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Report

# Evaluation of maximum contaminant levels in Turkish bottled drinking waters utilizing parameters reported on manufacturer's labeling and government-issued production licenses

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**Abstract**

A total of 189 domestic brands of bottled water consisting of natural spring, natural mineral, drinking and processed drinking types were evaluated by means of both physical and chemical parameters reported on their manufacturer's labeling and/or in government-issued production licenses. A comparison between the water composition and the maximum contaminant levels imposed by the Turkish legislation (*Resmi Gazete*, No. 23144) for all parameters is discussed. The results obtained were also compared with the European Economic Community Council Directive 98/83/EC and standards set by International Bottled Water Association, US Food and Drug Administration, US Environmental Protection Agency and World Health Organization. Results show that a significant number of bottled water brands contain some elements (e.g. sodium, chloride, sulfide, fluoride, polycyclic aromatic hydrocarbons (PAHs) and several heavy metals) above the maximum concentration allowed for bottled waters by the Turkish legislation as well as several other international organizations.


*Keywords:* Bottled water; Mineral water; Drinking water standards; Maximum contaminant level; Turkey; Food safety

## 1. Introduction

Freshwater is scarce, and resources are unevenly distributed throughout the world, with much of the water located far from human populations. Today, 450 million people in 29 countries suffer from water shortages (UNEP, 2002), and water-related concerns are the most acute in arid or semi-arid areas. Many countries with scarce water resources rely on alternative or non-conventional water resources. For example, the demand for water in Kuwait is met from three non-freshwater sources such as seawater desalination plants (53%), brackish groundwater (37%) and treated wastewater (10%) (Abu Hijleh, 1988). In such countries, consumption of bottled water is a growing practice (Al Fraij et al., 1999; Nsanze et al., 1999) and is a necessity rather than a choice because of lack of access to clean water resources. Nowadays, many people living in urban areas are increasingly consuming bottled water because it is associated with ''naturalness'' (Saad et al., 1998), because they object to unpleasant tastes and odors such as chlorine from municipal water supplies (Tamagnini and González, 1997), and because bottled water is often regarded as safer and healthier than tap water (Armas and Sutherland, 1999). In many parts of the world, there is also a common belief that natural (mineral) waters have beneficial medicinal and therapeutic effects (Warburton et al., 1992). Bottled water is also utilized in emergency or water shortage situations caused by natural disasters (e.g. drought, earthquake, flood and hurricane) or human-made disasters (e.g. sabotage, siege, terrorism and war), which can severely damage public and private water supplies for extended periods of time.

The popularity of bottled water can be gauged by the number of brands produced worldwide (over 5000); a significant portion of these brands are traded internationally. For instance, Turkey exports bottled water to some 60

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different countries, with the bulk of the exports to European countries (58%) and the rest to Africa and Asia (42%). In a 2002 survey, published by a market research company, it is estimated that people all over the world drink annually about $131 \times 10^9$ L of bottled water (Beverage Marketing Corporation, 2003); and western Europeans, as a whole, drink nearly half of all the world's bottled water (Williams, 2001). Western Europe is not only the largest regional market, but it is also the most developed. It is dominated by Italy, France, Belgium, Germany and Spain, in all of which per capita consumption of bottled water has exceeded the 100 L barrier in L per capita per year (Table 1). This estimated US$45 billion worldwide industry is growing faster than ever as water quality concerns, fitness and health awareness increase among the consumers (based on an estimated price of 0.35 US$ per L of bottled water, Pilat, 2002).

Table 1
Per capita consumption of bottled water in leading countries (in liters per capita per year)

| Country | Year | | | |
|---|---|---|---|---|
| | 1996 | 1997 | 2001 | 2002 |
| Italy[a] | 126.8 | 132.9 | 164.3 | 167.3 |
| Mexico[a] | 106.4 | 108.3 | 129.8 | 142.7 |
| France[a] | 97.3 | 103.3 | 131.4 | 140.4 |
| United Arab Emirates[a] | 97.3 | 101.4 | 118.5 | 133.2 |
| Belgium-Luxemburg[a] | 109.0 | 114.7 | 123.4 | 123.8 |
| Germany[a] | 96.9 | 99.9 | 106.4 | 109.0 |
| Spain[a] | 84.4 | 90.5 | 103.3 | 106.7 |
| Lebanon[a] | 48.1 | 52.2 | 85.2 | 93.9 |
| Switzerland[a] | 79.9 | 85.9 | 90.1 | 91.6 |
| Saudi Arabia[a] | 57.2 | 64.7 | 85.2 | 90.1 |
| United States of America[a] | 49.6 | 53.4 | 73.8 | 81.4 |
| Cyprus[a] | 53.8 | 65.1 | 76.5 | 81.0 |
| Czech Republic[a] | 48.8 | 53.8 | 74.2 | 79.9 |
| Austria[a] | 70.0 | 70.0 | 77.6 | 79.1 |
| Turkey[b] | — | — | 70.0 | 78.0 |
| Thailand[a] | 54.9 | 59.8 | 73.4 | 76.1 |

[a]Beverage Marketing Corporation (2003).
[b]Çelik (2003).

During the past decade, there has been a considerable increase in the consumption of bottled water in Turkey, and it is estimated that 70% of the households in Turkey regularly utilize bottled water to meet their daily drinking water requirements (Çelik, 2003). Turkish people consumed about $5.2 \times 10^9$ L of bottled water in 2002, which is approximately 78 L per capita (Çelik, 2003). The source of 89% of bottled water sold in Turkey is from protected springs, and the remaining 11% is pumped from drilled wells tapping an aquifer. However, at present, only 20% of natural spring water (still) resources and 1% of natural mineral water (sparkling) resources are utilized by the Turkish bottled water industry. The industry's annual capacity usage averages around 35–55% because of demand differences between winter/summer seasons and improving quality of tap water supplied by municipalities.

Beginning with early 1990s, especially in major cities, a drinking water crisis occurred which has boosted bottled water consumption and the number of manufacturers (brands) in Turkey (Fig. 1). There were several reasons for this water crisis: (1) faulty design and construction of the water supply networks; (2) insufficient water supply from city water distribution networks; (3) problems in the taste, purity and odor of tap water and (4) erratic power supply. All these factors resulted in public distrust of tap water. As a result, in Turkey (population about 70 million) bottled water has become a lucrative market with a US$500 million retail value (Çelik, 2003). This is a proof that the bottled water industry has done an outstanding job in marketing its product as a safe alternative to tap water, even though the price of bottled water is 250–600 times higher than that of tap water.

