International Journal of Environmental Trends (IJENT)
http://dergipark.gov.tr/ijent
International Journal of Environmental Trends (IJENT)
2023; 7 (2),101-112
ISSN: 2602-4160
Turkish JournalPark ACADEMIC

Research Article

Determination of Elements in Turkish Bottled Drinking Waters Using ICP-OES: Method Validation

F. Gökbel*[1] and N. E. Gümüş[2]

[1] Karamanoğlu Mehmetbey University, Department of Food Engineering, Karaman, Türkiye (*ORCID Number: 0000-0002-0265-1881)*

[2] Karamanoğlu Mehmetbey University, Kazım Karabekir Vocational School, Department of Environmental Protection Technology, Karaman, Türkiye (*ORCID Number: 0000-0001-8275-3871)*

Received
16 November 2023

Accepted
21 December 2023

Abstract

Heavy metal pollution has been a major problem in drinking water worldwide. Increasing water pollution due to population growth and inadequate municipal services has caused people to prefer consuming bottled water more. Hence, it is crucial to determine the mineral composition of the bottled drinking water. In this study, Antimony (Sb), Arsenic (As), Beryllium (Be), Cadmium (Cd), Chromium (Cr), Cobalt (Co), Copper (Cu), Iron (Fe), Lead (Pb), Lithium (Li), Manganese (Mn), Nickel (Ni), Strontium (Sr) and Vanadium (V) were analyzed by inductively coupled plasma optic emission spectrometry (ICP-OES) in bottled drinking water samples sold in supermarkets. Linearity, limit of detection (LOD), limit of quantification (LOQ), reproducibility and recovery (%) values were determined. Method validation data results showed that the method is applicable for elemental analysis in bottled drinking water samples. As, Cr, Cu, Fe, Ni and Pb were not detected in the samples (<LOD). To evaluate the obtained data, Factor Analysis (FA) and Pearson Correlation Index (PCI), which are widely preferred statistical methods, were used. The results were compared with the limit values of the authorities regulations Rebuplic of Türkiye Ministry of Health Regulation on Water for Human Consumption (RWHC), World Health Organization (WHO) and the United States Environmental Protection Agency (EPA). It has been determined that the measured element levels of bottled drinking water except for sample 21 and sample 38 from two brands do not pose any significant risk to human health.

Keywords
Bottled drinking waters
ICP-OES
Trace elements
Heavy metals
Method validation

TÜRK ŞIŞELENMIŞ İÇME SULARINDAKI ELEMENTLERIN ICP-OES KULLANILARAK BELIRLENMESI: YÖNTEM VALIDASYONU

Özet

Ağır metal kirliliği tüm dünyada içme suyunda önemli bir sorun olmuştur. Nüfus artışı ve yetersiz belediye hizmetleri nedeniyle su kirliliğinin artması, insanların şişelenmiş su tüketimini daha fazla tercih etmesine neden olmuştur. Bu nedenle, şişelenmiş içme suyunun mineral bileşiminin belirlenmesi büyük önem taşımaktadır. Bu çalışmada, süpermarketlerde satılan şişelenmiş içme suyu örneklerinde Antimon (Sb), Arsenik (As), Berilyum (Be), Kadmiyum (Cd), Krom (Cr), Kobalt (Co), Bakır (Cu), Demir (Fe), Kurşun (Pb), Lityum (Li), Mangan (Mn), Nikel (Ni), Stronsiyum (Sr) ve Vanadyum (V) indüktif eşleşmiş plazma optik emisyon spektrometresi (ICP-OES) ile analiz edilmiştir. Algılama sınırı (LOD), tayin sınırı (LOQ), tekrarlanabilirlik ve geri kazanım (%) değerleri belirlenmiştir. Metot validasyon verileri, metodun şişelenmiş

Anahtar Kelimeler
Şişelenmiş içme suları
ICP-OES
Eser elementler
Ağır metaller
Yöntem validasyonu

içme suyu örneklerinde element analizi için uygulanabilir olduğunu göstermiştir. Örneklerde As, Cr, Cu, Fe, Ni ve Pb tespit edilmemiştir (<LOD). Elde edilen verileri değerlendirmek için yaygın olarak tercih edilen istatistiksel yöntemler olan Faktör Analizi (FA) ve Pearson Korelasyon İndeksi (PCI) kullanılmıştır. Sonuçlar, T.C. Sağlık Bakanlığı İnsani Tüketim Amaçlı Sular Hakkında Yönetmelik, Dünya Sağlık Örgütü (WHO) ve Amerika Birleşik Devletleri Çevre Koruma Ajansı (EPA) limit değerleri ile karşılaştırılmıştır. İki markaya ait iki örnek (örnek 21 ve örnek 38) dışında şişelenmiş içme suyunda ölçülen element seviyelerinin insan sağlığı açısından önemli bir risk oluşturmadığı tespit edilmiştir.

