986). The chemical composition of minerals in pyroxene consists of Al, Ca, Cr, Mg, Mn, Li, Fe, Na, Si and Ti. Granite is primarily composed of feldspar and quartz along with various other minerals and includes Al, K, Fe and Mg.

The volcanic unit consisting of dacite, basalt and latite developed in the marginal zones of the Central Anatolian granitoids composed of composite veins and surface rocks. The crystalline glassy tuff in the unit is composed of lithic crystal rhyodacitic tuffs containing primary quartz, dissociated plagioclase microlites and mafic minerals. The gas cavities are filled with calcite and chlorite. The crystal glass fragments are chloritized and fused. The dough is albitized and carbonated. The rocks are unconformably overlain by sediments which are composed of limestone, pebbles and sandstones. These rock-types tend to have very limited primary porosity and permeability with more reliance on structural discontinuities to capture water. In addition, the absence of significant primary porosity tends to mean that sustainable yields are typically low. In contrast, the recent sediments that blanket the valley bottoms in the study area frequently have a noteworthy porous matrix that yields significant groundwater. In general, the main limestone aquifers in the region supply the domestic water requirements. The lithological characteristics of the region have a strong influence on the surface and groundwater quality in the study area. The volcanic units generally consist of dacite and basalt and are widely distributed north of the study area. Although this unit is extensively jointed and fractured, its water-bearing potential is low and the yields typically range from 0.01 to 1 L/s. In addition, most of the springs can be seen in limestones which are located near the centre of the region. The existing springs come to the surface as a groundwater resource in a variety of places. The public fountains were constructed by people to utilize these springs.

Material and method

During 2017, 177 fountain water samples were collected around the Yozgat region. Figure 3 shows the locations of the water fountain. The method given by the American Public Health Association (APHA, 1992) was used to collect water samples. The collected water samples were divided into two groups: (i) heavy metal ions and (ii) major ions.

All water samples were placed in sterile containers of 100 ml and stored in a refrigerator prior to completing related analyses at Bozok University Technology Application and Research Center, Yozgat, Turkey. The

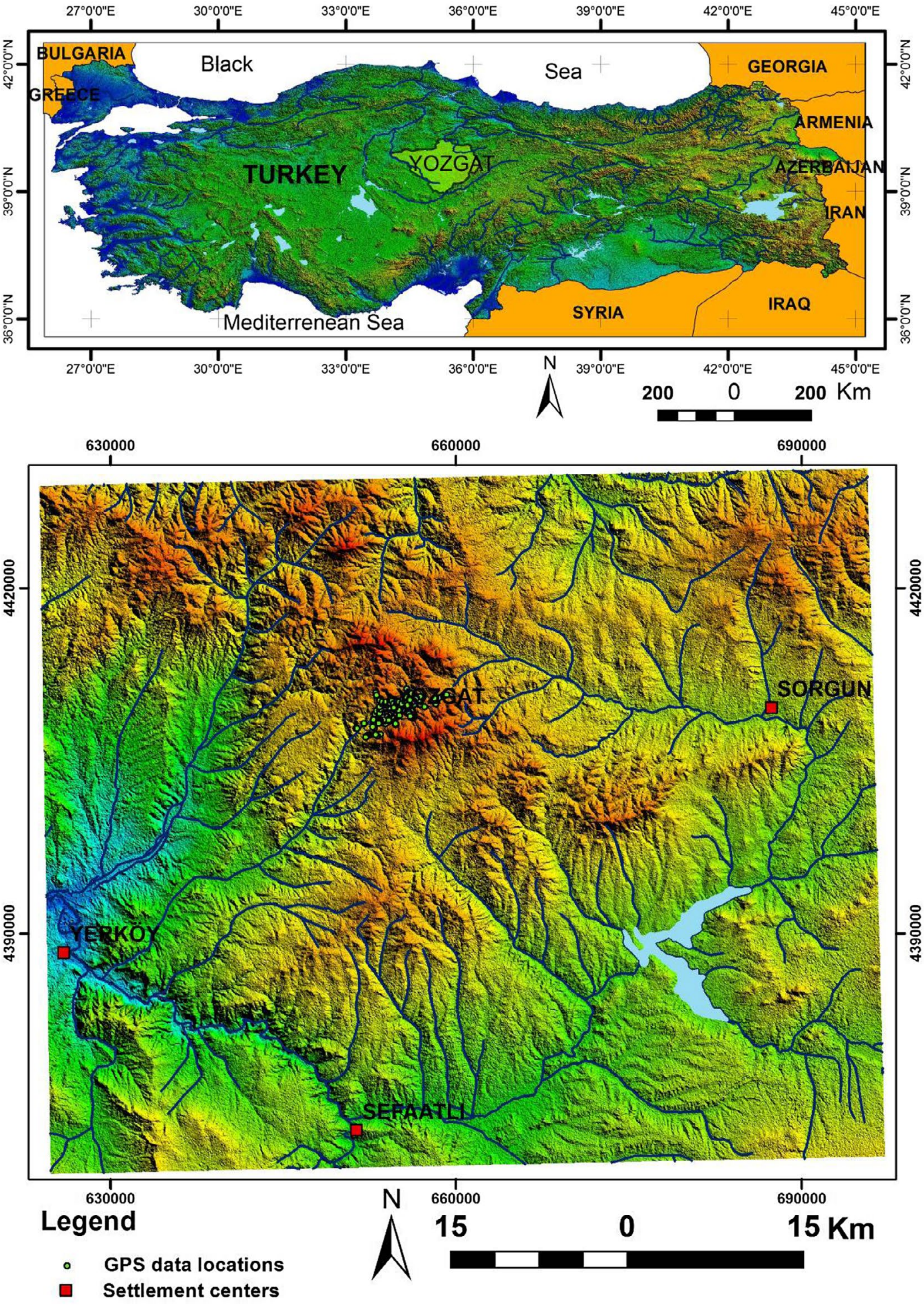

Fig. 1. Location map of the study area. [Colour figure can be viewed at wileyonlinelibrary.com]

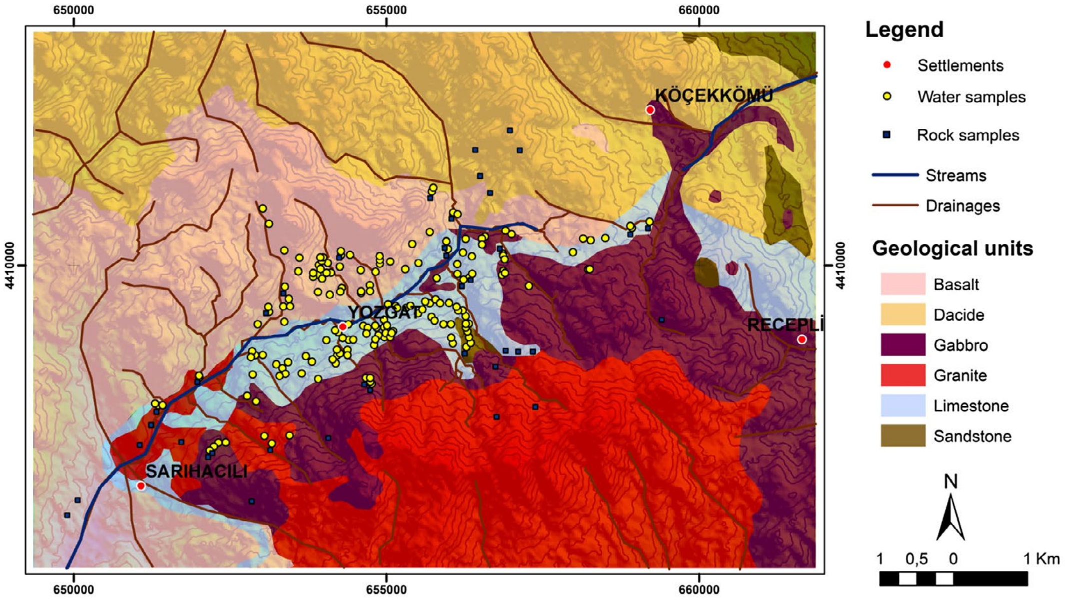

Fig. 2. Geological map of the study area (modified from MTA, 2007). [Colour figure can be viewed at wileyonlinelibrary.com]

