Chemical Quality of Bottled Waters: A Review

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Abstract: Bottled water has become very popular for quenching thirst and as a dietary (mineral) supplement. The plethora of natural mineral waters precludes any unequivocal system of classification, which makes it difficult for the consumer to choose a water with properties that suits him/her exactly. The ever-increasing popularity of bottled waters means that it is of the utmost importance to determine not only their mineral content, but above all, the content of possible contaminants, especially organic ones. In this respect bottled waters are a special case, because apart from organic contamination from the environment, the water may become secondarily contaminated as a result of its being improperly transported and stored. Pesticides, volatile organic compounds, and carbonyl compounds have been detected in samples of bottled water. This overview shows the available published information on levels of inorganic constituents and organic contaminants in samples of bottled water in the context of sample preparation procedures and analytical techniques.

Keywords: analytical techniques bottled water, chemical composition, classification

Introduction

Just 15 to 20 y ago, water in a plastic bottle was not a regular item on many consumers' shopping lists. Today, however,thousands of millions of liters of water are sold in all types of packaging and containers. The mineral water market is the most dynamically expanding branch of the nonalcoholic beverage sector (Bong and others 2009). There are many reasons for this ever-increasing popularity of bottled water. For example, success can be attributed to effective marketing strategies. Drinking water out of a bottle not only quenches one's thirst, but it is equated with a hygienic lifestyle, fitness, health, and good looks as well (de Beaufort 2007). The sales campaigns of food conglomerates have discouraged people from drinking municipal water, even though it is subjected to very much the same rigorous quality requirements as bottled water.

Bottled water is also frequently chosen as an alternative to municipal water for reasons of taste and smell, because in most countries of the world water cannot be disinfected by chemical means. Bottled water, in contrast, can be bought not only in every food shop but also at most service points. The demand for bottled water is completely independent of the supply of municipal water, which is frequently of identical, if not even higher, quality. Suffice it to say that sales of bottled water are greatest in highly developed countries, where tap water is of high and even very high quality. Against this, a single bottle of *Evian* water costs as much as it would to fill it with municipal water once a day for more than 10 years! On average, a liter of bottled water is from 250 to 600 times more costly than a liter of tap water.

A serious environmental problem connected with the constantly rising consumption of bottled water is the bottles in which it is sold. Because of their immense numbers, they are littering the world all over and have become the most troublesome item of rubbish at the present time (Coelho and others 2011). Most water bottles are produced from polyethylene terephthalate (PET), which in itself is an innocuous substance and is recyclable but not biodegradable (Hansen and Pergantis 2006). However, only 23% of PET bottles are recycled in the USA, and approximately 17% in Poland (Benefits of Recycling). To produce 38 thousand million plastic containers for bottled water consumed in the USA in 2006 alone, one and a half million barrels of crude oil was needed, not to mention the fuel required for transportation around the country.

Classification of mineral waters

The very concept of "mineral water" was first defined, at the International Balneological Congress at Nauheim, Germany, in 1911, as water containing at least 1000 mg of dissolved mineral constituents per liter, and this norm was accepted by all the countries represented at the Congress. Over the next 80 y or so this definition was changed many times, resulting in waters with a lower mineral content also being labeled "mineral"; by 1990 the acceptable level had fallen to 200 mg/L [PL–BN]. Consequently, the market became flooded with pseudo-mineral waters. In spite of disclaimers in various directives playing down this reduction in mineral content, most bottled waters are still falsely labeled "mineral waters"; in fact, only about 30 of the more than 200 brands on the market in Poland deserve this name.

To a very great extent, the composition of subterranean water depends on the type and structure of the rocks with which it comes into contact. The multifarious minerals forming the Earth's crust, as well as the various hydrogeochemical processes (sorption, oxidation and reduction, leaching, weathering, hydrolysis) and physical parameters (temperature, pressure) affecting these processes, have given rise to an immense diversity of mineral waters.

This makes it impossible to draw up a uniform system of classification, even if the only criterion is the chemical composition. Analysis of the sum of all the mineral constituents of water permits a classification based on the degree of mineralization (mineral content) (Table 1). This categorization can be extended by basing it on the content of specific constituents, which are chemical elements or compounds with proven physiological or medicinal activity (Table 1). The better known among these are

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iron, bromine, iodine, manganese, and carbon dioxide (van der Aa 2003).