The purpose of this paper is to investigate the specific physical, chemical and industry characteristics of domestic brands of bottled water sold in Turkish market utilizing parameters reported on both manufacturer's labeling and in government-issued production licenses. A review of the

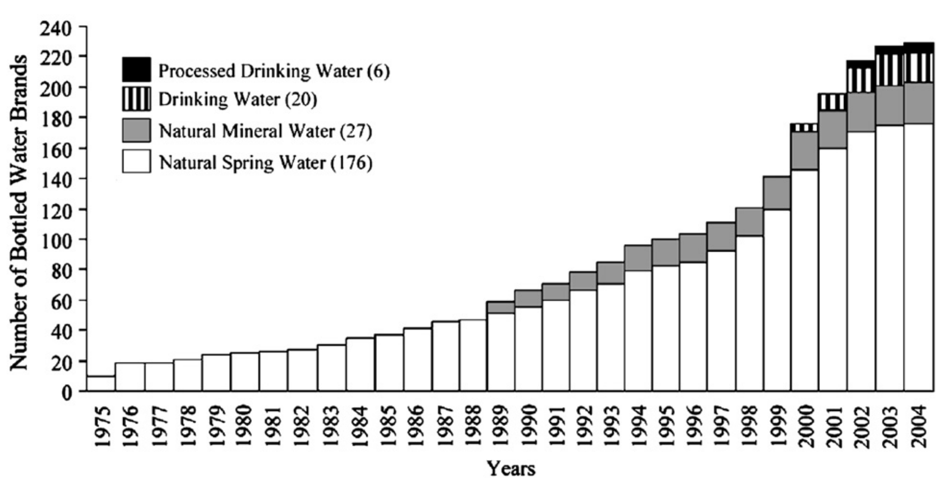


Fig. 1. Number of domestic brands of bottled water vs. their establishment years.

current regulations regarding bottled water in Turkey was also made and compared to several standards around the world including European Economic Community Council Directive 98/83/EC (EEC, 1998), International Bottled Water Association (IBWA) (IBWA, 2003), United States Food and Drug Administration (FDA, 2003), United States Environmental Protection Agency (EPA, 2002) and World Health Organization (WHO, 1998).

## 2. Materials and methods

### 2.1. Bottled water dataset

The physicochemical parameters reported on the manufacturer's labeling and/or government-issued production licenses of 189 domestic brands of bottled water were used as dataset for this study. The analyses results that are shown on the bottle labeling are based on data provided on the production licenses issued by the Ministry of Health. When the production license for a particular brand was not available (or not found), the manufacturer's labeling was used to obtain the data. Labels were mostly obtained directly from the bottled waters sold in different regions in Turkey. To obtain copies of the production licenses, bottled water manufacturers were contacted by telephone and/or electronic mail. Where available, production licenses were also obtained from the company websites found on the internet. In all, information about 189 brands—which represent 82.5% of the domestic brands of bottled water currently sold in Turkish market—was obtained through all these methods. Information on about 40 brands was not available through any of these methods; these are all small-scale local bottled water producers with a total market share of less than 2%. To keep the brand names anonymous, the waters were numbered from 1 through 189 and this convention was used throughout the text.

### 2.2. Bottled water types in Turkey

Today, there are 229 domestic brands of bottled water (excluding fruit-flavored bottled waters) recognized and certified by the Turkish Ministry of Health, and their numbers and diversity continues to increase (Fig. 1). The Turkish Ministry of Health distinguishes between several types of water according to their source (the point of emergence) and physical/chemical properties, each with its own definition (Resmi Gazete, 1997). In Turkey, commercialization of surface waters (e.g. lake, reservoir and river waters) is prohibited. In other words, surface waters cannot be bottled and sold for human consumption. Turkish bottled waters are divided into several classes as follows: (1) natural spring water (176 brands); (2) natural mineral water (27 brands); (3) drinking water (20 brands); and (4) processed drinking water (6 brands). Drinking water and processed drinking water types were recently (beginning with the years 2000 and 2002, respectively) added categories with the entrance of global-scale soft drink companies into the Turkish market. These companies take advantage of their large distribution networks to sell mostly purified water. The sources of drinking and processed drinking water types are mostly from drilled wells tapping an aquifer unlike the natural spring and mineral waters, which are generally from protected (free flowing) spring sources.

According to Turkish legislation (*Resmi Gazete* no. 23144) "natural spring water" must be derived from an underground formation with favorable geologic conditions, from which water flows naturally and constantly to the surface of the earth, and its physical/chemical properties conform to the standards set by the Turkish Ministry of Health (Table 2). Natural spring waters may be subjected to filtration, ultraviolet irradiation and ozonation processes in order to protect the product from pollution of microorganisms originating from the water itself (autochthonous microflora) or microorganisms introduced during the bottling process (allochthonous microflora). Ozonation is widely used in bottling process and it destroys any bacteria or biofilms that are present in bottles (Warburton and Austin, 1997). Other means of disinfection processes such as chlorination is not allowed for this type of water. "Natural mineral water" must be derived from an underground formation with favorable geologic conditions, contains at least 1000 mg $L^{-1}$ dissolved minerals and/or trace elements, naturally contains carbon dioxide ($CO_2$) gas and radioactive elements and flows naturally to the surface of the earth or extracted by an approved method (water may be hot or cold at source) and having clinically proven health-benefit effects determined by the Turkish Ministry of Health; its physical/chemical properties conform to the standards set by the Turkish Ministry of Health (Table 2). "Drinking water" must be derived from an underground formation with favorable geologic conditions, from which water flows naturally to the surface of the earth or is extracted by a method (generally drilling a borehole) approved by the Turkish Ministry of Health; its physical/chemical properties conform to the Turkish standards set for drinking water (Table 2). "Processed drinking water" is extracted from an unpolluted aquifer by a method approved by Turkish Ministry of Health and this type of water may be subject to disinfection (e.g. with ozone), filtration (e.g. with activated carbon), purification (e.g. with reverse osmosis) or other suitable processes and its physical/chemical properties may be changed by removal and/or addition of minerals (e.g. removal of arsenic and addition of fluoride); it also conforms to the standards set for "drinking waters" (Table 2).

### 2.3. Bottled water regulations and standards

Today, consumers from all age groups drink bottled water on a daily basis for many different reasons. Therefore, in many parts of the world, bottled water is considered an important element in the human diet and plays a major role in the intake of a number of nutritional and toxic trace elements (Nkono and Asubiojo, 1997). Water is known as a universal solvent and even in its natural state may contain substantial amount of elements in rather high concentrations. Concentrations vary over a wide range depending on the aquifer lithology from which

Table 2
Present regulations and standards for water intended for human consumption