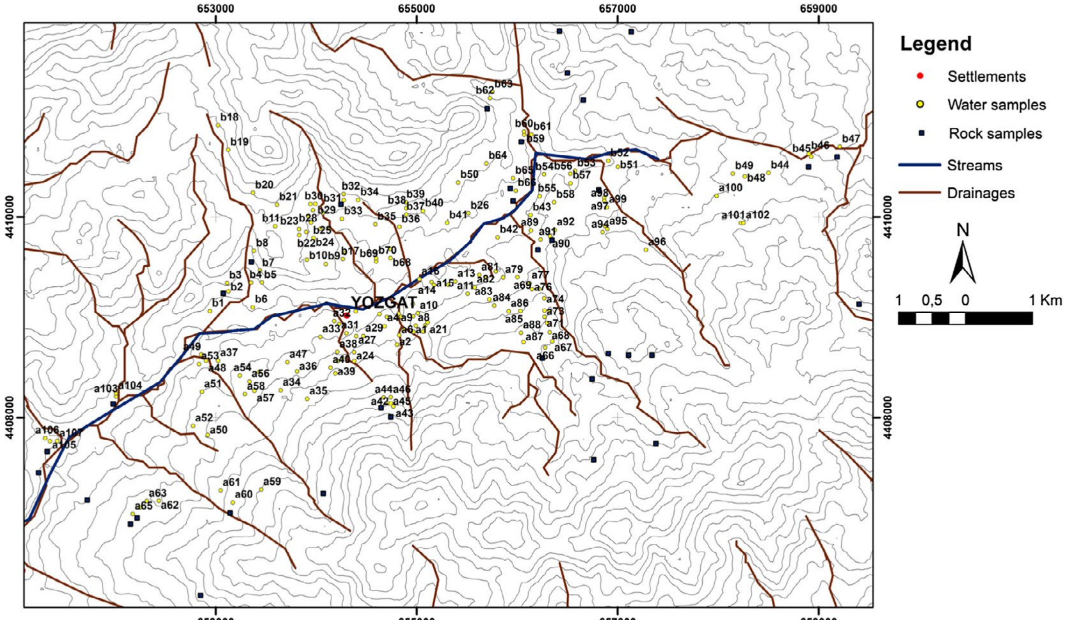

Fig. 3. Sample location map. [Colour figure can be viewed at wileyonlinelibrary.com]

100 ml samples of water were used for determination of the selected variables. The water samples for ICP MS analysis were usually made up in 2% w/v HNO_3 prepared with ultrapure water. However, water samples for IC analysis used directly. The cations and elements Ag, Al, As, B, Ba, Be, Br, Ca, Cd, Cl, Co, Cr, Cu, Fe, Hg, K, Li, Mg, Mn, Mo, Na, Ni, Pb, Sb, Se, Tl, U, V and Zn were measured with the Inductively Coupled Plasma Mass Spectrometry (ICP-MS) (Thermo Scientific ICAPQc) technique. The regression line was produced using 11 different standards prior to analyses of the samples. At least 99.5% regression coefficient was achieved prior to readings.

Three replicates were read for each sample analysed and their mean value was taken into account for the final assessment.

In addition, a total of 32 rock samples taken from the granites, gabbro, dacites, basalts and limestones in the region were numbered and brought to the laboratory. In the laboratory, these samples were first made into small pieces in the crusher and then milled. The obtained material was analysed by adding 3 ml of HNO_3 and 6 ml of HCl. The elements Ag, Al, As, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Li, Mg, Mn, Mo, Na, Ni, Pb, Sb, Se, Th, U, V and Zn were measured with the ICP-MS technique. All rock samples were analysed at Bozok University Technology Application and Research Center, Yozgat, Turkey.

Ion chromatography (IC) (Thermo Scientific Dionex ICS-5000) was used for anion and cation measurements in water. Also, F, NH_4, NO_2, NO_3, PO_4 and SO_4 of each sample was measured at the laboratory. Ionic strength was computed using major ion concentrations expressed as molality.

Upon completion of data control and correction, the results of the study were analysed with the Statistical Package for the Social Sciences (SPSS) program (SPSS ver. 20, Chicago, IL, USA). Chi-square goodness-of-fit, Student's *t*-test and variance analysis were used in statistical analysis of the data. The *P*-values below 0.05 were accepted as significant for all statistical analysis.

Results and discussion

Mineral concentrations of the fountain water vary between districts in Yozgat and even among different water sources within the same district. The quality of spring water which feeds a fountain is a combination of a number of factors, such as hydrogeological and geological properties and anthropogenic stresses that are effective in the study area. In particular, water–rock interactions are among the primary factors that create local and temporal changes in the overall quality of water resources (Baba and Gunduz, 2017). The results of the water quality monitoring campaign from all the fountains are shown in Table 1.

Statistical parameters of random samples taken from gabbro (6), granites (7), basalts (5) and dacites (5) and limestones (4) are given in Table 2. The variation ranges of gabbros (except B, Ba, Ca, Mg, Na, Se and V), basalts (except Al, As, B, Cr, Hg, Mo, Pb and Sb), dacites (except Mn) and limestones (except Cr, Cu, Hg, Na, Ni, Sb and Th) and As, Be, Mo, Se, U and V elements in granites are very small. Therefore, it is remarkable that the standard deviations are very small according to the arithmetic mean. This suggests that the composition of gabbros, granites, basalts, dacites and limestones is quite uniform (Table 2).

The pH values of all water samples ranged from 7.6 to 8.7 with an overall mean value of 8.2 that represented the basic nature of the fountain water in the study area. In general, some trace element concentrations in the study area were found to be high. Widespread and intense zones of alteration in the study area can be observed in volcanic rocks. These alteration zones give rise to distinct mineral forms. In general, Fe, Mg, Ca and Ni were enriched in alteration areas. Overall, the iron levels in the study area ranged from 204.57 to 3011.38 µg/L with an overall mean of 903.71 µg/L (Table 1). The spatial distribution of iron in the study area is given in Fig. 4. The iron levels of the study area ranged from 0.003 to 1.19 ppm with an overall mean of 0.77 ppm (Table 2) in the basalt and ranged from 1.11 to 5.97 mg/kg with an overall mean 2.68 mg/kg in the dacite. The presence of the high iron concentration in water is a direct result of the volcanic rocks.

Iron is an essential element for human nutrition. Estimates of the minimum daily requirement for iron range from about 10 to 50 mg/day depending on age, sex, physiological status and iron bioavailability (FAO, 1988). No health-based maximum concentration guideline is proposed for iron (WHO, 2011).

The chromium values obtained from all fountains are shown on the Fig. 5. The results are within the maximum limits allowed in international drinking water quality standards (Fig. 5). The concentration of chromium ranged from 15.2 to 49.72 µg/kg (mean 26.85) in the gabbro, 0.05 to 1.26 µg/kg (mean 0.44) in the granite, 0.03 to 1.85 µg/kg mean (0.49) in the basalt, 5.93 to 10.34 µg/kg (mean 7.43) in the dacite and 5.32 to 196.38 µg/kg (mean 56.34) in the limestone (Table 2). Chromium concentrations are generally lower in geological rocks of study area. Therefore, the leaching of chromium to water is small.

The concentration of nickel (Ni) ranged from 1.74 to 210.64 µg/L with an overall mean of 43.35 µg/L (Fig. 6). Nickel, which comes from volcanic rocks, is a very abundant natural element. Nickel concentrations in groundwater depend on the soil type and pH. One hundred and eleven fountains have high concentrations of nickel. The guideline maximum value for nickel is 20 µg/L which would be considered protective for nickel-sensitive individuals. In our study, about 34% of samples nickel concentration exceeds the WHO limits (Ni = 70 µg/L). The nickel levels in the study area ranged from 0.03 to 1.85 µg/kg with an overall mean of 0.49 µg/kg in the basalt and ranged from 5.93 to 10.34 µg/kg with an overall mean 7.43 µg/kg in the dacite (Table 2).