Depending on the concentrations at which they are present, some of the constituents of water impart specific properties to the water. On this basis we can distinguish waters of varying hardness, salinity, or CO_2 saturation (Table 1). The temperature of the water is also a significant parameter, on the basis of which cold and thermal waters are differentiated; the latter can be further subdivided into tepid, warm, and hot waters (Table 1) (van der Aa 2003).

Natural mineral waters are classified according to geological, hydrogeological, physicochemical, and microbiological criteria. Pharmacological, physiological, and clinical criteria are also taken into account if the natural properties of the water justify this (Petraccia and others 2006). Water can be admitted for consumption only when the concentrations of its constituents do not exceed the norms specified in the table showing the various legal regulations (Table 2). When these norms are established, nutritional standards and the highest permissible levels (limiting values) in the case of harmful or potentially toxic substances have to be taken into account (Güler 2007).

The Problems and Challenges Posed by the Analysis of Bottled Waters

Subterranean waters, the main source of mineral waters, have fairly constant physicochemical properties, and their composition is the result of the interplay of numerous hydrogeochemical processes. Anthropogenic contamination is not of the same importance for such waters as it is for surface waters. A real danger for the quality of subterranean waters, however, is their over-exploitation, which may increase the inflow of adjacent surface waters. It is also worth remembering that, in many countries, access to subterranean waters is very limited; there, the main source of bottled water is desalinated sea water (Al-Mudhaf and others 2009).

The challenge now facing analytical chemists is to develop a method for the qualitative and quantitative determinations of the wide range of analytes present in bottled waters. Determining the content of inorganic and organic compounds is difficult, mainly because of

- the low levels of individual compounds present in samples,
- the complex composition (high degree of mineralization),
- interactions between the constituents present in samples,

Table 1–Classifications of mineral waters.

Type of water	Parameter	Unit	Reference
Criterion: mineral content			
Very low mineral content	Total content of mineral salts < 50	mg/L	(van der Aa 2003)
Low mineral content	Total content of mineral salts 50–500		
Medium mineral content	Total content of mineral salts 500–1500		
High mineral content	Total content of mineral salts >1500		
Criterion: content of specific constituents			
Chloride	Chlorides > 200	mg/L	(van der Aa 2003)
Bicarbonate	Bicarbonates > 600		
Sulfate	Sulfates > 200		
Sodium	Sodium > 200		
Calcium	Calcium > 150		
Magnesium	Magnesium > 50		
Iron	Iron > 1		
Bromide	Bromide > 5		
Iodide	Iodide > 1		
Manganese	Manganese > 1		
Oxalic	CO_2 > 250		
Fluoride	Fluoride > 1		
Sulfide	Sulfide > 1		
Arsenic	Arsenic > 0.7		
Criterion: salinity			
Fresh	Cl < 5	mg/L	(van der Aa 2003)
Slightly saline	Cl 5–30		
Saline	Cl 30–150		
More saline	Cl 150–300		
Very saline	Cl 300–1000		
Mineral	Cl 1000–10000		
Criterion: hardness			
Very soft	Ca + Mg 0 –0.5	mEq/L	(van der Aa 2003)
Soft	Ca + Mg 0.5 –1		
Medium hard	Ca + Mg 1–2		
Hard	Ca + Mg 2–4		
Very hard	Ca + Mg > 4		
Criterion: CO_2 saturation			
Unsaturated	No CO_2	mg/L	(van der Aa 2003)
Slightly saturated	CO_2 < 1500		
Medium saturated	CO_2 1500–4000		
Highly saturated	CO_2 4000–6000		
Criterion: temperature			
Cold	< 20	°C	(Petraccia and others 2006)
Thermal			
Tepid	20–30		
Warm	30–40		
Hot	40		

- possible changes in composition during transport and storage as a result of reactions and the potential desorption of constituents from packaging materials, and
- the interdependence between constituents present in samples (for example, the Ca:Mg ion ratio).