International Journal of Environmental Trends, *7* (2), 101-112. DOI: not now possible

[1] Corresponding Author Email: fgkbel@kmu.edu.tr

INTRODUCTION

Water plays a crucial role in the body by facilitating vital functions like maintaining and regulating body temperature, transporting nutrients into cells, eliminating waste products, dissolving carbon dioxide, oxygen, and salts, and distributing these essential substances to various organs through the circulatory system [1, 2].

The growth of cities, worldwide waste and pollution, global warming and climate change are cited as causes of major water problems in this century. The quality and quantity of water and water systems significantly affect human life [2-4]. Over time, with the increasing population and industrial growth, many pollutants such as the increase in domestic and industrial wastes, industrial and sewage waters discharged without treatment, agricultural fertilizers and pesticides threaten groundwater and surface waters, which are of essential importance for living things to fulfill their vital functions [5].

One of the most important problems in the world is the need for clean and consumable water resources. For this reason, monitoring and controlling existing water resources is an important issue. However, water pollution accidents occur frequently with the rapid development of the economy in recent years. Accidents occurring near drinking water sources have seriously affected public health and social security [6, 7, 8].

The worldwide preoccupation with trace element contamination in aquatic environments has arisen because of its potential to negatively impact both aquatic ecosystems and human health. Heavy metals, natural sediments and mining waste can pollute water sources through industrial and agricultural activities [9]. The characteristics of water resources should be thoroughly investigated before direct and indirect use [10].

High concentrations of trace metals pose a potential health risk to humans. Consequently, assessing the levels of trace metals in drinking water is a crucial parameter. These metals may find their way into water sources through various means such as plastic stabilizers, pigments, paints, fertilizers, sewage sludge disposal, fossil fuel, smelting operations and mining. Additionally, the treatment process itself can introduce these metals into drinking water [11]. Numerous studies have documented about metal leaching to the water from both glass and plastic bottles [12, 13].

Over the last 30 years, bottled water has gained popularity and high sales worldwide [14]. The impressive increase in worldwide bottled water consumption is driven by consumers' increasing water pollution concerns. Unpleasant tastes and odors of municipal water supplies caused by the chlorination process is another major factor in people choosing bottled water [15]. Furthermore, bottled water has been considered a healthier alternative than tap water and other beverages [3, 16].

Most of bottled drinking water has been sold in polyethylene terephthalate (PET) bottles. Research on elemental concentrations in bottled water is mainly directed at natural mineral waters, and the number of publications covering all continents and countries has been increasing [2, 15, 17-22]. The use of bottled water has been constantly increasing in Türkiye, also. In 2020, the total volume of bottled water in Türkiye reached 12.1 × 109 liters, and annual bottled water consumption per capita reached 126 liters [23].

This study aims to create an analytical method using the ICP-OES device in the determination of As, Cd, Cr, Cu, Fe, Mn, Li, Ni, Pb, Sb, Co, Sr, Be an V elements in bottled water. For this purpose, performance features such as linearity, LOD, LOQ and recovery (%) were determined. The element results of bottled water were compared with WHO, EPA and RWHC quality criteria [3, 24, 25] and the data were also evaluated using Factor Analysis (FA) and Pearson Correlation Index (PCI).

MATERIAL AND METHOD

Reagents

ICP multi-element standard solution XVI (Merck) and %65 nitric acid (Merck, Suprapur®) were used during analyses. The ultra-pure water (18.2 MΩ cm) was produced by an Ultrapure Water System (ELGA Centra R200, UK).

Standard preparation

At first, 6% (v/v) nitric acid solution was prepared to be used in dilution processes in preparing standard solutions from the stock solution. Then, standard solutions of 2.5-200 µg/L were prepared using 6% (v/v) nitric acid from the stock solution containing 100 mg/L of each element.

Sample preparation

42 bottled drinking water samples of different brands in Türkiye were purchased from local markets in 2021. These 42 drinking water samples were bottled at facilities located in 20 different cities spanning 5 distinct geographical regions (8 samples each from Sakarya and Bursa, 4 samples from Osmaniye, 2 samples each from Adana, Ankara, Aydın, Kocaeli and Muğla, and samples each from Antalya, Bolu, Burdur, Düzce, Eskişehir, Isparta, İstanbul, Kahramanmaraş, Karabük, Kırşehir, Konya and Niğde).