Table 1 The concentration of physical and chemical properties of the fountain's water in the study area (µg/L and *mg/L)

Elements	Mean	Std. Dev.	Median	Minimum	Maximum	WHO limits	TSI limits	EPA limits	*t*	*P*
pH	8.212	0.185	8.200	7.60	8.70	6.5–8	6.5–9.5	6.5–8.5		
Ag	4.915	1.441	5.288	1.161	6.891	–	–	100	–877.954	0.000
Al	26.241	40.064	14.817	0	259.303	200	200	200	–57.701	0.000
As	1.526	2.146	0.967	0.004	17.139	10	10	10	–52.525	0.000
B	127.424	135.656	67.587	18.496	938.618	2400	1000	–	–222.878	0.000
Ba	79.49	110.97	33.35	1.65	729.07	700	–	2000	–74.396	0.000
Be	0.004	0.016	0	0	0.171	–	–	4	–160.667	0.000
Br	4.015	30.941	0.002	0	310.042	10	10	10	1.512	0.132
Ca	55.696	32.681	48.105	6.676	231.051	–	–	–	–7.858	0.000
Cd	0.139	0.067	0.134	0	0.359	3	5	5	–564.826	0.000
Cl	32.102	38.432	16.56	1.44	272.321	250*	250*	250*	–75.430	0.000
Co	1.654	1.249	1.298	0.173	6.85	–	–	–	–35.634	0.000
Cr	10.602	6.912	8.251	0.557	35.609	50	50	100	–75.883	0.000
Cu	4.059	7.384	2.105	0.313	67.433	2000	2000	1300	–3596.138	0.000
F	0.121	0.091	0.105	0.034	0.872	1.5*	1.5*	2*	–202.133	0.000
Fe	903.712	448.415	789.246	204.572	3011.38	–	200	300	20.879	0.000
Hg	0.133	0.158	0.078	0	0.86	6	1	2	–364.529	0.000
K	0.123	0.311	0.055	0.004	3.924	–	–	–	–508.386	0.000
Li	4.19	11.867	1.707	0.182	122.906	–	–	–	–219.525	0.000
Mg	31.089	15.817	28.279	2.918	78.695	–	–	–	–15.906	0.000
Mn	10.588	87.869	1.83	0.024	1170.593	–	50	50	–58.960	0.000
Mo	0.485	1.997	0	0	18.628	–	–	–	–463.076	0.000
Na	28.448	30.54	17.327	5.34	208.172	200*	200*	20*	–74.733	0.000
Ni	43.354	40.313	27.72	1.74	210.642	70	20	–	–8.794	0.000
Pb	0.679	2.764	0.301	0	32.542	10	10	15	–44.871	0.000
Sb	0.1	0.076	0.085	0.012	0.613	20	5	6	–3488.834	0.000
Se	3.036	1.244	3.005	0.099	9.558	40	10	50	–74.461	0.000
Tl	0.014	0.05	0.003	0	0.403	–	–	–	–524.203	0.000
U	2.871	2.305	2.524	0.053	12.116	30	–	–	–156.559	0.000
V	13.077	10.471	10.803	0	50.874	–	–	–	–110.438	0.000
Zn	41.419	157.289	4.153	0.494	1570.399	3000	5000	5000	–419.416	0.000
NH_4	0.002	0.008	0	0	0.096	–	0.5*	–	–791.254	0.000
NO_2	0.001	0.005	0	0	0.04	3*	0.5*	1*	–1395.986	0.000
NO_3	16.258	18.657	8.96	0	95.722	50*	50*	10*	–24.061	0.000
PO_4	0.01	0.053	0	0	0.536	–	–	–	–248.740	0.000
SO_4	53.005	54.99	36.07	0	422.68	500*	250*	250*	–35.566	0.000

The upper limit values of the WHO/EPA are given on the table. In addition, limit values determined by TSE (Turkish Standards Institution) are shown (Republic of Turkey Ministry of Health, 2005; Republic of Turkey Ministry Of Forestry and Water Affairs, 2012; WHO, 2017; US.EPA, 2018).

Chromium (III) compounds are classified as 'Group-3' and chromium (VI) compounds are classified as 'Group-I' carcinogenic substances according to the International Agency for Research on Cancer (IARC) classification. The relationship between chromium (VI) compounds and respiratory tract and lung cancer formation has been identified (IARC, 2018). The epigenetic effects of nickel and chromium were also determined by Chervona *et al*. (2012).

Aluminium (Al) is the most abundant metal in the earth's crust in the form of various compounds (oxygen, fluorine, silica, etc.). Small amounts of aluminium can be found dissolved in water. Most of the springs in the study area surface from the volcanic rocks. The aluminium levels in the study area ranged from 0.002 to 2.26 mg/kg (mean 0.74) in the basalt and 0.15 to 7.83 mg/kg (mean 4.12) in the dacite (Table 2).

The concentrations of aluminum (Al) in these springs ranged from 0 to 259.30 µg/L in this region (Fig. 7). Five fountains have high levels of Al that exceed the maximum allowable limits (200 µg/L) in the international standards for drinking water quality. There are studies reporting the neurotoxic effect of aluminium production, including high Al levels in the pathophysiology of Alzheimer's disease and it is defined as Group-I carcinogenic by the IARC (2018; Marques *et al*., 2014; Xu *et al*., 2018).

Arsenic (As) is a heavy metal with various dangerous health effects. It is classified as a Group-I carcinogen by the IARC. Chronic arsenic exposure is known to cause

Table 2 The concentration of the rock samples in the study area (µg/kg and *mg/kg)

	Gabbro					Granite					Basalt				
	Mean	Std. Dev.	Median	Minimum	Maximum	Mean	Std. Dev.	Median	Minimum	Maximum	Mean	Std. Dev.	Median	Minimum	Maximum
Al	3.79	2.78	4.06	0.47	7.07	0.17	0.42	0.01	0.0003	1.12	0.74	0.90	0.61	0.002	2.26
Ag	0.14	0.13	0.11	0.01	0.31	0.08	0.14	0.02	0	0.38	0.01	0.01	0.01	0	0.03
As	2.18	1.45	2.11	0.07	4.01	0.39	0.35	0.50	0	0.97	0.28	0.40	0.15	0	0.99
B	0.30	0.32	0.21	0.03	0.86	6.07	7.72	0.38	0.02	17.67	0.18	0.24	0.07	0.02	0.58
Ba	3.14	3.54	1.89	0.6	9.96	1.09	1.67	0.31	0	4.45	1.09	1.04	0.68	0.01	2.4
Be	5.69	2.76	5.49	1.17	9.1	0.01	0.01	0.01	0	0.01	0.01	0.01	0.01	0	0.02
Ca	85.4	91.2	63.3	8.9	254.7	0.3	0.51	0.05	0.003	1.33	0.64	0.59	0.66	0.003	1.53
Cd	27.7	26.0	22.0	4.2	71.8	0.1	0.08	0.03	0.01	0.21	0.04	0.04	0.03	0	0.1
Co	130.8	64.2	146.1	14.9	209.1	0.26	0.39	0.17	0	1.12	2.52	1.97	2.69	0.01	5.29
Cr	26.85	13.29	20.47	15.2	49.72	0.44	0.46	0.15	0.05	1.26	0.49	0.77	0.21	0.03	1.85
Cu	223.2	201.3	196.5	52.9	612.8	3.52	5.58	0.54	0	12	0.66	0.56	0.98	0.01	1.12
Fe	7.04	3.59	8.00	2.35	10.89	0.10	0.14	0.03	0.001	0.39	0.77	0.46	0.85	0.003	1.19
Hg	9.56	3.83	10.82	4.76	13.37	0.33	0.49	0.17	0.04	1.42	1.49	1.95	0.80	0.21	4.95
K	20.85	19.15	10.57	6.01	52.73	2.89	3.19	2.12	0.24	9.61	3.51	2.18	4.20	0.64	6.07
Li	8.55	3.19	8.35	4.94	13.18	19.07	37.50	0.05	0.01	99.08	0.29	0.23	0.41	0	0.52
Mg	29.76	35.87	17.28	4.78	101.6	0.11	0.15	0.02	0.0003	0.4	0.44	0.39	0.39	0.0004	0.89
Mn	51.0	29.0	54.2	2.8	85.7	3.0	4.4	0.5	0.01	11.9	14.7	11.9	19.6	0.01	26.2
Mo	169.1	99.8	183.3	3.2	301.6	0.09	0.09	0.06	0.02	0.29	0.19	0.26	0.08	0.03	0.65
Na	1.63	1.96	1.02	0.15	5.42	0.28	0.59	0.07	0	1.61	0.08	0.07	0.10	0	0.16
Ni	0.13	0.07	0.10	0.08	0.26	1.13	1.44	0.32	0.18	3.56	0.50	0.27	0.51	0.2	0.84
Pb	0.08	0.07	0.06	0.03	0.21	0.64	0.68	0.19	0.07	1.67	0.22	0.23	0.15	0.06	0.63
Sb	0.20	0.19	0.14	0.04	0.49	0.00	0.01	0.00	0	0.02	0.00	0.01	0.00	0	0.02
Se	15.28	15.68	6.32	2.87	38.72	1.68	1.37	1.24	0.21	4.25	1.69	1.05	1.67	0.65	3.1
Th	5.84	2.35	6.13	1.89	8.85	0.02	0.03	0.01	0	0.09	0.21	0.21	0.25	0	0.5
U	2.66	1.29	2.99	0.38	3.89	0.01	0.01	0.01	0	0.01	0.02	0.02	0.03	0	0.04
V	0.88	0.99	0.42	0.03	2.38	1.86	1.69	1.85	0.03	4.84	3.29	1.96	3.81	0.03	5.26
Zn	0.38	0.23	0.50	0.02	0.58	8.12	12.24	2.32	0.06	34.06	11.89	10.36	12.57	0.1	26.57