| Parameter | Unit | EEC[a] (1998) | WHO[a] (1998) | EPA[a] (2002) | IBWA[a] (2003) | FDA[a] (2003) | Turkish Legislation R.G. no. 23144[a] (1997) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Drinking water (MAC[b]) | Drinking water (GV[c]) | Drinking water (MCL[d]) | Bottled water (SOQ[e]) | Bottled water (MAL[f]) | Bottled drinking water (MAC[b]) | Bottled spring water (MAC[b]) | Bottled mineral water (MAC[b]) |
| *Physical* | | | | | | | | | |
| Color | Pt/Co scale | — | — | 15[g] | 5 | 15[h] | 10 | 5 | 5 |
| pH | — | 6.5–9.5 | — | 6.5–8.5[g] | 6.5–8.5 | — | 5.5–8.5 | 5.5–8.5 | — |
| BOD | $mg\,L^{-1}$ | — | — | — | — | — | 3.5 | 2 | 5 |
| TDS | $mg\,L^{-1}$ | — | — | 500[g] | 500[h] | 500[h] | — | — | — |
| Turbidity | NTU | — | — | 1 | 0.5 | 5 | 5 | 2 | 5 |
| *Disinfectants and disinfection byproducts* | | | | | | | | | |
| Bromate | $mg\,L^{-1}$ | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | — | — | — |
| Chlorine | $mg\,L^{-1}$ | — | 5 | 4 | 0.1 | 4 | — | — | — |
| Chlorite | $mg\,L^{-1}$ | — | 0.7 | 1 | 1 | 1 | — | — | — |
| Haloacetic Acids | $mg\,L^{-1}$ | — | See[i] | 0.06 | 0.06 | 0.06 | — | — | — |
| Total Trihalomethanes | $mg\,L^{-1}$ | 0.1 | See[i] | 0.08 | 0.01 | 0.08 | — | — | — |
| *Inorganic chemicals* | | | | | | | | | |
| Aluminum ($Al^{3+}$) | $mg\,L^{-1}$ | 0.2 | — | 0.2[g] | 0.2 | 0.2 | 0.2 | 0.05 | 0.2 |
| Ammonium ($NH_4^+$) | $mg\,L^{-1}$ | 0.5 | — | — | — | — | 0.05 | 0 | — |
| Antimony (Sb) | $mg\,L^{-1}$ | 0.005 | 0.018 | 0.006 | 0.006 | 0.006 | 0.005 | 0.005 | 0.005 |
| Arsenic (As) | $mg\,L^{-1}$ | 0.01 | 0.01[j] | 0.01 | 0.01 | 0.05 | 0.01 | 0.01 | 0.01 |
| Asbestos (fibers $>10\,\mu m$) | $10^6$ fibers $L^{-1}$ | — | — | 7 | — | — | — | — | — |
| Barium ($Ba^{2+}$) | $mg\,L^{-1}$ | — | 0.7 | 2 | 1 | 2 | — | — | 1 |
| Beryllium (Be) | $mg\,L^{-1}$ | — | — | 0.004 | 0.004 | 0.004 | — | — | — |
| Boron ($B^{3+}$) | $mg\,L^{-1}$ | 1 | 0.5[j] | — | — | — | 3 | 1 | 30 as BO |
| Cadmium ($Cd^{2+}$) | $mg\,L^{-1}$ | 0.005 | 0.003 | 0.005 | 0.005 | 0.005 | 0.003 | 0.005 | 0.003 |
| Calcium ($Ca^{2+}$) | $mg\,L^{-1}$ | — | — | — | — | — | 100 | 100 | — |
| Chloride ($Cl^-$) | $mg\,L^{-1}$ | 250 | — | 250[g] | 250[h] | 250[h] | 250 | 40 | — |
| Chromium (Cr) | $mg\,L^{-1}$ | 0.05 | 0.05[j] | 0.1 | 0.05 | 0.1 | 0.05 | 0.05 | 0.05 |
| Copper (Cu) | $mg\,L^{-1}$ | 2 | 2[j] | 1.0[g]–1.3[k] | 1 | 1 | 1.5 | 0.1 | 1 |
| Cyanide ($CN^-$) | $mg\,L^{-1}$ | 0.05 | 0.07 | 0.2 | 0.1 | 0.2 | 0.01 | 0.01 | 0.01 |
| Fluoride ($F^-$) | $mg\,L^{-1}$ | 1.5 | 1.5 | 2[g] | 0.8–1.7[l] | 0.8–2.4[l] | 1.5 | 1.5 | 2 |
| Iron (Fe) | $mg\,L^{-1}$ | 0.2 | — | 0.3[g] | 0.3[h] | 0.3[h] | 0.3 | 0.05 | — |
| Lead (Pb) | $mg\,L^{-1}$ | 0.01 | 0.01 | 0.015[l] | 0.005 | 0.005 | 0.01 | 0.01 | 0.01 |
| Magnesium ($Mg^{2+}$) | $mg\,L^{-1}$ | — | — | — | — | — | 50 | 30 | — |
| Manganese ($Mn^{2+}$) | $mg\,L^{-1}$ | 0.05 | 0.4 | 0.05[g] | 0.05[h] | 0.05[h] | 0.05 | 0.02 | 2 |
| Mercury (Hg) | $mg\,L^{-1}$ | 0.001 | 0.001 | 0.002 | 0.001 | 0.002 | 0.001 | 0.001 | 0.001 |
| Nickel (Ni) | $mg\,L^{-1}$ | 0.02 | 0.02[j] | 0.1 | 0.1 | 0.1 | 0.02 | 0.02 | 0.5 |
| Nitrate ($NO_3^-$) | $mg\,L^{-1}$ | 50 | 50 | 44 | 44 | 44 | 45 | 25 | 25 |
| Nitrite ($NO_2^-$) | $mg\,L^{-1}$ | 0.5 | 0.2 | 3.3 | 3.3 | 3.3 | 0.05 | 0 | 0.05 |
| Potassium ($K^+$) | $mg\,L^{-1}$ | — | — | — | — | — | 12 | 10 | — |
| Selenium (Se) | $mg\,L^{-1}$ | 0.01 | 0.01 | 0.05 | 0.01 | 0.05 | 0.01 | 0.01 | 0.05 |
| Silver (Ag) | $mg\,L^{-1}$ | — | — | 0.1[g] | 0.025 | 0.1 | — | — | — |
| Sodium ($Na^+$) | $mg\,L^{-1}$ | 200 | — | — | — | — | 175 | 30 | — |
| Sulfate ($SO_4^{2-}$) | $mg\,L^{-1}$ | 250 | — | 250[g] | 250[h] | 250[h] | 250 | 40 | 0.05 as S |
| Thallium (Tl) | $mg\,L^{-1}$ | — | — | 0.002 | 0.002 | 0.002 | — | — | — |
| Uranium (U) | $mg\,L^{-1}$ | — | 0.002 | — | 0.03 | 0.03 | — | — | — |
| Zinc ($Zn^{2+}$) | $mg\,L^{-1}$ | — | — | 5[g] | 5[h] | 5[h] | 5 | 5 | 6 |
| *Organic chemicals* | | | | | | | | | |
| Total pesticides | $mg\,L^{-1}$ | 0.0005 | See[i] | See[i] | See[i] | See[i] | 0.0001 | 0.0001 | 0.0001 |
| PAHs | $mg\,L^{-1}$ | 0.0001 | See[i] | See[i] | See[i] | See[i] | 0.0002 | 0.0002 | 0.0002 |
| Total recov. phenolics | $mg\,L^{-1}$ | See[i] | See[i] | See[i] | 0.001 | 0.001 | 0.02 | 0.00001 | — |

Table 2 (*continued*)

| Parameter | Unit | EEC[a] (1998) | WHO[a] (1998) | EPA[a] (2002) | IBWA[a] (2003) | FDA[a] (2003) | Turkish Legislation R.G. no. 23144[a] (1997) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Drinking water (MAC[b]) | Drinking water (GV[c]) | Drinking water (MCL[d]) | Bottled water (SOQ[e]) | Bottled water (MAL[f]) | Bottled drinking water (MAC[b]) | Bottled spring water (MAC[b]) | Bottled mineral water (MAC[b]) |
| *Radionuclides* | | | | | | | | | |
| Gross α-activity | $pCi\,L^{-1}$ | — | 2.7 | 15 | 15 | 15 | 2.7 | 2.7 | 40.5 |
| Gross β-activity | $pCi\,L^{-1}$ | — | 27 | 50 | 50 | 50 | 27 | 27 | 54 |