Elemental analysis of bottled water samples were carried out by using ICP-OES (Agilent 720) at Karamanoğlu Mehmetbey University Scientific and Technological Research Application and Research Center (BİLTEM) under the conditions listed in Table 1. This center has an international accreditation certificate within the scope of TS EN/ISO IEC 17025 issued by the Turkish Accreditation Agency (TÜRKAK). The bottled drinking water samples were stored at +4°C until analysis, The wavelengths of the elements measured in the devices were As 188.980 nm, Be 312.042 nm, Cd 214.439 nm, Co 238.892 nm, Cr 206.158 nm, Cu 324.754 nm, Fe 238.204 nm, Li 670.783 nm, Mn 257.610 nm, Ni 221.468 nm, Pb 220.353 nm, Sb 206.834 nm, Sr 407.771 nm and V 292.401 nm. All measurements were performed in triplicate.

Table 1. The main operating parameters of the ICP-OES.

Parameters	ICP-OES operating conditions
RF Power	1.0 kW
Plasma gas flow rate (Ar)	15 L/min
Auxilary gas flow rate (Ar)	1.5 L/min
Nebulizer gas flow rate (Ar)	0.75 L/min
Copy and reading time	1s

Validation parameters

For method validation, various parameters such as linear range, method linearity, recovery at three levels (minimum, medium, and maximum), LOD, LOQ, method reproducibility and recovery (%) were considered. Analytical method validation for elemental determination of ICP-OES was performed following the Eurachem Guide [26] and the acceptable recovery range specified as 80–110% mentioned in the AOAC Guideline for Standard Method Performance Requirements [27].

Statistical analysis

Pearson Correlation Index (PCI) and Factor Analysis (FA) were performed to evaluate the results using the Minitab® 18 (2017) program.

RESULT AND DISCUSSION

Method and validation

Firstly, method validation studies were carried out to determine the elemental compositions of plastic bottled water samples supplied from local markets in Türkiye. In this regard, LOD, LOQ, repeatability, and recovery values were calculated (Table 2). The regression coefficients of the calibration equations were found to be between 0.995 - 0.9999. LOD values were determined in the range of 0.099-7.187 (µg/L) and LOQ values were determined in the range of 0.331-23.957 (µg/L). The relative standard deviation value (%RSD) of the results obtained from the recovery study is expressed as the repeatability value. %RSD values obtained by experiments varied between 0.233-6.919. The values reached in recovery studies by spiked samples were found to be in the range of %81-104 (Table 2).

Table 2. Method validation of elements.

	% RSD	*LOD*	*LOQ*	Regression equation	Linear range (ppb)	Recovery
As	1.880	6.916	23.054	$y = 1.2x + 18.7$	2.5-100	104.18
Be	0.458	0.099	0.331	$y = 1425.3x - 306.0$	5.0-200	92.36
Cd	0.804	0.673	2.242	$y = 25.6x + 12.7$	5.0-200	90.46
Co	1.223	1.208	4.027	$y = 10.2x + 9.6$	5.0-200	88.44
Cr	5.592	7.162	23.874	$y = 1.8x + 14.6$	5.0-200	84.72
Cu	0.831	0.851	2.836	$y = 72.4x + 907.4$	2.5-100	89.65
Fe	1.239	0.983	3.278	$y = 24.8x + 165.6$	2.5-100	100.83
Li	0.812	0.180	0.602	$y = 7939.5x + 670.0$	5.0-200	81.74
Mn	0.233	0.178	0.593	$y = 310.0x + 64.6$	5.0-200	94.83
Ni	3.028	6.128	20.426	$y = 2.0x + 19.9$	5.0-200	90.94
Pb	2.657	5.438	18.127	$y = 2.3x + 18.0$	2.5-100	100.25
Sb	6.918	7.187	23.957	$y = 2.1x + 18.8$	5.0-200	93.46
Sr	0.342	0.167	0.557	$y = 7571.9x + 10722$	5.0-200	92.52
V	0.822	0.589	1.962	$y = 31.8x + 15.1$	5.0-200	94.04

Element analysis of samples

As, Cr, Cu, Fe, Ni and Pb elements could not be detected in any of the 42 drinking water samples (<LOD). Co could only be detected in 5 brands, Sb in 2 brands, Cd and Mn in only one brand (Table 3).