	Dacite					Limestone				
	Mean	Std. Dev.	Median	Minimum	Maximum	Mean	Std. Dev.	Median	Minimum	Maximum
Al	4.12	2.74	4.03	0.15	7.83	9.90	5.40	11.60	2.12	14.3
Ag	0.12	0.01	0.12	0.11	0.13	0.10	0.03	0.10	0.07	0.13
As	39.26	5.33	39.50	32.61	46.37	50.31	16.27	51.36	29.39	69.12
B	2.40	1.05	2.61	1.16	3.72	2.66	1.37	2.60	1.13	4.32
Ba	34.1	28.9	32.9	1.4	66.9	19.3	17.5	17.7	3.0	38.8
Be	0.19	0.16	0.22	0.01	0.42	0.22	0.08	0.22	0.13	0.31
Ca	0.57	0.52	0.48	0.15	1.46	14.58	10.99	16.76	0.18	24.63
Cd	0.02	0.01	0.02	0.01	0.03	0.08	0.09	0.05	0.02	0.21
Co	35.96	18.09	29.99	18.32	60.95	20.30	5.80	19.02	14.72	28.42
Cr	7.43	1.79	6.62	5.93	10.34	56.34	93.43	11.82	5.32	196.38
Cu	1.66	1.02	1.49	0.55	3.34	6.83	7.27	5.50	0.64	15.66
Fe	2.68	1.91	2.21	1.11	5.97	10.62	4.64	11.49	4.56	14.92
Hg	36.67	29.77	22.80	11.28	79.06	11.39	15.14	5.84	0.43	33.44
K	159.1	127.4	179.8	3.9	301.6	126.8	103.4	110.6	20.2	266.0
Li	2.44	1.38	2.54	0.32	4.08	11.95	11.88	9.43	2.15	26.81
Mg	0.43	0.34	0.36	0.05	0.98	2.62	2.52	1.77	0.77	6.19
Mn	55.1	61.8	45.5	4.2	155.1	364.7	251.1	248.9	220.6	740.5
Mo	0.88	1.02	0.24	0.07	2.35	0.36	0.20	0.35	0.15	0.6
Na	0.38	0.25	0.44	0.02	0.66	0.57	0.76	0.29	0.02	1.68
Ni	1.42	0.61	1.35	0.95	2.45	11.61	15.52	5.54	0.74	34.63
Pb	4.43	2.90	3.71	1.25	8.95	2.46	2.26	1.53	0.96	5.82
Sb	0.04	0.02	0.05	0.01	0.07	0.09	0.10	0.05	0.02	0.23
Se	133.4	21.5	125.3	112.5	161.6	170.3	57.8	167.0	103.3	243.8
Th	4.45	3.54	4.90	0.36	8.67	3.23	3.79	2.11	0.03	8.66
U	0.65	0.60	0.51	0.07	1.38	0.52	0.51	0.31	0.17	1.28
V	171.69	24.96	165.20	147.04	199.72	184.15	43.88	188.91	135.27	223.5
Zn	7.04	3.99	6.88	3.48	13.23	22.02	3.49	22.94	17.13	25.05

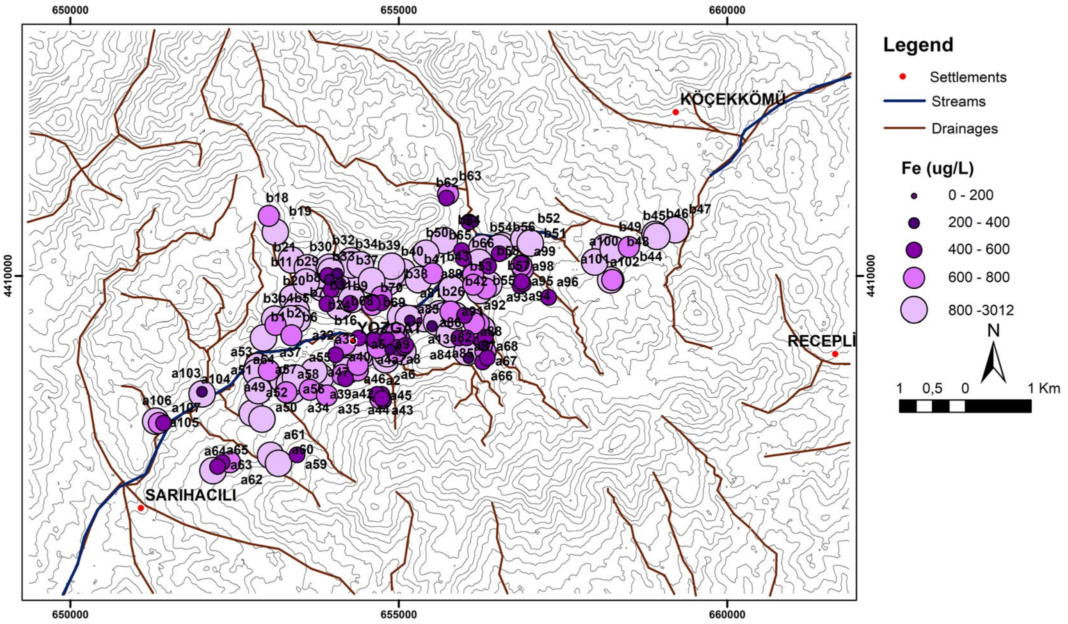

Fig. 4. Spatial distribution of iron (Fe) in the public water fountains. [Colour figure can be viewed at wileyonlinelibrary.com]

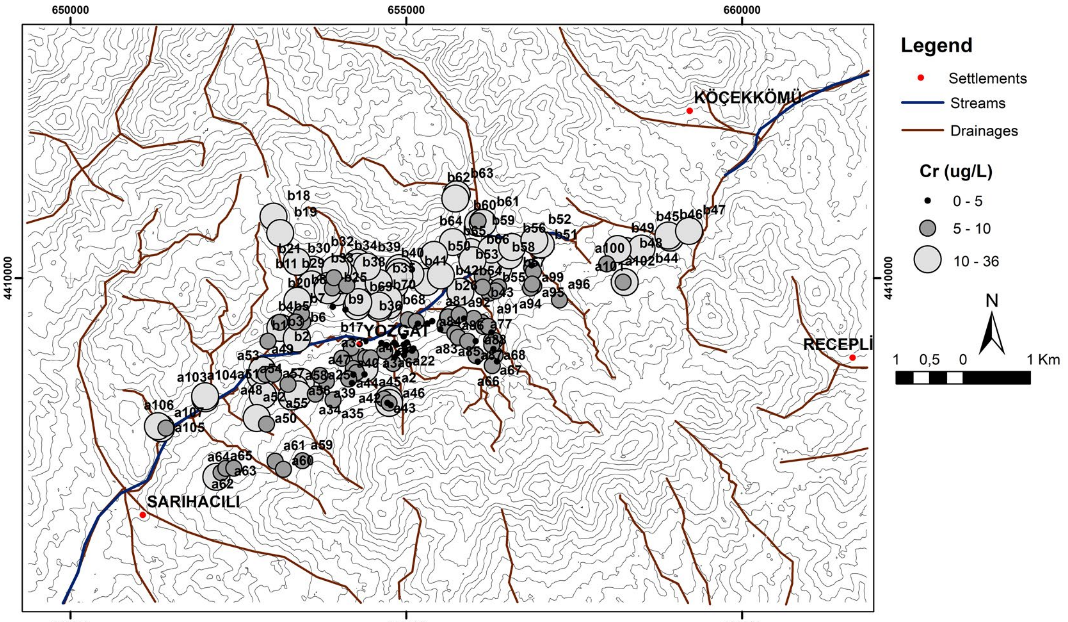

Fig. 5. Spatial distribution of chromium (Cr) in the public water fountains. [Colour figure can be viewed at wileyonlinelibrary.com]