Method for determining the organic and inorganic constituents of bottled waters

It is frequently the case that quality control of bottled water is limited to the determination of the levels of inorganic constituents such as the anions Br^-, BrO_3^-, Cl^-, ClO_3^-, ClO_4^-, F^-, I^-, NO_2^-, NO_3^-, SO_4^{2-}, PO_4^{3-}, HCO_3^-; the cations Na^+, K^+, NH_4^+, Mg^{2+}, Ca^{2+} (Azoulay and others 2001; Saleh and others 2001; Rosborg and others 2005; Morr and others 2006; Bong and others 2009); and certain metals, Be, Cd, Cr, Cu, Hg, Fe, Mg, Mn, Ni, Se, Sr, V, Zn, Co, Hg, Pb, Th, U, Li, As, Al, Ba, Bi, Zr, Sn, Rb, Sb, Sc, Te, Tl (Al.-Saleh and Al.-Doush 1998; Saleh and others 2001; Ikem and others 2002; Costa and others 2003; Baba and others 2007; Shotyk and Krachler 2007a, 2007b; Westerhoff and others 2008; Keresztes and others 2009; Krachler and Shotyk 2009). Other elements, such as boron, are rarely determined. Table 3 provides data on the analytical techniques used for determining the inorganic constituents of bottled water.

The information available in the literature on the analytical techniques for determining the concentrations of organic compounds in bottled mineral waters is of fairly recent date, the first information on this subject having appeared in 2002. But the problem probably existed long before mineral water began to be sold in

Table 2–Regulations and standards for water intended for human consumption.

Parameter	Unit	ECC[a] (1998) Drinking water (MAC)[b]	ECC[a] (2003) Bottled water (MAC)[b]	WHO[a] (2008) Drinking water (GV)[c]	EPA[a] (2009) Drinking water (MCL)[d]	IBWA[a] (2009) Bottled water (SOQ)[e]	FDA[a] (2010) Bottled water (SOQ)[e]	Polish legalization Dz. U. Nr 276, poz, 2738[a] (2004) Bottled water (MAC)[b]
Disinfectants and disinfection by products								
Bromate	mg/L	0.01	–	0.01	0.01	0.01	0.01	–
Chlorine	mg/L	–	–	5[f]	0.1	0.1	4.0	–
Chlorite	mg/L	–	–	0.7[f]	1	1	1	–
Haloacetic acids	mg/L	–	–	–	0.06	0.06	0.06	–
Total trihalogenometals	mg/L	0.1	–	1	0.08	0.01	0.08	–
Inorganic chemicals								
Aluminum	mg/L	0.2	–	–	–	0.2	0.2	–
Amonium	mg/L	0.5	–	–	–	–	–	2
Antimony	mg/L	0.005	0.005	0.02	0.006	0.006	0.006	0.005
Arsenic	mg/L	0.01	0.01	0.01[f]	0.01	0.01	0.01	0.01
Barium	mg/L	–	–	0.7	2	1	2	1
Beryllium	mg/L	–	–	–	0.004	0.004	0.004	–
Boron	mg/L	1	1	0.5[f]	–	–	–	5
Cadmium	mg/L	0.005	0.003	0.003	0.005	0.005	0.005	0.003
Chloride	mg/L	250	–		–	250	250	250
Chrome	μg/L	0.05	0.05		0.1	0.05	0.1	0.05
Copper	mg/L	2	1	2	1.3[g]	1	1	1
Cyanide	mg/L	0.05	0.07	0.07	0.2	0.1	0.1	0.07
Fluoride	mg/L	1.5	5	1.5	4.0	see	see	5
Iron	mg/L	0.2	–	–	–	0.3	0.3	0.5
Lead	mg/L	0.01	0.01	0.01	0.015[g]	0.005	0.005	0.01
Manganese	μg/L	0.05	0.5	0.4[f]	–	0.05	0.05	0.5
Mercury	mg/L	0.001	0.001	0.006	0.002	0.001	0.002	0.001
Molybdenum	mg/L	–	–	0.07	–	–	–	–
Nickel	mg/L	0.02	0.02	0.07	–	0.1	0.1	0.02
Nitrate	mg/L	50	50	50	10[h]	10	10	50
Nitrite	mg/L	0.5	0.1	0.2[f]	1[h]	1	1	0.1
Selenium	mg/L	0.01	0.01	0.01	0.05	0.01	0.05	0.01
Silver	mg/L	–	–	–	–	0.025	0.1	–
Sodium	mg/L	200	–	–	–	–	–	200
Sulfate	mg/L	250	–	–	–	250	250	250
Thallium	mg/L	–	–	–	0.002	0.002	0.002	–
Uranium	mg/L	–	–	0.015[f]	0.03	0.03	0.03	–
Zinc	mg/L	–	–	–	–	5	5	1
Organic chemicals								
Acrylamide	mg/L	0.0001	–	0.0005	–	–	–	–
Benzene	mg/L	0.001	–	0.01	0.005	0.001	0.005	–
Total pesticides	μg/L	0.5	–	–	–	–	–	0.5
PAHs	μg/L	0.1	–	–	–	–	–	0.1
Phenolics	mg/L	–	–	–	–	0.001	0.001	0.002