Although Be is a metal that has the potential to pose a risk to human health, there is no limit value in WHO, EPA and RWHC [3, 24, 25] regulations due to its very low amount in water. Be content of samples was determined in the range of 0.591 - 0.885 µg/L.

Sb is a trace element that has the potential for toxicity and lacks a recognized physiological role. Nonetheless, there is limited understanding of both its natural and anthropogenic geochemical cycles. [28]. Although Sb amount is relatively high and is often difficult to measure this element directly using the ICP-OES instrument. However, Sb was detected in two bottled water samples tested in this study. Sb content of sample 21 and sample 38 exceeded the EPA limit value. This result was in line with previous studies [12, 22, 29].

Mn does not pose a risk to human health when found in normal concentrations in drinking water but can cause problems with the taste of water when its concentration exceeds 100 µg/L [3, 22]. Mn content of samples that were detected in only one brand did not exceed 100 µg/L. This result was parallel to previous studies [9, 22].

It is well known that Li does not pose a risk to human health [22]. Additionally, in recent years, there have been some researches describing the positive effects of Li on mental health [30, 31]. Li content of water samples were determined in the range of 0.089 - 10.130 µg/L. Li concentrations in various samples of the same brand were generally satisfactorily consistent. Similar results were obtained in various locations. Its source in these waters is most likely of natural origin. Turksoy et al. (2019) found similar Li results in water samples [29].

V is extensively present in the Earth's crust and has been identified as a potentially hazardous pollutant [32, 33]. Compounds containing vanadium pose significant toxicity to both humans and animals, with their atmospheric presence primarily attributed to the combustion of fossil fuels containing substantial amounts of vanadium. As vanadium can enter the human body through drinking water, accurately assessing its presence in these samples becomes crucial [34]. V could not be detected in 9 water samples. The maximum V content in bottled water samples was determined as 4.486 µg/L. In general, the results obtained in this study were compatible with the results published [35].

Multivariate statistical analysis

Factor Analysis (FA)

Factor Analysis is a powerful statistical technique that facilitates the interpretation of large datasets and has been widely used, particularly in recent years, in water quality assessment studies [36, 37]. In this study, Factor Analysis was conducted using correlated variables to identify influential variables on bottled waters. To improve the reliability of the FA, unrelated variables (As, Cr, Cu, Fe, Ni and Pb – not detected in water samples) were removed and only eight variables were used.

The percentage of variance (% Var) represents the share of variability in the data elucidated by individual factors, while the communality value for % Var indicates the overall variation explained collectively by all factors in the analysis. According to analysis, it was clearly seen that all four factors together explain 68.4% of the data (Table 4).

When the variance values of the first four factors were analyzed, the first factor was more dominant than the others. Sr, Li and Sb parameters in the first component group were characterized as the main component. One could argue that the parameters examined in the analysis effectively represent the overall state of water resources.

Table 3. Element results of bottled water samples (µg/L).