cancers of skin, bladder, lung, liver and stomach (IARC, 2004, 2018; Tapio and Grosche, 2006). Four fountains had high concentrations of arsenic (Fig. 8). In these fountains, water exceeded the maximum allowable limits (10 μg/L) stated in international standards for drinking water quality.

Both calcium (Ca) and magnesium (Mg) are essential for human health. Inadequate intake of either nutrient can impair health. Hard water contains a high concentration of calcium and magnesium ions. Carbonate hardness is caused by the metals combined with a form of alkalinity which is attributed to compounds, such as carbonate.

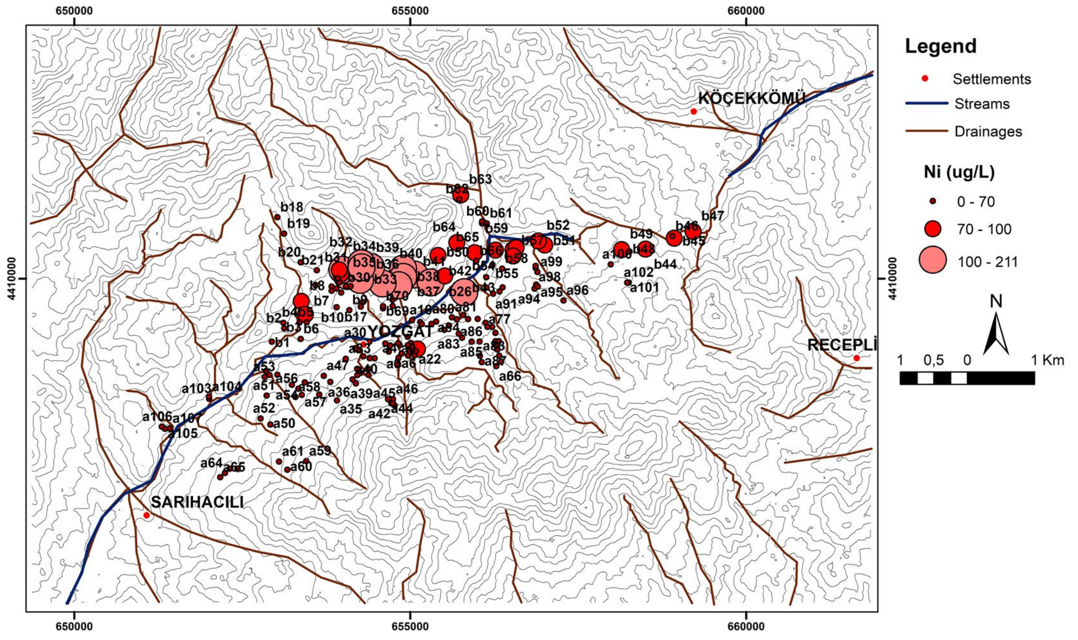

Fig. 6. Spatial distribution of nickel (Ni) in the public water fountains. [Colour figure can be viewed at wileyonlinelibrary.com]

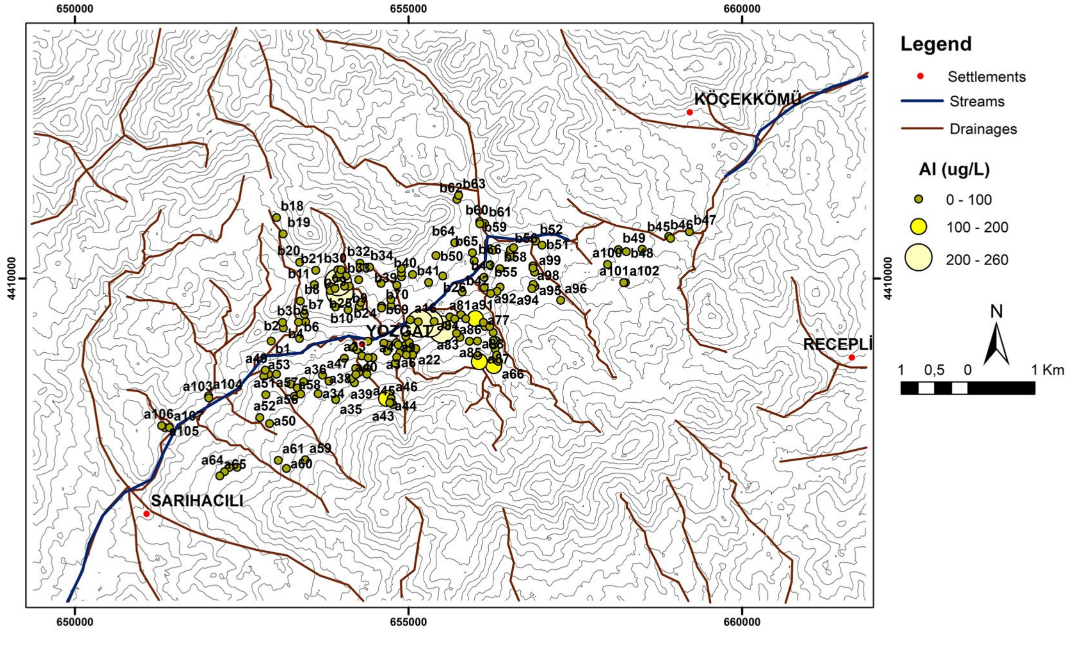

Fig. 7. Spatial distribution of aluminium (Al) in the public water fountains. [Colour figure can be viewed at wileyonlinelibrary.com]

The concentration of calcium ranged from 8.89 to 254.67 μg/kg (mean 85.39) in the gabbro, 0.003 to 1.33 μg/kg (mean 0.34) in the granite, 0.003 to 1.53 μg/kg (mean 0.64) in the basalt, 0.15 to 1.46 μg/kg (mean 0.57) in the dacite and 0.18 to 24.63 μg/kg (mean 14.58) in the limestone (Table 2). The chemical composition of minerals in pyroxene consists of calcium. The concentration of calcium in water is ranged from 6.68 to 231.05 mg/L (Fig. 9). There have been a number of studies which have investigated the association between calcium intake and cardiovascular disease risk and related mortality in older women and men (Bell *et al*; 1992; Daly and Ebeling, 2010; Sabbagh and Vatanparast, 2009). Some studies mention that it is important to consider that total calcium