[a] *Sources* (see References): EEC = European Economic Community; WHO = World Health Organization; EPA = US Environmental Protection Agency; IWBA = International Bottled Water Association; FDA = U.S. Food and Drug Administration; Dz. U. Nr 276, poz. 2738 (Official acts of Polish Government).
[b] Maximum admissible concentration.
[c] Guideline value.
[d] Maximum contaminant level.
[e] Standard of quality.
[f] Provisional guideline value.
[g] Action level.
[h] Measured as nitrogen.

plastic bottles, as evidenced by the ubiquity of organic compounds in the various compartments of the environment. The following groups of organic compounds have been determined in samples of bottled water: pesticides, volatile organic compounds, perfluorinated carbon compounds, and carbonyl compounds (Nawrocki and others 2002; Ericson and others 2008; Greulich and Alder 2008; Al-Mudhaf and others 2009; Diaz and others 2009). Table 4 gives data on the analytical procedures for determining organic compounds in bottled waters.

Levels of Target Inorganic and Organic Constituents of Bottled Waters

Inorganic constituents (natural and contaminants) of bottled waters

The analytical results given in the literature (Table 5) show the breadth of the range of parameters determined in bottled waters. The differences in the compositions of particular waters are very evident. This is the direct result of the geology of the region from which the water is drawn, and also of the legislation in force in a particular country. The differences in mineral content directly affect the taste and odor of the water. Bottled waters are perceived by many to taste better, have fewer impurities, and to confer higher social status on the consumer than does tap water (Saad and others 1998). Mineral water is also often used as a replacement for tap water, which is always chemically disinfected (Nawrocki and others 2002).

The main dangers to the quality of subterranean water that are sources of bottled water stem from area pollution caused by the application of agricultural chemicals, the lack or malfunction of sewage disposal systems, negligently planned landfill sites, and the insufficient number and poor efficiency of sewage treatment plants, effluent basins, sewage ponds, and poorly designed and executed petrol stations. Line-level sources can also include leaking pipes, gas mains, and sewers (Polkowska 2003).

Organic contaminants in bottled waters

Bottled mineral waters are a special case as far as the analysis of organic contaminants is concerned. Apart from substances derived from various compartments of the environment, like pesticides (Greulich and Alder 2008; Diaz and others 2009;) and perfluoro derivatives (Ericson and others 2008), as well as those that can form during the treatment of water (Al-Mudhaf and others 2009), the material from which the bottle or container is made can also constitute a source of contamination (Nawrocki and others 2002). Table 6 lists the levels of organic contaminants determined in bottled waters.

PET is the usual material from which bottles for mineral water are made. Studies of the possible migration of PET degradation products have shown that if bottled water is stored at elevated temperatures or exposed to sunlight, the aldehyde content in the water increases (Nawrocki and others 2002). Moreover, the size of the bottle is of greater concern. Water stored in small-capacity bottles (0.2 to 0.25 L) contains more contaminants than that in bottles of larger capacity (1.5 L). It has also been demonstrated that the bottle material degrades faster if the water is carbonated (Azoulay and others 2001; Burlingame 2003; Bong and others 2009).

Studies of the possible degradation of the polymers from which bottles are made is of major importance, because in developing countries a process known as solar disinfection is frequently used to rid the water of microorganisms. This is a simple, cheap, and effective method: the bottle is filled with water, capped, then exposed to solar radiation for 15 to 18 h (Schmid and others 2008).

Table 3–Analytical techniques for determining inorganic constituents.