Sample	BRAND#	Location	As	Be	Cd	Co	Cr	Cu	Fe	Li	Mn	Ni	Pb	Sb	Sr	V
1	BRAND1	ANKARA	<LOD	0.774	<LOD	<LOD	<LOD	<LOD	<LOD	5.504	<LOD	<LOD	<LOD	<LOD	96.640	4.486
2	BRAND2	ANKARA	<LOD	0.757	<LOD	<LOD	<LOD	<LOD	<LOD	4.407	<LOD	<LOD	<LOD	<LOD	257.007	0.641
3	BRAND3	BURSA	<LOD	0.755	<LOD	<LOD	<LOD	<LOD	<LOD	3.114	<LOD	<LOD	<LOD	<LOD	79.398	0.521
4	BRAND4	SAKARYA	<LOD	0.742	<LOD	<LOD	<LOD	<LOD	<LOD	0.536	<LOD	<LOD	<LOD	<LOD	63.646	0.816
5	BRAND5	SAKARYA	<LOD	0.798	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	175.415	0.883
6	BRAND6	AYDIN	<LOD	0.780	<LOD	<LOD	<LOD	<LOD	<LOD	1.784	<LOD	<LOD	<LOD	<LOD	16.563	<LOD
7	BRAND7	SAKARYA	<LOD	0.775	<LOD	<LOD	<LOD	<LOD	<LOD	0.298	<LOD	<LOD	<LOD	<LOD	23.936	0.695
8	BRAND8	K.MARAŞ	<LOD	0.796	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	30.964	0.841
9	BRAND9	OSMANİYE	<LOD	0.779	<LOD	<LOD	<LOD	<LOD	<LOD	1.218	<LOD	<LOD	<LOD	<LOD	44.015	2.331
10	BRAND10	OSMANİYE	<LOD	0.792	<LOD	<LOD	<LOD	<LOD	<LOD	0.548	<LOD	<LOD	<LOD	<LOD	40.522	1.368
11	BRAND11	KONYA	<LOD	0.830	<LOD	<LOD	<LOD	<LOD	<LOD	5.252	<LOD	<LOD	<LOD	<LOD	171.036	4.257
12	BRAND12	ANTALYA	<LOD	0.804	<LOD	<LOD	<LOD	<LOD	<LOD	0.212	<LOD	<LOD	<LOD	<LOD	59.180	1.356
13	BRAND13	SAKARYA	<LOD	0.751	<LOD	<LOD	<LOD	<LOD	<LOD	0.194	<LOD	<LOD	<LOD	<LOD	59.779	3.504
14	BRAND14	OSMANİYE	<LOD	0.790	<LOD	<LOD	<LOD	<LOD	<LOD	1.651	<LOD	<LOD	<LOD	<LOD	41.477	1.232
15	BRAND15	DÜZCE	<LOD	0.807	<LOD	<LOD	<LOD	<LOD	<LOD	0.343	<LOD	<LOD	<LOD	<LOD	14.102	<LOD
16	BRAND16	ESKİŞEHİR	<LOD	0.830	<LOD	<LOD	<LOD	<LOD	<LOD	0.928	<LOD	<LOD	<LOD	<LOD	63.823	<LOD
17	BRAND17	ISPARTA	<LOD	0.829	<LOD	<LOD	<LOD	<LOD	<LOD	10.130	<LOD	<LOD	<LOD	<LOD	126.942	0.649
18	BRAND18	SAKARYA	<LOD	0.885	<LOD	<LOD	<LOD	<LOD	<LOD	2.227	<LOD	<LOD	<LOD	<LOD	65.042	0.712
19	BRAND19	BURDUR	<LOD	0.797	<LOD	1.341	<LOD	<LOD	<LOD	0.864	<LOD	<LOD	<LOD	<LOD	25.749	1.216
20	BRAND20	ADANA	<LOD	0.812	<LOD	<LOD	<LOD	<LOD	<LOD	1.557	0.352	<LOD	<LOD	<LOD	31.403	<LOD