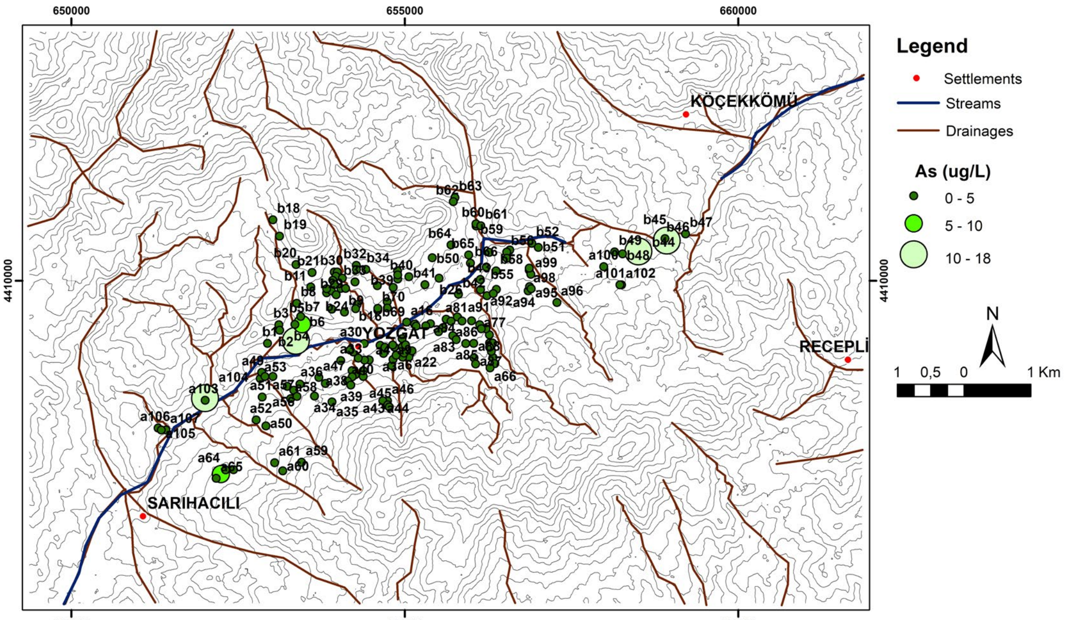

Fig. 8. Spatial distribution of arsenic (As) in the public water fountains. [Colour figure can be viewed at wileyonlinelibrary.com]

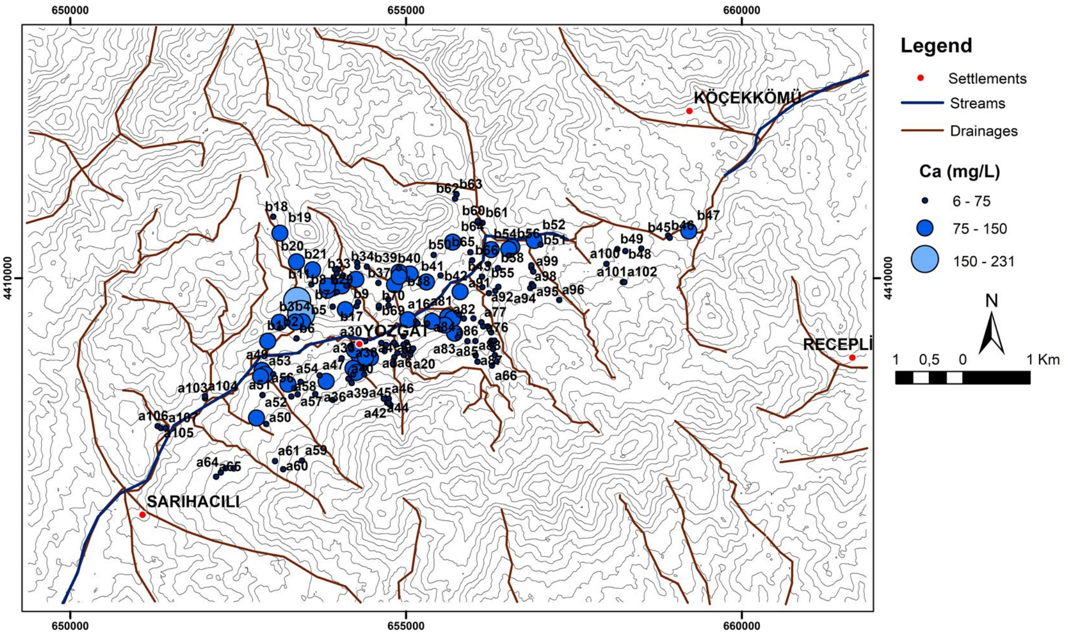

Fig. 9. Spatial distribution of calcium (Ca) in the public water fountains. [Colour figure can be viewed at wileyonlinelibrary.com]

intakes may exceed 2000–2500 mg per day. At these levels, there may well be some cause for concern, but several important questions still remain (Daly and Ebeling, 2010).

The basaltic volcanics are tholeiitic (Fe + Mg-rich) in the study area. The concentration of magnesium in the fountains ranged from 2.92 to 78.70 mg/L (Fig. 10). The concentration of magnesium ranged from 0.79 to 0.89 µg/kg (mean 0.39) in the basalt (Table 2). Recent studies confirm the strong and essential role of magnesium in the prevention of cardiovascular diseases (Del Gobbo *et al*., 2013; Chiuve *et al*., 2013).

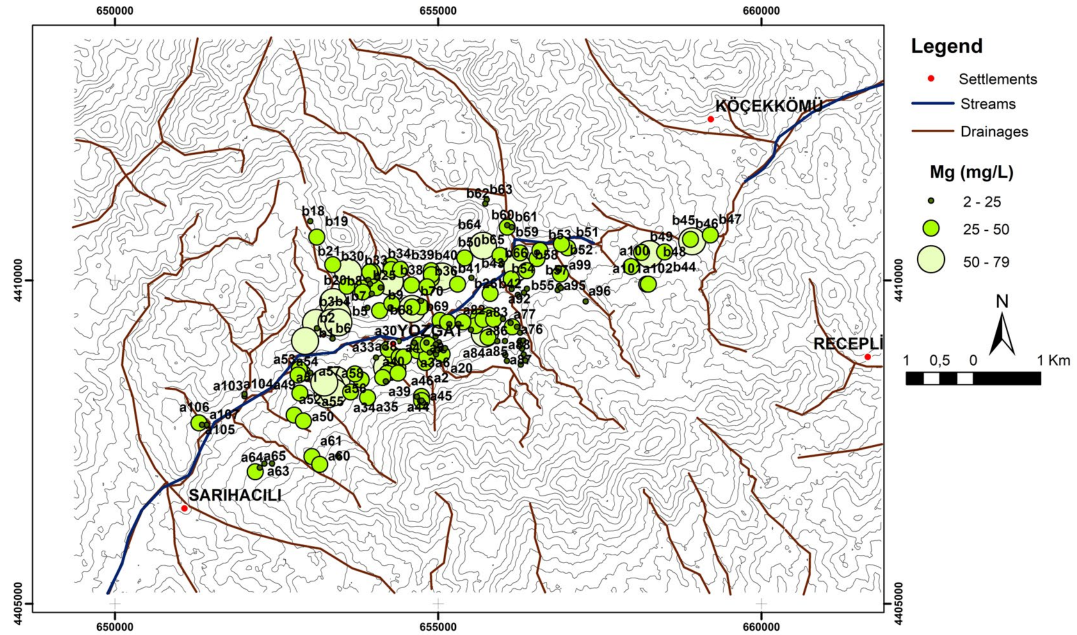

Fig. 10. Spatial distribution of magnesium (Mg) in the public water fountains. [Colour figure can be viewed at wileyonlinelibrary.com]

Table 3 Comparison of water quality with the WHO and US.EPA limits

	Cases						Water limit	
	Exceed WHO limit		Normal		Total		WHO (2017)	US.EPA (2018)
Element	Number	Percent	Number	Percent	Number	Percent	µg/L/*mg/L	µg/L/*mg/L
Na	2	1.1	175	98.9	177	100.0	200*	
Al	5	2.8	172	97.2	177	100.0	200	
Mn	2	1.1	175	98.9	177	100.0	–	50
Fe	172	97.1	5	2.9	177	100.0	–	300
Ni	34	19.2	143	80.8	177	100.0	70	
As	4	2.3	173	97.7	177	100.0	10	
Ba	1	0.6	176	99.4	177	100.0	700	
Pb	2	1.1	175	98.9	177	100.0	10	
Cl	1	0.6	176	99.4	177	100.0	250*	
Br	4	2.3	173	97.7	177	100.0	10	
NO_3	11	6.2	166	93.8	177	100.0	50*	

The other elements and anions in fountain water do not exceed the maximum allowable limits depicted in international standards of drinking water quality. In general, the following percentages of fountains exceeded WHO and US.EPA limits for elements; 1.1% for Na, 2.8% for Al, 1.1 % for Mn, 97.1 % for Fe, 19.2% for Ni, 2.3% for As, 0.6% for Ba, 1.1% for Pb, 0.6% for Cl, 2.3% for Br and 6.2% for NO_3 and (Table 3). Some fountain water contained high concentrations of more than one element. Figure 11 shows important elements which exceeded limits together. It clearly indicates that many fountains have a high concentration of elements linked to geogenic factors.