[a] *Sources* (see References): EEC = European Economic Community; WHO = World Health Organization; EPA = US Environmental Protection Agency; IBWA = International Bottled Water Association; FDA = US Food and Drug Administration; R.G. no. 23144 = Resmi Gazete (Official Newspaper of the Turkish Government), no. 23144.
[b] Maximum admissible concentration.
[c] Guideline value.
[d] Maximum contaminant level.
[e] Standard of quality.
[f] Maximum allowable level.
[g] Secondary maximum contaminant level (SMCL, which are [not enforceable] guidelines established by the EPA for use in evaluating esthetic properties in water).
[h] Mineral water is exempt from allowable level (the exemptions are esthetically based allowable levels).
[i] No total value is available and each individual substance has its own MCLs.
[j] Provisional guideline value (this term is used for constituents for which there is some evidence of a potential hazard).
[k] Action level.
[l] Fluoride MAC varies according to average temperature in geographical area concerned.

the spring flows and the presence of any water processing/treatment methods prior to bottling of the water. At elevated concentrations some elements can be harmful to health and can cause morphological abnormalities, mutagenic effects, reduced growth and increased mortality in humans (Nkono and Asubiojo, 1997). Anthropogenic contaminants can also be found in the water. They include agricultural chemicals (e.g. pesticides, insecticides, fungicides, fertilizers and nutrients), industrial chemicals (e.g. hydrocarbon derivatives and heavy metals), microorganisms and many more. Therefore, standards have been developed by international, national and non-governmental organizations to define a quality of water that is safe and acceptable to consumers. Most of these standards set limits for physical parameters, chemical constituents and microorganisms that are dangerous, potentially hazardous or obnoxious to consumers (Table 2). A substantial number of these standards are based on the WHO 1971 international standards for drinking water.

In developing the guideline values (GVs) for potentially hazardous chemicals, a daily consumption level of 2 L of drinking water by a person weighing 60 kg was generally assumed by most regulatory agencies (WHO, 1993). Where it was judged that infants and children were at a particularly high risk from exposure to certain chemicals, the GVs were derived on the basis of a 5-kg infant consuming 0.75 L per day or a 10-kg child consuming 1 L per day (WHO, 1998). The WHO guidelines for drinking water are the most comprehensive standard; they set limits for 99 different contaminants (WHO, 1998). The WHO "GVs" that are recommended are not mandatory limits and they are intended to be used in the development of risk management strategies.

In the United States of America, the quality of bottled water is regulated by the Food and Drug Administration because it is classified as a food product under the Federal Food, Drug and Cosmetic Act (FDA, 2003); however, all other water supplies for drinking waters are regulated by the EPA (EPA, 2002). The Hammer Provision of 1996 establishes that when the EPA changes or adds to its contamination standards, the FDA must also set a similar level for bottled water or report reasons for not doing so in the Federal Register. Therefore, the quality standards for bottled water set by the FDA must be at least as stringent as those adopted by the EPA for public drinking water systems. The FDA has established "maximum allowable levels" for 88 contaminants under the bottled water quality standard; some of them are presented in Table 2.

The EPA has established National Primary Drinking Water Regulations which set mandatory water quality standards for 79 drinking water contaminants (EPA, 2002). These are enforceable standards called "maximum contaminant levels", established to protect the public against consumption of drinking water contaminants that present a risk to human health. In addition, the EPA has established National Secondary Drinking Water Regulations that set non-mandatory water quality standards for 15 contaminants. The EPA does not enforce these "secondary maximum contaminant levels". They are established only as guidelines to assist public water systems in managing their drinking water for esthetic considerations, such as taste, color and odor.

The bottled water industry in the United States also has its own self-regulating body, the IBWA. IBWA was established in 1958 and maintains standards (standard of quality, SOQ) for its members which are often stricter than federal and state regulations on bottled water (Table 2). Each member bottler of IBWA is required to pass a yearly unannounced inspection of its bottling facilities by the National Sanitation Foundation. In addition to meeting standards set by the FDA, bottlers must also comply with IBWA regulations called the Model Code of the IBWA (IBWA, 2003).

Current bottled water standards in EEC countries are based on requirements set out in Council Directive 98/83/EC relating to "the quality of water intended for human consumption," which has replaced Council Directive 80/778/EEC (EEC, 1980, 1998). The new Directive laid down a set of mandatory quality standards (maximum admissible concentrations, MACs) for drinking water throughout the EEC. New parameters have been added (15), but overall the total number of parameters has been reduced (from 66 in 80/778/EEC to 50 in 98/83/EC for bottled water) to include only those considered essential at the level of the EEC. Natural mineral waters and medicinal products are not covered by the new Directive (EEC, 1998).

In Turkey, the quality of bottled waters has been regulated by the Turkish Ministry of Health since 1997 (Resmi Gazete, 1997). Unlike the other regulating agencies, Turkish legislation divides bottled waters into four categories and sets different standards for each category as shown in Table 2. Under Turkish legislation, bottled drinking waters and bottled processed drinking waters are subject to the same standards as those set by the Turkish Ministry of Health (Table 2). In contrast, US legislation does not distinguish between bottled drinking water and bottled mineral water, classifying them both as bottled water (EPA, 1989). The basis used for the Turkish bottled water standards includes the previous WHO guidelines and EEC Directives. Therefore Turkey's bottled water legislation is similar to these standards. However, Turkish legislation did not set standards for the following parameters: total dissolved solids (TDS), disinfectants and disinfection byproducts (e.g. bromate, chlorine, chlorite, haloacetic acids (HAA) and total trihalomethanes), asbestos, beryllium (Be), silver (Ag), thallium (Tl) and uranium (U) (Table 2).

## 3. Results and discussion

In order to identify the main characteristics of Turkish bottled waters, an extensive dBASE IV database was built, consisting of 189 rows (bottled water brands) and 45 columns (measured parameters). This equals 8505 ($189 \times 45$) spreadsheet cells in total; however, only about 60% of these cells (5113) contain a reported parameter value, and almost 35% of the cells having a reported parameter value (1758) show a value of zero or below detection limit values (indicated as "trace") (Fig. 2). Parameters reported on the labels and production licenses consist of:

(1) Physical properties: alkalinity, biological oxygen demand, color, electrical conductivity (EC), total hardness, pH, TDS, turbidity;
(2) Inorganic chemicals: aluminum (Al), arsenic (As), boron (B), barium (Ba), bromide (Br), calcium (Ca), cadmium (Cd), chloride (Cl), chromium (Cr), copper (Cu), cyanide (CN), fluoride (F), iron (Fe), mercury (Hg), bicarbonate ($HCO_3$), potassium (K), magnesium (Mg), manganese (Mn), sodium (Na), nickel (Ni), ammonium ($NH_4$), nitrite ($NO_2$), nitrate ($NO_3$), lead (Pb), selenium (Se), antimony (Sb), strontium (Sr), sulfate ($SO_4$), silica ($SiO_2$), zinc (Zn), active chloride;
(3) Organic chemicals: total recoverable phenolics, (TRPs) polycyclic aromatic hydrocarbons (PAHs), total pesticides (TPs);