Parameter	Type of water	Analytical technique	Validation parameters	Reference
Be, Cd, Cr, Cu, Hg, Fe, Mg, Mn, Ni, Se, Sr, V, Zn	Bottled	ICP–PED	Detection limit (μg/mL)	(Al-Saleh and Al Doush 1998)
Ag, Al., As, Ca, Cd, Co, Cr, Cu, Fe, Hg, Mg, Mn, Mo, Na, Pb, Th, U, Zn Ca, K, Mg, Na	Bottled	ICP–OES	–0.000098–0.018	(Ikem and others 2002) (Rosborg and others 2005)
Sb Ag, Al, As, B, Ba, Be, Bi, Br, Ca, Ce, Cd, Co, Cu, Cr, Cs, Fe, Ge, Hg, I, Li, Mg, Mn, Mo, Na, Pb, Rb, Se, Sb, Sc, Sr, Te, Ti, Tl, Th, U, V,W, Zn, Zr	Bottled	ICP–MS	Detection limit (μg/L) 0.004–0.028 – Detection limit (μg/L) 0.01–10 Recovery (%) 91.6–111 Detection limit (μg/L) 0.001–26	(Westerhoff and others 2008) (Krachler and Shotyk 2009) (Saleh and others 2001) (Rosborg and others 2005)
Al, B, Ba, Bi, Ca, Cd, Co, Cr, Cu, Fe, La, Mn, Ni, Pb, Sb, Sn, Sr, Ti, U, Zn, Zr	Bottled (c, nc)	ICP–AES	–	(Baba and others 2007)
Ca, K, Mg, Na	Bottled		–	(Bong and others 2009)
Sb	Bottled (c, nc)	ICP–SF–MS	Detection limit (pg/mL) 0.7	(Keresztes and others 2009)
NO_3–N	Bottled	FIA	Detection limit (μg/L) 60	(Rosborg and others 2005)
F, Cl, SO_4–S Br, BrO_3^-, Cl, ClO_3^-, F, I, NO_2^-, NO_3^-, SO_4^{2-}, PO_4^{3-} Cl, NO_3^-,SO_4^{2-},HCO_3^-	Bottled	IC–CD	Detection limit (μg/L) 100–190 – –	(Rosborg and others 2005) (Saleh and others 2001, Liu and Mou 2004) (Bong and others 2009)
Ba, Ca, Cr, Cu, Ge, K, Mn, Ni, Pb, Rb, Sr, Ti, Zn	Bottled (c, nc)	STR–XRF	Detection limit (μg/L) 0.02–22.2	(Costa and others 2003)
As, Ca, Cd, Cu, K, Mg, Na, P, Se, Zn	Bottled	MIP–MS	–	(Chiba and others 2006)
ClO_4^-	Bottled	ESI–MS–MS	–	(Shi and others 2007)

c = carbonated, nc = noncarbonated.

Table 4–Analytical techniques for determining organic constituents.