A number of statistical analyzes were performed on the water quality data (Table 4). Although Fe was significantly higher than the limit value ($P < 0.001$), Br was not significantly higher than the limit value ($P > 0.05$). Some elements such as Na–B, Ca–B, As–Li, Mo–Li and F–Mo have a strong correlation with each other. The strongest correlation was found between Fe and Ca ($r = 0.988$, $P < 0.01$). These element pairs in the rock samples showed low positive and negative correlations with Na–B (0.22),

(Continued)

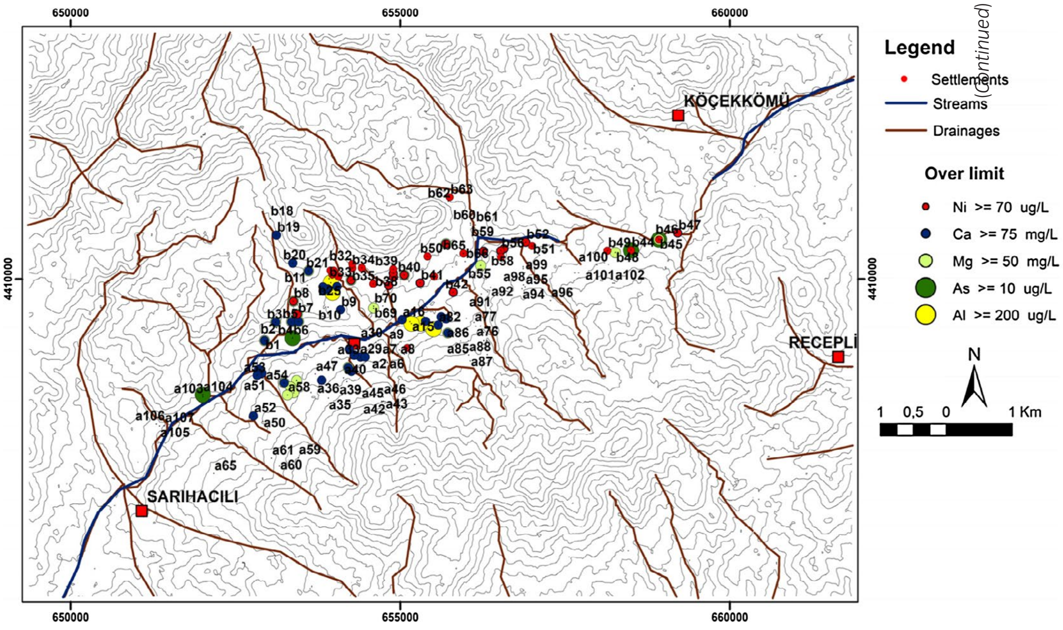

Fig. 11. Distribution of the public water fountains which is exceeding the limit values. [Colour figure can be viewed at wileyonlinelibrary.com]

Ca–B (−0.01), As–Li (−0.11), Mo–Li (−0.11) and Fe–Ca (0.416) (Table 5), while positive correlations were observed between the element pairs in the water samples.

Considering our literature and study results, it is thought that the variations are due to natural differences in terms of regional rock structures rather than anthropological influences. Source studies of the public fountains determined to have high NO_3 values should be designed.

Conclusions

1. The chemical properties of the fountain waters were observed to be related to the solubility of the minerals forming the geological unit. Presence and amount of toxic substances and concentration of trace elements affect to potability of water. Overall, the identified health risks of the water fountains are limited, especially when looking at the public drinking water system as a whole. Some studies were completed about the effect of fountain water on human health in the United States (Craun *et al*. 2010; Phurisamban and Gleick, 2017). More recent reports mention special linkages between the water fountains and disease outbreaks between 2005 and 2012 (Brunkard *et al*. 2011; CDC, 2013; Beer *et al*. 2015).
2. The natural concentrations of a number of elements, known to be extremely toxic, with no maximum allowable concentration levels for drinking water set by the WHO and US.EPA can reach surprisingly high levels.
3. Due to limited exposures having an effect on chronic diseases and cancer development, it is important to help ensure the availability of safe and reliable drinking fountains and encourage their use. Organizations providing free drinking water should adopt best management practices for maintaining fountains and invest in new, modern installations as needed. Also, it is important to monitor and test all public water fountains and develop and implement standard protocols for water fountain maintenance, repair and replacement.
4. Public fountain water is extremely essential for people's health. In recent years, there has been a significant growth of awareness in environmental issues, including public fountain water quality, within in Turkey. This brings with it an enormous social responsibility to sustain and safeguard our environment by monitoring and solving risk factors that may be potentially threatening the health. Therefore, a comprehensive protection and control system must be developed for the control and elimination of pollution.
5. In addition, the fountains should be monitored with analyses to be made considering seasonal changes. In order to protect community health, the public fountains with values exceeding the maximum limits due to seasonal influences should be restricted or prevented from being used.

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Table 4 Correlation between each elements

N = 177	pH	Li	Be	B	Na	Mg	Al	K	Ca	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
pH	1																
Li	.172	1															
Be	–.070	–.054	1														
B	–.220	.290**	–.117	1													
Na	–.109	.670**	–.118	.804**	1												
Mg	–.132	.054	–.115	.642**	.405**	1											
Al	.077	–.026	–.032	–.169*	–.133	–.360**	1										
K	.057	.124	–.021	.257**	.183*	.222**	–.046	1									
Ca	–.362**	–.025	–.116	.738**	.525**	.687**	–.368**	.122	1								
V	–.319**	–.021	–.109	.514**	.404**	.516**	–.311**	.041	.537**	1							
Cr	.323**	.154*	–.152*	.287**	.308**	.423**	–.108	.188*	.225**	.207**	1						
Mn	.126	–.010	–.021	–.028	–.025	–.055	–.005	–.017	–.066	–.095	–.035	1					
Fe	–.320**	–.023	–.126	.707**	.502**	.687**	–.363**	.111	.988**	.525**	.256**	.038	1				
Co	.133	.069	–.154*	.429**	.418**	.433**	–.169*	.128	.516**	.309**	.825**	.076	.548**	1			
Ni	.211**	.080	–.151*	.321**	.332**	.341**	–.112	.116	.352**	.228**	.856**	–.005	.378**	.958**	1		
Cu	.004	.017	.137	.008	.003	.031	–.047	–.001	–.077	–.065	–.041	–.016	–.092	–.089	–.073	1	
Zn	.102	.308**	–.035	–.007	.146	–.118	–.030	–.014	–.176*	–.109	–.021	–.016	–.189*	–.124	–.094	.299**	1
As	.042	.751**	–.098	.407**	.610**	.223**	–.137	.053	.161*	.327**	.177*	–.011	.171*	.172*	.145	–.039	.159*
Se	–.078	.196**	–.214**	.653**	.582**	.554**	–.193**	.188*	.698**	.421**	.474**	.006	.697**	.609**	.507**	–.008	–.032
Mo	.091	.850**	.013	.289**	.634**	–.083	–.043	.237**	–.022	.005	.037	–.010	–.017	.013	.008	–.013	.257**
Ag	.320**	.105	–.240**	.101	.133	.126	–.012	.123	.106	.008	.504**	.087	.144	.408**	.407**	.068	.033
Cd	.117	.091	.178*	.082	.081	.108	–.078	.157*	.092	–.032	.314**	.075	.115	.263**	.268**	.128	.050
Sb	–.127	.432**	.171*	.249**	.322**	.230**	–.141	.088	.101	.179*	–.020	–.045	.090	–.030	–.062	.067	.051
Ba	.174**	.179*	–.092	.281**	.227**	.306**	–.087	.383**	.313**	–.101	.470**	–.016	.317**	.471**	.455**	–.051	–.005
Tl	.047	.107	.568**	–.068	–.095	.056	–.058	–.008	–.042	–.089	–.010	–.015	–.043	.010	.015	.033	–.049
Pb	.087	.024	.022	–.032	–.008	.008	–.019	–.011	–.060	–.016	.106	–.007	–.064	–.051	–.041	.232**	.256**
U	–.280**	.076	–.105	.670**	.541**	.707**	–.313**	.178*	.816**	.528**	.329**	–.084	.806**	.474**	.343**	–.067	–.110
F	.141	.843**	–.056	.241**	.556**	.035	–.118	.082	–.064	.078	.113	–.020	–.056	–.017	–.018	–.043	.212**
Cl	–.381**	.128	–.068	.731**	.637**	.521**	–.239**	.131	.841**	.469**	.057	–.052	.813**	.360**	.217**	–.082	–.091
NO_2	–.253**	.044	–.058	.598**	.448**	.289**	–.054	.159*	.546**	.260**	–.017	–.016	.488**	.219**	.125	–.015	–.062
Br	–.324**	.066	–.031	.626**	.489**	.302**	–.015	.162*	.574**	.233**	–.028	–.006	.512**	.199**	.100	.017	–.031
NO_3**	–.236	.019	–.122	.371**	.346**	.359**	–.221**	.027	.492**	.491**	.172*	–.062	.506**	.332**	.243**	–.103	–.104
SO_4**	–.324	.203**	–.112	.891**	.735**	.671**	–.213**	.202**	.846**	.484**	.221**	–.054	.811**	.439**	.306**	–.040	–.071
PO_4**	–.171	–.026	–.029	.262**	.206**	.090	.053	.173*	.170*	.223**	–.051	–.014	.176*	.028	–.016	.007	–.026
NH_4	.046	–.040	–.025	.071	.030	–.025	–.044	.002	–.004	.046	–.130	–.019	–.020	–.078	–.089	–.003	–.028