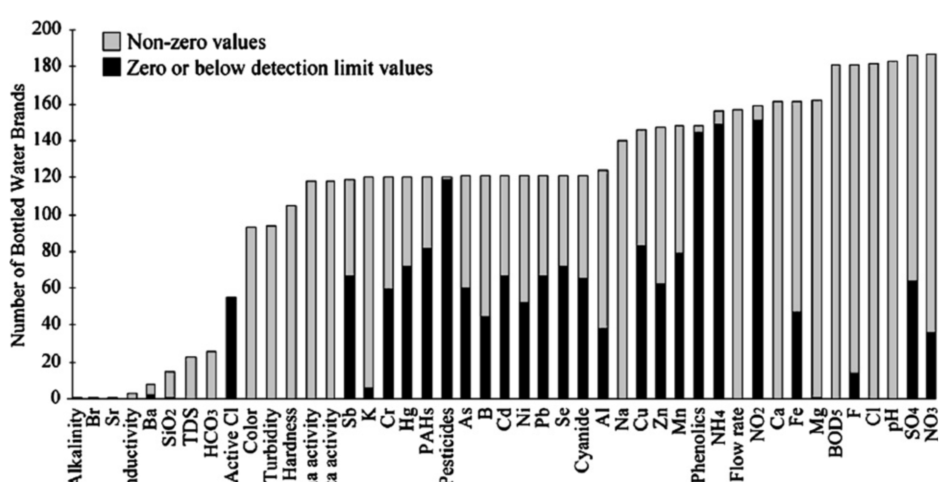


Fig. 2. Number of domestic brands of bottled water vs. frequency of the reported parameters.

(4) Radionuclides: gross $\alpha$- and $\beta$-activities; and
(5) Microorganisms: coliform bacteria, fecal streptococci, germ count at 22 °C—72 h, germ count at 37 °C—48 h, and *Pseudomonas aeruginosa*.

The number and type of parameters reported on the labels of Turkish bottled water showed a lack of homogeneity (Fig. 2). The most and least number of parameters reported on the labels were 41 (brand 180) and 4 (brand 98), respectively. Basic parameters (major ions) were usually indicated on the labels, whereas only three labels for example reported on the EC values, and only one label reported on the alkalinity, Br and Sr (Fig. 2). The other extreme is for $NO_3$, which was reported on the 187 out of 189 labels. Government-issued production licenses, however, consistently reported on up to 34 parameters and was a valuable information source for this study. Reporting frequencies for all 45 parameters are shown in Fig. 2.

Analysis of chemical and physical properties of all the bottled waters were carried out by official laboratories that have been certified by the Turkish Ministry of Health and accuracy/precision of the laboratory results were not questioned in this study. A complete analytical control is scheduled with a three to six months frequency, depending on the water type. Locations of springs and/or wells used for bottling are shown in Fig. 3. The majority of waters are found in western part of Turkey; producers are concentrated mainly around the big cities such as İstanbul, İzmir and Ankara because the demand for bottled water is very high in these densely populated areas. Bottled water producers choose locations (springs or wells) near population centers to reduce high transportation costs as well.

The physicochemical composition of Turkish bottled waters in four categories (natural spring, natural mineral, drinking and processed drinking) is summarized in Table 3. The mean, standard deviation ($\pm$S.D.), minimum and maximum concentrations were determined. The data screening showed that the data used in this study were universally skewed positively; the data contained a small number of high values. Most naturally occurring element distributions follow this pattern (Miesch, 1976). The results obtained indicated that there are considerable variations among the examined bottled waters with respect to their chemical constituents (Table 3). For most elements the difference between the lowest and the highest elemental concentration was one–three orders of magnitude. Of all the water types studied, natural mineral water showed the highest mean concentration for the chemical constituents reported on labels and production licenses. A comparison of the mean values of the elements in the natural spring and natural mineral waters showed that, with the exception of Cd, the concentrations of Al, Ca, Cl, F, Fe, Mn and $SO_4$ are approximately 10 times higher in the natural mineral waters compared to natural spring waters (Table 3).

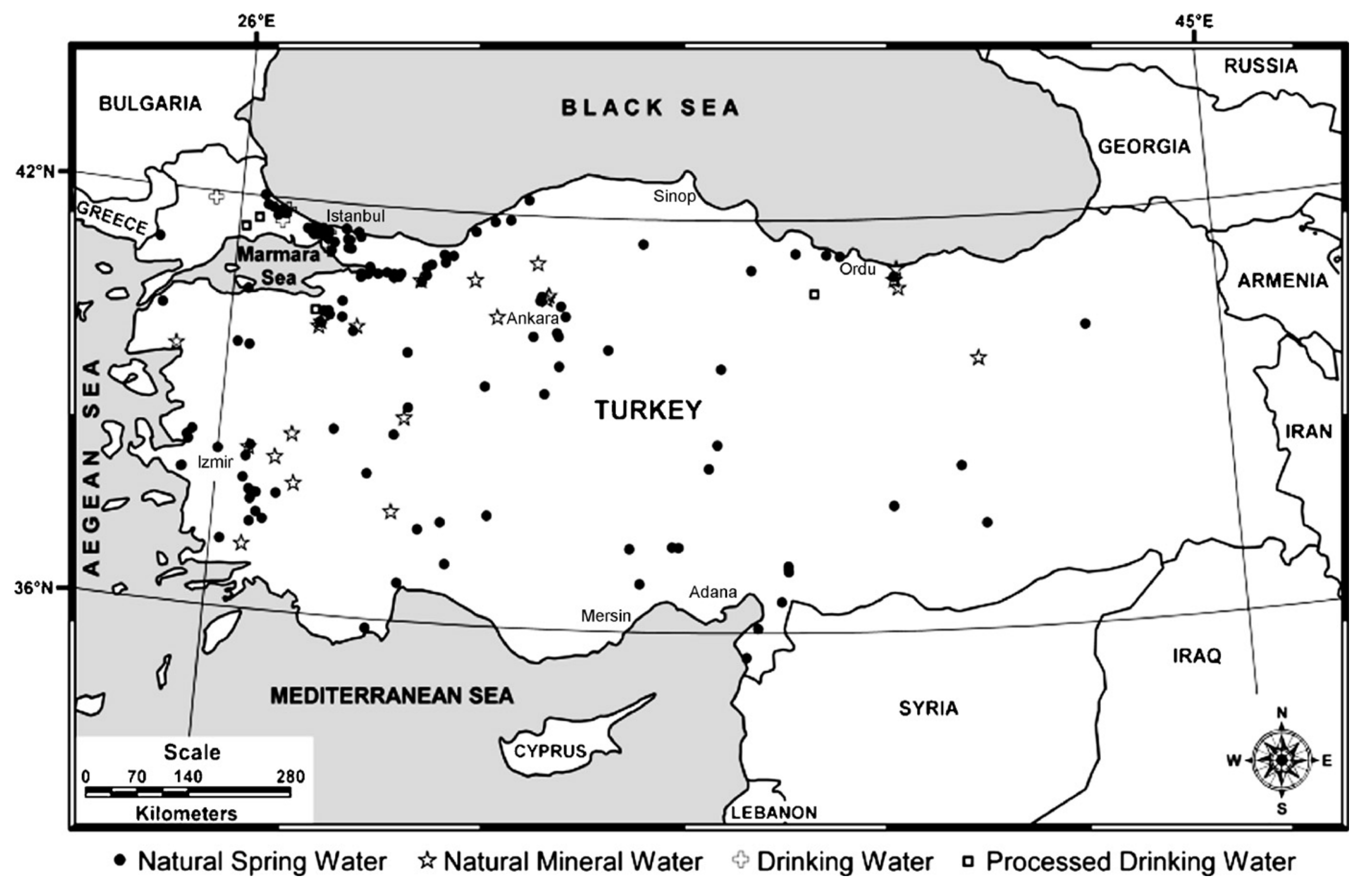


Fig. 3. Location of springs and wells used for bottling natural spring, natural mineral, drinking and processed drinking water types in Turkey.