Parameter	Type of water	Sample preparation	Analytical technique	Reference
Pesticides				
α-HCH β-HCH β-HCH δ-HCH Aldrin DDD DDE DDT Dieldrin Endosulfan I Endosulfan II Endosulfan sulfate Endrin Endrin aldehyde	Bottled 1.5-19L	A 500 mL aliquot of each bottled water sample was transferred to a separating funnel, then extracted by shaking with 75 mL of ether–hexane (25%, v/v). Separately another 500 mL aliquot was extracted with 75 mL of hexane and the two extracts combined so that 1 L of sample was extracted in total. The organic phase was passed through anhydrous sodium sulfate to remove remnants of water then the samples evaporated in a rotary evaporator to 5 mL.	GC-ECD	(Diaz and others 2009)
Volatile organic compounds				
1,2,4-Trimethylobenzene 1,2-Dichloropropanne 1,3,5-Trimethylobenzene 1,3-Dichlorobenzene Bromodichloromethane Bromoform Chloroform Dibromochloromethane Dibromomethane Ethylbenzene *iso*-Propylbenzene Xylene Naphthalene Styrene Toluene Trichloroethene Chloral-hydrate Trichloropropanone Dichloroacetonitrile	Bottled	In this method, VOCs and surrogates with low water solubility are extracted (purged) from the sample matrix by bubbling helium gas through the aqueous sample. Purged sample components are trapped in a tube containing suitable sorbent materials. When purging is complete, the sorbent tube is heated and backflushed with helium to desorb the trapped sample components into a capillary GC column interfaced to the MS. Bottled water was directly analyzed without the addition of sodium thiosulfate. The US Environmental Protection Agency (EPA) method 52.2 with some modifications was employed for purge and trap extraction of THMs and analysis by gas chromatography/mass spectrometry. – –	GC-MS	(Leivadara and others 2008, Al-Mudhaf and others 2009, Ahmad and Bajahlan 2009, Ikem 2002, Saleh and others 2001)
Haloacetic acid				
Formic acid Dichloroacetic acid Ethanedioic acid	Bottled (purified, mineral, natural)	Samples were filtered with 0.45 μm filters. One hundred-milliliter polytetrafluoroethylene (PTFE) beakers were used for sample concentration. The beakers were cleaned a 150 W AS3120A sonicator.	IC-ED	(Liu and Mou 2003)
Antioxidant				
Butylated hydroxytoluene	Bottled 0.5–2L	Solid-phase micro extraction (SPME) was implemented and applied for the extraction of BHT 2.2 from water samples and further determination by capillary gas chromatography–mass spectrometry. Used an SPME manual holder and fiber assembly with a 100 mm polydimethylsiloxane film, and an amber screw-top vial with white PTFE–silicone septa. The fiber was exposed to 15 mL aliquots (maximum capacity). Extractions were performed at room temperature (20 to 25 °C). The expon time was 30 min.	GC-MS	(Tombesi and Freije 2002)
4-Nonylphenol bisphenol A triclosan	Bottled (mineral, pure)	Before extraction, the pH value of each water sample was adjusted to 3 using 4 M H_2SO_4 and 50 mL of HPLC-grade methanol was added into the water to increase extraction efficiency. And 100 μL each of 1 mg/L of 4-n-NP, BPA-d16 and 13C-TCS were spiked into each sample as internal standards. The cartridges were conditioned by 10 mL of methanol and 10 mL of Milli-Q water. Then water samples passed through the SPE cartridges at a flow rate of 10 mL/min. After loading of the samples, the cartridges were dried under vacuum for 2 h. The analytes were eluted from the cartridges using 8 mL ethyl acetate. The eluates were concentrated to dryness under a gentle stream of nitrogen, and then redissolved in methanol to a final volume of 1 mL. Each final extract was filtered through a 0.45 μm membrane filter into a 2 mL amber glass vial and kept at −18 °C until analysis. First, 100 μL of the final extract in methanol was transferred to the test	GC-MS-NCI	(Li and others 2010)

(*Continued*)

Table 4–Continued

Parameter	Type of water	Sample preparation	Analytical technique	Reference
		tube and the solvent was dried under a gentle nitrogen stream. Secondly, 2 mL of 1 M $NaHCO_3$ and 1 mL of 1 M NaOH were added. After shaking for 30 s, 2 mL of n-hexane, 50 μL of 10% pyridine in toluene and 50 μL of 2% PFBOCl in toluene were added. The tube was tightly capped and handshaken violently for 1 min. After the organic phase and aqueous phase were separated thoroughly, the organic phase was transferred to a 5 mL glass centrifuge tube using a glass pipette. Third, 2 mL of n-hexane was added to the 10 mL tube for a second extraction. The tube was handshaken for 1 min, and the other procedures were the same as in the second step. After separated, the supernatant was transferred to the aforementioned 5 mL glass centrifugal tube. Then the combined n-hexane mixture was dried under a gentle nitrogen stream. Finally, the extract was redissolved in 100 μL of n-hexane, and then transferred to a 2 mL amber glass vial with a 250 μL flat-bottomed insert, which was ready for GC-NCI-MS analysis.		
Perfluorochemicals				
PFBuS PFDA PFDoDA PFDS PFHpA PFHxA PFHxS PFNA PFOA PFOS PFOSA PFTDA PFUnDA THPFOS	Bottled	Samples were filtered with glass microfiber filters. Samples were concentrated using solid-phase extraction. Briefly, 500 mL of water were used for extraction after adjusting the pH to 4 using an HCl solution. Extraction standards, 13C4-PFOS and 13C4-PFOA, and 10 mL of methanol (MeOH) were added. After 10 min, water samples were loaded onto Waters Oasis® WAX single use cartridges (6 cm^3/150 mg) previously conditioned with 4 mL MeOH and 4 mL water. Vacuum was used to speed up the concentrations of water samples. After drying, SPE cartridges were eluted with 4 mL acetate buffer solution (discarded) and 2 mL 2% NH4 in MeOH (target fraction). This fraction was filtered (2 μm nylon filter) and evaporated under nitrogen. The final volume was set to 500 μL including 13C5-labeled PFNA added as performance standard and 300 μL of 2 mM sodium acetate in water.	HPLC-MS	(Ericsson and others 2008)
Formaldehyde Acetaldehyde Acetone	0.5–1.5 L; c, nc	20 mL of water samples were collected in glass vials with glass caps. One milliliter of 1 mg/mL aqueous PFBOA solution was added to the sample and kept at room temperature for 1 h, then 2 drops of concentrated sulfuric acid were added to complete the derivatization reaction. The extract was then purified with 3 mL of 0.2 N sulfuric acid solution. The hexane layer was separated and transferred to vials containing approximately 50 mg of sodium sulfate to dry the extract	GC-ECD	(Nawrocki and others 2002)