Table 4 (*Continued*)

N = 177	As	Se	Mo	Ag	Cd	Sb	Ba	Tl	Pb	U	F	Cl	NO_2	Br	NO_3	SO_4	PO_4	NH_4
As	1																	
Se	.282**	1																
Mo	.678**	.085	1															
Ag	.104	.605**	–.050	1														
Cd	.025	.253**	.039	.421**	1													
Sb	.548**	.077	.363**	–.139	–.025	1												
Ba	.116	.381**	.061	.295**	.195**	.091	1											
Tl	.352**	–.059	.009	–.089	.050	.412**	.155*	1										
Pb	–.027	.022	–.026	.098	.168*	–.058	–.029	–.005	1									
U	.240**	.575**	.113	.042	.041	.231**	.371**	–.058	–.051	1								
F	.687**	.107	.795**	.057	.088	.326**	.010	–.008	–.026	.074	1							
Cl	.226**	.576**	.170*	–.072	–.012	.163*	.176*	–.056	–.090	.672**	–.003	1						
NO_2	.149*	.487**	.048	.061	.014	.087	.158*	–.003	–.043	.380**	–.012	.591*	1					
Br	.140	.492**	.047	.020	–.007	.116	.164*	.014	–.028	.421**	–.042	.628*	.856**	1				
NO_3**	.190*	.361**	.053	.055	.054	–.015	.072	–.085	–.079	.448**	.001	.481*	–.013	–.113	1			
SO_4**	.292**	.670**	.168*	.031	.033	.211**	.305**	–.048	–.062	.731**	.089	.872*	.640**	.707**	.448**	1		
PO_4**	.132	.105	.128	–.011	–.180*	.185*	–.005	–.021	–.030	.151*	–.028	.148*	.192*	.249**	.010	.225**	1	
NH_4	.055	–.010	.038	–.044	–.070	.064	–.071	–.035	–.031	–.050	–.014	.075	.204**	–.024	.117	.030	–.022	1

$^*P < 0.05$; $^{**}P < 0.01$.

Table 5 Correlation between each elements in the rock samples

N = 32	Ag	Al	As	B	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe
Ag	1											
Al	0.33	1										
As	0.30	.59**	1									
B	.53**	–0.09	–0.05	1								
Ba	.38*	.56**	.46**	0.00	1							
Be	.37*	.47**	.56**	–0.02	.85**	1						
Ca	0.05	0.27	.76**	–0.01	–0.04	0.10	1					
Cd	.46**	0.14	–0.13	.51**	–0.04	–0.05	–0.02	1				
Co	0.27	0.31	.45*	–0.14	.38*	.38*	–0.03	–0.22	1			
Cr	0.11	.58**	.36*	0.02	0.11	0.24	0.32	–0.02	0.17	1		
Cu	.41*	.67**	.37*	0.14	0.25	0.05	0.18	0.24	0.13	0.18	1	
Fe	0.33	.80**	.72**	–0.08	.42*	.59**	.42*	0.10	0.34	.46**	.48**	1
Hg	0.19	0.08	0.24	–0.15	0.13	0.09	–0.14	–0.21	.93**	–0.05	0.13	0.12
K	0.27	0.25	.41*	–0.03	.79**	.83**	–0.05	–0.18	.41*	0.02	–0.04	0.28
Li	0.27	–0.10	–0.11	.71**	–0.09	–0.09	–0.06	0.32	–0.09	0.04	0.12	–0.08
Mg	0.35	.78**	.35*	–0.10	.41*	0.25	0.10	0.10	0.16	0.27	.73**	.64**
Mn	0.23	.58**	.60**	–0.04	.38*	.60**	0.34	–0.02	0.23	0.33	0.33	.826**
Mo	0.23	0.20	0.12	–0.13	0.12	0.13	0.15	0.32	0.16	0.14	0.08	0.11
Na	.37*	.58**	0.23	0.22	.47**	0.28	–0.07	0.34	0.20	0.05	.74**	.42*
Ni	0.32	.63**	.39*	0.00	.36*	.41*	0.23	0.01	0.11	.66**	.43*	.61**
Pb	0.32	0.10	.47**	0.11	.59**	.68**	0.11	–0.06	.50**	–0.01	–0.07	0.18
Sb	0.09	0.25	.72**	0.02	–0.03	0.15	.87**	–0.02	0.08	.363*	0.08	.43*
Se	0.30	.58**	.99**	–0.05	.46**	.55**	.74**	–0.11	.45*	0.33	.385*	.71**
Th	0.20	0.11	0.27	–0.06	.67**	.68**	–0.17	–0.22	.44*	–0.10	–0.16	0.08
U	0.20	0.18	.49**	–0.02	.61**	.70**	0.15	–0.23	.39*	0.07	–0.16	0.21
V	.43*	.73**	.87**	–0.09	.67**	.71**	.36*	–0.12	.66**	0.34	.46**	.77**
Zn	0.29	.37*	0.00	–0.01	0.01	0.02	0.04	.55**	–0.02	0.24	.352*	0.23

N = 32	Hg	K	Li	Mg	Mn	Mo	Na	Ni	Pb	Sb	Se	Th	U	V	Zn
Hg	1														
K	0.22	1													
Li	–0.08	0.00	1												
Mg	0.07	0.08	–0.07	1											
Mn	0.05	.44*	–0.04	.43*	1										
Mo	0.15	0.11	–0.11	–0.03	0.01	1									
Na	0.15	0.16	.40*	.64**	0.22	–0.01	1								
Ni	–0.05	0.23	0.01	.68**	.60**	0.07	0.27	1							
Pb	.38*	.80**	0.08	0.00	0.23	0.24	0.10	0.12	1						
Sb	–0.03	0.00	–0.02	0.06	0.25	0.22	–0.12	0.26	0.25	1					
Se	0.25	.41*	–0.12	.37*	.60**	0.07	0.25	.38*	.46**	.67(**)	1				
Th	0.30	.91**	0.02	–0.04	0.17	0.10	0.09	–0.06	.80**	–0.12	0.27	1			
U	0.20	.88**	0.03	–0.05	0.25	0.20	–0.02	0.095	.84**	0.27	.46**	.89**	1		
V	.45*	.58**	–0.12	.53**	.62**	0.07	.46**	.46**	.53**	.38*	.87**	.45**	.52**	1	
Zn	–0.02	–0.03	0.19	0.23	0.13	.75**	0.35	0.22	–0.08	0.04	–0.03	–0.07	–0.05	0.04	1

[a]$P < 0.05$; [b]$P < 0.01$.

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