Table 3
Statistics for the water quality parameters for each of the water classes (parameters were reported on the label and production licenses of 189 brands of Turkish bottled water)

| Parameter | Natural spring water (148 brands) | | | Natural mineral water (24 brands) | | | Drinking water (12 brands) | | | Processed drinking water (5 brands) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $n^a$ | Mean ± S.D. | Min.–Max. | $n^a$ | Mean ± S.D. | Min.–Max. | $n^a$ | Mean ± S.D. | Min.–Max. | $n^a$ | Mean ± S.D. | Min.–Max. |
| BOD ($mg\,L^{-1}$) | 142 | 0.7 ± 0.3 | 0.2–2 | 22 | 1.2 ± 0.64 | 0.2–3.04 | 12 | 0.55 ± 0.29 | 0.2–1.1 | 5 | 0.56 ± 0.33 | 0.2–1.1 |
| Color (Pt–Co scale) | 68 | 0.97 ± 0.99 | 0.1–3 | 12 | 1.66 ± 1.76 | 0.3–5 | 9 | 0.87 ± 1.2 | 0.1–3 | 4 | 0.35 ± 0.1 | 0.3–0.5 |
| Spring flow rate ($L\,s^{-1}$) | 128 | 16.8 ± 141.6 | 0.041–1600 | 18 | 2.4 ± 2.8 | 0.4–10 | 10 | 4.4 ± 3.3 | 1.2–12.6 | 1 | 1.4 ± 0 | 1.4 |
| Hardness (°Fr) | 84 | 4.8 ± 3.6 | 0.7–17 | 11 | 73.7 ± 44 | 9–125 | 5 | 4.36 ± 1.6 | 2.5–6.3 | 5 | 1.38 ± 0.95 | 0.5–2.5 |
| pH | 147 | 7.1 ± 0.63 | 5.6–8.2 | 19 | 6.36 ± 0.59 | 5.3–7.9 | 12 | 6.9 ± 0.74 | 6.04–8.2 | 5 | 6.8 ± 0.8 | 5.75–8.02 |
| Turbidity (NTU) | 67 | 0.59 ± 0.59 | 0.048–2 | 13 | 1.47 ± 1.1 | 0.28–3.82 | 10 | 0.28 ± 0.13 | 0.02–0.5 | 4 | 0.28 ± 0.05 | 0.2–0.3 |
| Aluminum ($mg\,L^{-1}$) | 102 | 0.027 ± 0.05 | Trace–0.38 | 11 | 0.24 ± 0.75 | Trace–2.5 | 11 | 0.015 ± 0.02 | Trace–0.05 | — | — | — |
| Ammonium ($mg\,L^{-1}$) | 120 | N.D. | N.D. | 20 | 0.078 ± 0.14 | 0–0.44 | 11 | N.D. | N.D. | 5 | N.D. | N.D. |
| Antimony ($mg\,L^{-1}$) | 101 | 0.003 ± 0.002 | Trace–0.005 | 7 | 0.0016 ± 0.002 | Trace–0.005 | 11 | 0.0027 ± 0.003 | 0–0.005 | — | — | — |
| Arsenic ($mg\,L^{-1}$) | 102 | 0.007 ± 0.004 | Trace–0.01 | 8 | 0.006 ± 0.005 | 0–0.01 | 11 | 0.004 ± 0.005 | 0–0.01 | — | — | — |
| Barium ($mg\,L^{-1}$) | — | — | — | 8 | 0.14 ± 0.35 | 0–1 | — | — | — | — | — | — |
| Boron ($mg\,L^{-1}$) | 102 | 0.14 ± 0.2 | Trace–1 | 8 | 4.3 ± 7.1 | 0.16–21.38 | 11 | 0.08 ± 0.09 | 0–0.3 | — | — | — |
| Cadmium ($mg\,L^{-1}$) | 102 | 0.0034 ± 0.002 | Trace–0.005 | 8 | 0.0016 ± 0.002 | Trace–0.003 | 11 | 0.002 ± 0.002 | 0–0.005 | — | — | — |
| Calcium ($mg\,L^{-1}$) | 122 | 16.8 ± 15.1 | 0.48–97.1 | 23 | 179.8 ± 119.2 | 46.09–420.84 | 11 | 11.7 ± 5.9 | 6–25 | 5 | 2.7 ± 3.1 | 0.8–8.16 |
| Chloride ($mg\,L^{-1}$) | 145 | 12.2 ± 8.2 | 0.15–40 | 20 | 119.6 ± 182.3 | 7.3–759.7 | 12 | 32.1 ± 19 | 10.7–73.8 | 5 | 10.6 ± 6.1 | 2.94–19 |
| Chromium ($mg\,L^{-1}$) | 102 | 0.017 ± 0.008 | Trace–0.05 | 7 | 0.011 ± 0.01 | Trace–0.02 | 11 | 0.011 ± 0.016 | 0–0.05 | — | — | — |
| Copper ($mg\,L^{-1}$) | 127 | 0.017 ± 0.01 | Trace–0.06 | 8 | 0.012 ± 0.009 | Trace–0.02 | 11 | 0.012 ± 0.01 | 0–0.02 | — | — | — |
| Cyanide ($mg\,L^{-1}$) | 102 | 0.003 ± 0.003 | 0–0.01 | 8 | 0.0011 ± 0.001 | 0–0.002 | 11 | 0.0025 ± 0.004 | 0–0.01 | — | — | — |
| Fluoride ($mg\,L^{-1}$) | 146 | 0.16 ± 0.16 | 0.006–0.9 | 18 | 0.58 ± 0.49 | 0.03–1.52 | 12 | 0.26 ± 0.3 | 0–1 | 5 | 0.17 ± 0.3 | 0–0.7 |
| Iron ($mg\,L^{-1}$) | 129 | 0.061 ± 0.33 | Trace–3.08 | 20 | 0.76 ± 1.4 | Trace–4.5 | 12 | 0.013 ± 0.01 | 0–0.02 | — | — | — |
| Lead ($mg\,L^{-1}$) | 102 | 0.009 ± 0.003 | Trace–0.01 | 8 | 0.006 ± 0.005 | Trace–0.01 | 11 | 0.005 ± 0.005 | 0–0.01 | — | — | — |
| Magnesium ($mg\,L^{-1}$) | 123 | 3.7 ± 3.4 | 0.012–17.4 | 23 | 92.3 ± 108.9 | 9.24–447.34 | 11 | 3.7 ± 2.3 | 0.9–8.5 | 5 | 1.7 ± 1.9 | 0.07–4.86 |
| Manganese ($mg\,L^{-1}$) | 128 | 0.016 ± 0.008 | Trace–0.062 | 8 | 0.23 ± 0.3 | 0.02–0.9 | 12 | 0.009 ± 0.01 | 0–0.02 | — | — | — |
| Mercury ($mg\,L^{-1}$) | 101 | 0.0008 ± 0.0003 | Trace–0.001 | 8 | 0.0005 ± 0.001 | Trace–0.001 | 11 | 0.0005 ± 0.0005 | 0–0.001 | — | — | — |
| Nickel ($mg\,L^{-1}$) | 102 | 0.016 ± 0.007 | Trace–0.02 | 8 | 0.012 ± 0.009 | Trace–0.02 | 11 | 0.017 ± 0.03 | 0–0.1 | — | — | — |
| Nitrate ($mg\,L^{-1}$) | 146 | 4.5 ± 4.3 | 0.05–19.4 | 24 | 4.82 ± 6.3 | 0–20 | 12 | 1.7 ± 2.1 | 0–7.92 | 5 | 1.77 ± 1.7 | 1–4.84 |
| Nitrite ($mg\,L^{-1}$) | 120 | N.D. | N.D. | 23 | 0.005 ± 0.01 | 0–0.05 | 11 | N.D. | N.D. | 5 | N.D. | N.D. |
| Potassium ($mg\,L^{-1}$) | 105 | 1.8 ± 1.9 | 0.005–10 | 4 | 43.7 ± 28 | 16.2–77 | 11 | 4 ± 3.2 | 1.3–11.2 | — | — | — |
| Selenium ($mg\,L^{-1}$) | 102 | 0.009 ± 0.003 | Trace–0.01 | 8 | 0.01 ± 0.017 | Trace–0.05 | 11 | 0.005 ± 0.005 | 0–0.01 | — | — | — |
| Silica ($mg\,L^{-1}$) | 1 | 1 ± 0.0 | 1 | 14 | 38.5 ± 29.7 | 0–97.5 | — | — | — | — | — | — |
| Sodium ($mg\,L^{-1}$) | 110 | 6.9 ± 6.9 | 0.04–30 | 19 | 390.3 ± 493.2 | 1.61–1770 | 11 | 22.9 ± 14.4 | 7.3–50 | — | — | — |
| Sulfate ($mg\,L^{-1}$) | 146 | 9.3 ± 7.9 | 1–35.85 | 23 | 91.4 ± 149.3 | 0–702.4 | 12 | 13.6 ± 9.3 | 2.4–31 | 5 | 8.9 ± 5.6 | 2.3–15.2 |
| Zinc ($mg\,L^{-1}$) | 127 | 0.036 ± 0.03 | Trace–0.17 | 8 | 0.2 ± 0.34 | 0.006–0.98 | 12 | 0.018 ± 0.014 | 0–0.05 | — | — | — |
| Pesticides ($mg\,L^{-1}$) | 102 | 0.0000001 ± 0 | 0–0.00001 | 7 | N.D. | N.D. | 11 | N.D. | N.D. | — | — | — |
| Phenolics ($mg\,L^{-1}$) | 119 | N.D. | N.D. | 13 | 0.000008 ± 0 | 0–0.0001 | 11 | N.D. | N.D. | 5 | N.D. | N.D. |
| PAHs ($mg\,L^{-1}$) | 102 | 0.006 ± 0.007 | 0–0.0196 | 8 | 0.003 ± 0.005 | 0–0.01 | 11 | N.D. | N.D. | — | — | — |
| $\alpha$-activity ($pCi\,L^{-1}$) | 98 | 0.73 ± 0.66 | 0.054–6.14 | 9 | 2.54 ± 3.21 | 0.11–10.65 | 11 | 0.67 ± 0.31 | 0.22–1.2 | — | — | — |
| $\beta$-activity ($Pci\,L^{-1}$) | 98 | 1.89 ± 1.75 | 0.054–10.1 | 9 | 6.45 ± 5.53 | 0.54–16.38 | 11 | 1.53 ± 0.64 | 0.54–2.73 | — | — | — |