21	BRAND21	KOCAELİ	<LOD	0.802	<LOD	<LOD	<LOD	<LOD	<LOD	0.089	<LOD	<LOD	<LOD	8.328	0.943	0.722
22	BRAND22	KIRŞEHİR	<LOD	0.794	<LOD	<LOD	<LOD	<LOD	<LOD	3.547	<LOD	<LOD	<LOD	<LOD	125.898	2.099
23	BRAND23	NİĞDE	<LOD	0.755	<LOD	<LOD	<LOD	<LOD	<LOD	0.631	<LOD	<LOD	<LOD	<LOD	69.184	1.455
24	BRAND24	SAKARYA	<LOD	0.740	<LOD	<LOD	<LOD	<LOD	<LOD	0.309	<LOD	<LOD	<LOD	<LOD	48.912	1.796
25	BRAND25	KARABÜK	<LOD	0.756	<LOD	<LOD	<LOD	<LOD	<LOD	0.446	<LOD	<LOD	<LOD	<LOD	36.956	<LOD
26	BRAND26	BURSA	<LOD	0.661	<LOD	1.341	<LOD	<LOD	<LOD	0.355	<LOD	<LOD	<LOD	<LOD	38.970	0.912
27	BRAND27	ADANA	<LOD	0.620	<LOD	<LOD	<LOD	<LOD	<LOD	3.141	<LOD	<LOD	<LOD	<LOD	85.231	0.637
28	BRAND28	OSMANİYE	<LOD	0.662	<LOD	1.363	<LOD	<LOD	<LOD	5.090	<LOD	<LOD	<LOD	<LOD	94.428	0.519
29	BRAND29	BURSA	<LOD	0.672	<LOD	1.559	<LOD	<LOD	<LOD	0.986	<LOD	<LOD	<LOD	<LOD	24.549	0.564
30	BRAND30	İSTANBUL	<LOD	0.591	<LOD	<LOD	<LOD	<LOD	<LOD	3.477	<LOD	<LOD	<LOD	<LOD	27.827	<LOD
31	BRAND31	BURSA	<LOD	0.592	<LOD	<LOD	<LOD	<LOD	<LOD	0.436	<LOD	<LOD	<LOD	<LOD	12.094	0.532
32	BRAND32	BOLU	<LOD	0.624	<LOD	<LOD	<LOD	<LOD	<LOD	0.320	<LOD	<LOD	<LOD	<LOD	23.064	<LOD
33	BRAND32	KOCAELİ	<LOD	0.727	<LOD	<LOD	<LOD	<LOD	<LOD	0.255	<LOD	<LOD	<LOD	<LOD	31.862	0.398
34	BRAND33	BURSA	<LOD	0.618	<LOD	1.496	<LOD	<LOD	<LOD	2.371	<LOD	<LOD	<LOD	<LOD	51.857	1.229
35	BRAND34	MUĞLA	<LOD	0.657	0.879	<LOD	<LOD	<LOD	<LOD	0.248	<LOD	<LOD	<LOD	<LOD	3.321	<LOD
36	BRAND34	SAKARYA	<LOD	0.639	<LOD	<LOD	<LOD	<LOD	<LOD	0.261	<LOD	<LOD	<LOD	<LOD	87.649	2.546
37	BRAND35	BURSA	<LOD	0.760	<LOD	<LOD	<LOD	<LOD	<LOD	5.082	<LOD	<LOD	<LOD	<LOD	69.180	0.827
38	BRAND36	MUĞLA	<LOD	0.676	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	16.785	3.795	0.484
39	BRAND36	BURSA	<LOD	0.754	<LOD	<LOD	<LOD	<LOD	<LOD	5.807	<LOD	<LOD	<LOD	<LOD	129.932	0.885
40	BRAND37	AYDIN	<LOD	0.710	<LOD	<LOD	<LOD	<LOD	<LOD	2.921	<LOD	<LOD	<LOD	<LOD	11.985	<LOD
41	BRAND37	BURSA	<LOD	0.757	<LOD	<LOD	<LOD	<LOD	<LOD	0.362	<LOD	<LOD	<LOD	<LOD	55.158	0.611
42	BRAND37	SAKARYA	<LOD	0.738	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	50.569	4.223

<LOD: Below measurable limit

Table 4. Rotated component matrix.

Variable	Factor1	Factor2	Factor3	Factor4	Communality
Li	**0.758**	0.013	-0.078	-0.148	0.603
Sr	**0.748**	0.226	-0.289	-0.197	0.733
Sb	**-0.680**	0.086	-0.154	-0.234	0.548
Co	0.102	**-0.848**	0.072	-0.211	0.779
Be	0.183	**0.731**	0.116	-0.284	0.663
Mn	0.054	0.206	**0.845**	-0.140	0.779
V	0.216	0.248	**-0.590**	-0.251	0.520
Cd	-0.031	0.005	0.018	**0.919**	0.846
Variance	1.6908	1.4165	1.1947	1.1685	5.4705
% Var	0.211	0.177	0.149	0.146	0.684

Pearson Correlation Index (PCI)

Statistically significant relationships and correlation coefficient values between the data of the parameters detected in bottled water were given in Table 5 (n=42). Parameters that below the LOD value in the elemental analysis results of bottled water samples have been excluded in the Pearson correlation analysis. According to Pearson Correlation Index (PCI) results, positive correlations were recorded between Li - Sr ($p<0.01$), and negative correlations between Be - Co ($p<0.05$) and Sr - V ($p<0.05$) detected in water samples.

Table 5. Pearson's correlation coefficients.

	Be	Cd	Co	Li	Mn	Sb	Sr	V
Be	1,000							
Cd	-0,187	1,000						
Co	-0,321*	-0,057	1,000					
Li	0,124	-0,113	0,015	1,000				
Mn	0,153	-0,024	-0,057	-0,020	1,000			
Sb	-0,073	-0,033	-0,078	-0,173	-0,033	1,000		
Sr	0,244	-0,175	-0,103	0,555**	-0,090	-0,239	1,000	
V	0,172	-0,147	-0,066	0,110	-0,147	-0,096	0,316*	1,000

*Correlation is significant at the 0.05 level.
**Correlation is significant at the 0.01 level.