N.D. = not detected.
[a]Number of samples.

Whereas, concentrations of B, Mg, K, Na and Zn were 20–50 times higher in the natural mineral waters compared to natural spring waters. This difference in mean elemental concentrations is expected since natural mineral waters are mostly produced from areas close to geothermal regions with deep ground water circulation patterns.

Results of this study showed that Turkish bottled waters contain several $\alpha$- and $\beta$-emitting isotopes in widely varying concentrations and elevated concentrations were mostly restricted to natural mineral waters. Mean gross $\alpha$- and $\beta$-activities of the natural mineral waters were almost four times higher than all other water types (Table 3). Lowest mean elemental concentrations were observed for drinking water and processed drinking water types, in which concentrations of Al, As, B, Cd, Se and Zn were half the concentrations observed for the natural spring waters.

The pH values of the natural mineral waters are generally lower (mean pH = 6.36) than any other water type because they naturally contain high levels of $CO_2$. The minimum pH values and maximum concentrations of the major elements were generally observed for the natural mineral water samples. The minimum pH value of 5.3 was observed for the brands 157 and 160. A pH value of 6.50 is the minimum set by the EEC, EPA and IBWA standards (Table 2); thus, this parameter may represent a short-coming for over 22% of Turkish bottled water brands (42 brands). The maximum concentrations of the major elements (in mg $L^{-1}$) were 420.8 for Ca (brand 163), 447.3 for Mg (brand 161), 1769.9 for Na (brand 157), 77 for K (brand 157), 759.7 for Cl (brand 157), 702.4 for $SO_4$ (brand 150) and 1.52 for F (brand 157).

Table 4 shows 189 samples examined, 40 (21.1%) failed to comply with the standards set by the Turkish legislation, including parameters such as Al (2 brands), Fe (3 brands), Cd (2 brands), Ni (1 brand), Mn (1 brand), PAHs (30 brands) and $\alpha$-activity (1 brand). For a considerably high

Table 4
The number (no.) and percent (%) of samples in each bottled water category with a concentration value equal or greater than maximum allowable concentrations (MACs) set by Turkish legislation (Resmi Gazete, 1997)

| Parameter | Natural spring water | | Natural mineral water | | Drinking water | | Processed drinking water | |
|---|---|---|---|---|---|---|---|---|
| | n[a] | No. (%) | n[a] | No. (%) | n[a] | No. (%) | n[a] | No. (%) |
| BOD | 142 | 1 (0.7) | 22 | B.L.V. | 12 | B.L.V. | 5 | B.L.V. |
| Color | 68 | B.L.V. | 12 | 2 (16.7) | 9 | B.L.V. | 4 | B.L.V. |
| Turbidity | 67 | 8 (11.9) | 13 | B.L.V. | 10 | B.L.V. | 4 | B.L.V. |
| Aluminum | 102 | 15 (14.7)[b] | 11 | 1 (9.1)[c] | 11 | B.L.V. | — | — |
| Antimony | 101 | 24 (23.8) | 7 | 2 (28.6) | 11 | 6 (54.5) | — | — |
| Arsenic | 102 | 31 (30.4) | 8 | 4 (50.0) | 11 | 4 (36.4) | — | — |
| Barium | — | — | 8 | 1 (12.5) | — | — | — | — |
| Boron | 102 | 1 (1.0) | 8 | B.L.V. | 11 | B.L.V. | — | — |
| Cadmium | 102 | 16 (15.7) | 8 | 4 (50.0) | 11 | 2 (18.2)[d] | — | — |
| Chloride | 145 | 1 (0.7) | 20 | B.L.V. | 12 | B.L.V. | 5 | B.L.V. |
| Chromium | 102 | 1 (1.0) | 7 | B.L.V. | 11 | 1 (9.1) | — | — |
| Cyanide | 102 | 7 (6.9) | 8 | B.L.V. | 11 | 2 (18.2) | — | — |
| Iron | 129 | 10 (7.8)[e] | 20 | B.L.V. | 12 | B.L.V. | — | — |
| Lead | 102 | 32 (31.4) | 8 | 4 (50.0) | 11 | 6 (54.5) | — | — |
| Manganese | 128 | 31 (24.2)[f] | 8 | B.L.V. | 12 | B.L.V. | — | — |
| Mercury | 101 | 31 (30.7) | 8 | 4 (50.0) | 11 | 5 (45.5) | — | — |
| Nickel | 102 | 39 (38.2) | 8 | B.L.V. | 11 | 5 (45.5)[g] | — | — |
| Nitrite | 120 | B.L.V. | 23 | 1 (4.3) | 11 | B.L.V. | 5 | B.L.V. |
| Potassium | 105 | 1 (0.9) | 4 | B.L.V. | 11 | B.L.V. | — | — |
| Selenium | 102 | 30 (29.4) | 8 | 1 (12.5) | 11 | 5 (45.5) | — | — |
| Sodium | 110 | 1 (0.9) | 19 | B.L.V. | 11 | B.L.V. | — | — |
| Pesticides | 102 | 1 (0.98) | 7 | B.L.V. | 11 | B.L.V. | — | — |
| PAHs | 102 | 27 (26.5)[h] | 8 | 3 (37.5)[i] | 11 | B.L.V. | — | — |
| $\alpha$-activity | 98 | 1 (1.0)[j] | 9 | B.L.V. | 11 | B.L.V. | — | — |

B.L.V. = For the parameter indicated, concentrations in all samples are below the MAC.
[a]Total number of samples for each measured parameter.
[b]Limit exceeded for Al by one brand (86) and equals to MAC for the remaining 14 brands.
[c]Limit exceeded for Al by one brand (157).
[d]Limit exceeded for Cd by two brands (176, 183).
[e]Limit exceeded for Fe by three brands (71, 78, 110) and equals to MAC for the remaining seven brands.
[f]Limit exceeded for Mn by one brand (56) and equals to MAC for the remaining 30 brands.
[g]Limit exceeded for Ni by one brand (173) and equals to MAC for the remaining four brands.
[h]Limit exceeded for PAHs by all 27 brands (10, 24, 26, 70, 78, 86, 87, 92, 95, 97, 98, 99, 100, 101, 102, 105, 107, 113, 115, 119, 122, 123, 126, 129, 130, 131, 137).
[i]Limit exceeded for PAHs by three brands (168, 169, 170).
[j]Limit exceeded for gross $\alpha$-activity by only one brand (122).

Table 5
Number of times water standards are exceeded (189 Turkish bottled water brands)

| Parameter | EEC | WHO | EPA | IBWA | FDA |
|---|---|---|---|---|---|
| pH | 42 | — | 42 | 42 | — |
| Turbidity | — | — | 13 | 31 | — |
| Aluminum ($Al^{3+}$) | 2 | — | 2 | 2 | 2 |
| Barium ($Ba^{2+}$) | — | 1 | — | — | — |
| Boron ($B^{3+}$) | 6 | 10 | — | — | — |
| Cadmium ($Cd^{2+}$) | — | 18 | — | — | — |
| Chloride ($Cl^{-}$) | 2 | — | 2 | 2 | 2 |
| Fluoride ($F^{-}$) | 1 | 1 | — | 1 | 1 |
| Iron (Fe) | 9 | — | 9 | 9 | 9 |
| Lead (Pb) | — | — | — | 44 | 44 |
| Manganese ($Mn^{2+}$) | 7 | 1 | 7 | 7 | 7 |
| Nickel (Ni) | 1 | 1 | — | — | — |
| Selenium (Se) | 1 | 1 | — | 1 | — |
| Sodium ($Na^{+}$) | 9 | — | — | — | — |
| Sulfate ($SO_4^{2-}$) | 1 | — | 1 | 1 | 1 |
| PAHs | 32 | — | — | — | — |
| Total phenolics | — | — | — | 1 | 1 |
| α-activity | — | 3 | — | — | — |

Dashes indicate either no standard is available for the parameter or standard is not exceeded.

number of samples (14–43 samples), the parameters Al, Sb, As, Cd, Pb, Mn, Hg, Ni and Se display concentrations equal to the MACs set by the Turkish legislation (Table 4). These metals can cause chronic or acute poisoning and should be eliminated from drinking water (Saleh et al., 2001). Therefore, the brands containing high levels of these trace elements should be more rigorously tested to guarantee their continuous compliance with the water standards. Table 5 shows that as much as 23% (44 samples) of the Turkish bottled waters exceed the EEC, WHO, EPA, IBWA and FDA standards in terms of the concentration of Al (2 brands), Ba (1 brand), B (6–10 brands), Cd (18 brands), Cl (2 brands), F (1 brand), Fe (9 brands), Pb (44 brands), Mn (1–7 brands), Ni (1 brand), Se (1 brand), Na (9 brands), $SO_4$ (1 brand), PAHs (32 brands), total phenolics (1 brand), gross α-activity (3 brands), pH (42 brands) and turbidity (13–31 brands). The most striking ones are the Pb, PAHs and pH, which exceeded most of the standards for 17–23% of the Turkish bottled waters. Especially, PAHs are of great concern due to their mutagenic and carcinogenic properties, which are mostly emitted into the atmosphere by anthropogenic combustion sources.

## 4. Conclusion

The purpose of the present study was to survey the current status of the Turkish bottled waters and their compliance with national and international regulations. In Turkey, the bottling industry has witnessed continued expansion in the last decade and this positive trend has intensified in all developed countries recently. This study gives an insight into the diversity of Turkish bottled waters as an important natural resource as well as its shortcomings in terms of physical and chemical quality. Results of this survey have shown that even waters of the same type can have a significantly different composition concerning the major constituents and trace elements. Natural mineral waters are mostly characterized by higher mineral contents in comparison the other water types. Natural mineral waters showed elemental concentrations 10–50-fold higher than natural spring waters and 20–100-fold higher than the drinking and processed drinking water types. A significant number of bottled waters contain some elements (e.g. sodium, chloride, sulfide, fluoride, PAHs and several heavy metals) above the maximum concentration allowed for bottled waters by the Turkish legislation. In the light of these findings, bottled water producers recommending their products for the preparation of infant formula should be more strictly controlled to prevent the health of infants. However, reported cases suggest that bottled water may be detrimental to health of infants (Bruce and Kliegman, 1994), and bottled water producers should avoid making such statements on their labels.

The Turkish bottled water legislation did not set limits for the parameters such as disinfectants and disinfection byproducts (e.g. bromate, chlorine, chlorite, HAAs, total trihalomethanes), which are known to be carcinogenic even at sub-microgram levels. In Turkey, bottled waters are generally disinfected with ozone prior to being bottled to prevent the product from pollution of microorganisms. If the source water contains some halides (e.g. Cl and Br) during the ozonation, disinfection by-products such as bromate and HAAs may be produced. Bromate has been judged by both the WHO and the EPA as a potential carcinogen. HAAs, especially dichloroacetic acid and trichloroacetic acid were also found to be animal carcinogenic at low concentration.

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