CONCLUSION

In this study, toxic and trace elements in bottled water samples from various companies in different geographical regions were determined. Except for Sb, these values are below the maximum values allowed in national (RWHC) and international (EPA, WHO) regulations. The reason for the high concentrations of Sb may be attributed to the use of antimony trioxide (Sb_2O_3) in the production of polyethylene terephthalate (PET). Moreover, an analytical method was established using ICP-OES. Linearity, limits of detection and quantification, recovery, and accuracy were also determined. %RSD ranged from 0.23% to 6.91%. Recovery values were determined to be above 85% for toxic metals, indicating sufficient precision and accuracy of the analyses. Additionally, the results showed that there were no risk concerns for public health consuming bottled drinking water except for sample 21 and sample 38. However, repeating similar studies within a larger sample periodically is very important in terms of protecting public health and monitoring the issue.

ACKNOWLEDGMENT
The authors report no conflicts of interest.

REFERENCES

[1] Pandey, S. (2006). Water pollution and health. Kathmandu University Medical Journal (KUMJ), 4(1), 128-134.

[2] Alzaridi, F. M. N. S., & Kurnaz, A. (2020). Determination of concentration levels of toxic elements and radon in drinking waters consumed in Kastamonu province, Turkey. International Journal of Environmental Analytical Chemistry, 1-12.

[3] WHO (2022). Guidelines for Drinking-Water Quality, Fourth Edition, Incorporating the First and Second Addenda. World Health Organization, Geneva.

[4] Ji, Y., Wu, J., Wang, Y., Elumalai, V., Subramani, T. (2020). Seasonal variation of drinking water quality and human health risk assessment in Hancheng City of Guanzhong Plain, China. Exposure and Health, 12(3): 469-485.

[5] Matricon, J. (2015). Yaşasın su. Yapı Kredi Yayınları, İstanbul.

[6] Xiaowen D., Shouyan, W., Guihong, J. and Guohe, H. (2017) A simulation program on change trend of pollutant concentration under water pollution accidents and its application in Heshangshan drinking water source area. Journal of Cleaner Production. 167, 326-336.

[7] Aşıkkutlu B., Gümüş, N.E., & Akköz, C. (2021). Water Quality Properties of Acı Lake and Meke Lake (Konya/Turkey). Journal of Limnology and Freshwater Fisheries Research, 7(3), 260-270.

[8] Keskinkaya, H. B., Gümüş, N. E., Aşıkkutlu, B., Akköz, C., Okudan, E. Ş., & Karakurt, S. (2020). Macro and Trace Element Levels of Green Algae Codium fragile (Suringar) Hariot 1889 From Dardanelles (Çanakkale/Turkey). Anadolu Orman Araştırmaları Dergisi, 6(2), 55-61.

[9] Kibria, G. (2016). Trace metals/heavy metals and its impact on environment, biodiversity and human health-A short review. 5p. doi: 10.13140/RG. 2.1. 3102.2568.

[10] Aşıkkutlu, B. , Akköz, C. & Öztürk, B. Y. (2014). Çavuşçu Gölü'nün (Konya/Ilgın) Bazı Su Kalite Özellikleri. Selçuk Üniversitesi Fen Fakültesi Fen Dergisi, (39), 1-9.

[11] Bhardwaj, L. K., & Sharma, A. (2021). Estimation of Physico-Chemical, Trace Metals, Microbiological and Phthalate in PET Bottled Water. Chemistry Africa, 1-11.

[12] Fiket Ž, Roje V, Mikac N, Kniewald G (2007) Determination of arsenic and other trace elements in bottled waters by high resolution inductively coupled plasma mass spectrometry. Croat. Chem Acta 80(1):91–100 65.

[13] Shotyk W, Krachler M (2007) Lead in bottled waters: contamina-tion from glass and comparison with pristine groundwater. Environ Sci Technol 41(10):3508–3513.

[14] Gilbert, M. (2017). Plastics materials: Introduction and historical development. In Brydson's plastics materials (pp. 1-18). Butterworth-Heinemann.

[15] Güler, C., & Alpaslan, M. (2009). Mineral content of 70 bottled water brands sold on the Turkish market: assessment of their compliance with current regulations. Journal of Food composition and Analysis, 22(7-8), 728-737.

[16] Osei AS, Newman MJ, Mingle JA, Ayeh-Kumi PF, Kwasi MO (2013) Microbiological quality of packaged water sold in Accra, Ghana. Food Control 31(1):172–175.

[17] Cidu, R., Frau, F., & Tore, P. (2011). Drinking water quality: Comparing inorganic components in bottled water and Italian tap water. Journal of Food Composition and Analysis, 24(2), 184-193.

[18] Gümüş, N. E., Karataş, M., & Akköz, C. (2013). Chemical and bacteriological properties of fresh water fountains of Karaman province. Journal of Applied Biological Sciences, 7(1), 61-65.

[19] Michalski, R., Jabłońska-Czapla, M., Szopa, S., & Łyko, A. (2018). Analysis of commercially available bottled water in Poland. Environmental Engineering & Management Journal (EEMJ), 17(7), 1667-1677.

[20] Ehya, F., & Ghanavati, Z. (2019). Chemical characterization and quality assessment of some bottled water brands from the Kohgiluyeh-va-Boyer Ahmad province market, SW Iran. Toxin Reviews, 38(1), 77-85.

[21] Kilic, S., & Kilic, M. (2019). Determination of trace elements and human health risk assessment in bottled spring water: method validation. Atomic Spectroscopy, 40(5). 161–166.

[22] Roje, V., & Šutalo, P. (2019). Trace and major elements in Croatian bottled waters. Journal of Geochemical Exploration, 201, 79-87.

[23] SUDER, 2021. Packaged Water Manufacturers Association (Ambalajlı Su Üreticileri Derneği) Web Page: https://suder.org.tr/

[24] EPA (2018). Edition of the drinking water standards and health advisories tables. US Environmental Protection Agency, Washington.

[25] Republic of Turkey Ministry of Health. (2005). İnsani Tüketim Amaçlı Sular Hakkında Yönetmelik (Turkish Regulation on Water for Human Consumption).

[26] Eurachem Guide (2014) The Fitness of Purpose of Analytical Methods A Laboratory Guide to Method Validation and Related Topics, 2nd ed.;Magnusson, B., Örnemark, U., Eds.; Eurachem: Leoben, Austria; ISBN: 978-91-87461-59-0, https://www.eurachem.org.

[27] AOAC Official Methods of Analysis. (2016). Appendix F: Guidelines for standard method performance requirements.

[28] Shotyk, W., Krachler, M., & Chen, B. (2005). Anthropogenic impacts on the biogeochemistry and cycling of antimony. Metal ions in biological systems, 44, 171.

[29] Turksoy, V. A., Deniz, S., Tutkun, L., & Kirat, G. (2019). Evaluation of the Sources of Yozgat Fountain Water in Terms of Seasonal Distribution, Turkey. Journal of the Geological Society of India, 94(5), 538-544.

[30] Galbally, M., Bergink, V., Vigod, S. N., Buist, A., Boyce, P., Chandra, P., ... & Howard, L. M. (2018). Breastfeeding and lithium: is breast always best?. The Lancet Psychiatry, 5(7), 534-536.

[31] Eyre-Watt, B., Mahendran, E., Suetani, S., Firth, J., Kisely, S., & Siskind, D. (2021). The association between lithium in drinking water and neuropsychiatric outcomes: A systematic review and meta-analysis from across 2678 regions containing 113 million people. Australian & New Zealand Journal of Psychiatry, 55(2), 139-152.

[32] Kocak, N., Sahin, M., & Gubbuk, I. H. (2012). Synthesized of sporopollenin-immobilized Schiff bases and their vanadium (IV) sorption studies. Journal of Inorganic and Organometallic Polymers and Materials, 22(4), 852-859.

[33] Vasseghian, Y., Rad, S. S., Vilas–Boas, J. A., & Khataee, A. (2021). A global systematic review, meta-analysis, and risk assessment of the concentration of vanadium in drinking water resources. Chemosphere, 267, 128904.

[34] Wuilloud, R. G., Salonia, J. A., Olsina, R. A., & Martinez, L. D. (2000). Determination of vanadium (V) in drinking water by flow injection and pre-concentration in a knotted reactor by inductively coupled plasma optical emission spectrometry with ultrasonic nebulization. Spectrochimica Acta Part B: Atomic Spectroscopy, 55(6), 671-680.

[35] Kilic, S. (2019). Survey of trace elements in bottled natural mineral waters using ICP-MS. Environmental Monitoring and Assessment, 191(7), 1-7.

[36] Köse, E., Tokatli, C., & Çiçek, A. (2014). Monitoring Stream Water Quality: A Statistical Evaluation. Polish Journal of Environmental Studies, 23(5).

[37] Liu, C. W., Lin, K. H., & Kuo, Y. M. (2003). Application of factor analysis in the assessment of groundwater quality in a blackfoot disease area in Taiwan. Science of the total environment, 313(1-3), 77-89.