Summary

Bottled water is a product that is purchased by annually increasing numbers of people of all age groups. The quality control of mineral waters tends to concentrate on the determination of anion and cation levels, since it is these that govern the taste, odor, and possible nutraceutical properties of the water. The diversity of mineral waters causes problems in drawing up a uniform classification system that would make it easier for the consumer to choose a water suitable for his/her individual needs. In addition, the broad spectrum of inorganic constituents in mineral waters precludes the application of any one particular analytical technique. Ion chromatography remains the most popular method of determining the levels of ions in such waters.

The constantly rising sales of mineral waters bring with them ever-increasing exploitation of their sources. The consequences of this include deterioration in the quality of subterranean waters, for example, as a result of the inflow of adjacent ground waters, which are often exposed to anthropogenic contamination. The implication is that not only the mineral content but also the levels of possible organic contaminants must be subjected to constant quality control measures. If bottled water is not stored under the right conditions, that is to say, if it is exposed to high temperatures and/or sunlight, it can become contaminated by the degradation products of the material from which the bottle was made. This is a fairly new problem. Techniques such as GC-ECD, GC-MS, and HPLC-MS are used to determine organic contaminants in samples of bottled water. Emptied bottles are a serious danger to the environment. They are constantly increasing in number, yet no system for their reuse has met with approval. It is still the case that only a small fraction of them is recycled, which makes them one of the most troublesome items of refuse.

Table 5–Levels of inorganic constituents in bottled waters (literature information).

Country	Brand	Type of water	Parameter	Range	Unit	References
Europe						
England	Abbey Well	lm	Ca	39–114	mg/L	(Azoulay and others 2001)
	Aqua-Pura		Mg	1–36		
	Brecon Carreg		Na	6–46		
	Buxton					
	Chiltern					
	Highland Spring					
	Strathmore					
Austria	Montes	c	Ca	8157	μg/L	(Bong and others 2009)
			Cl	1059		
			HCO_3^-	28331		
			K	443		
			Mg	4056		
			Na	4309		
			NO_3^-	86.7		
			SO_4^{2-}	407		
	Romerquelle	mm	Ca	146	mg/L	(Azoulay and others 2001)
			Mg	65		
			Na	13		
	Voslauer	lm	Ca	57		
			Mg	37		
			Na	5		
Belgium	Bru	lm	Ca	23	mg/L	(Azoulay and others 2001, Morr and others 2006)
			Mg	23		
			Na	10		
	Chaudfontaine	m	Ca	65		
			Mg	18		
			Na	44		
	Duke	s	Ca	10–112		
	Leberg		Mg	6–47		
			Na	5–10		
	Valvert	lm	Ca	67.7–68		
			Mg	2		
			Na	1.9–2		
Finland	Vichi original	mm	Ca	100	mg/L	(Azoulay and others 2001)
			Mg	110		
			Na	220		
	Vichy Nouvelle	lm	Ca	70		
			Mg	110		
			Na	1		
France	Aix les Banes	m	Ca	72	mg/L	(Saleh and others 2001, Bong and others 2009, Azoulay and others 2001, Morr and others 2006)
			Mg	38		
			Na	14		
	Badoit	mm	Ca	200–467		
	Contrex		Mg	84–100		
			Na	7–160		
	Eau de Source-Oliviers	m	Ca	157		
			Mg	21		
			Na	14		
	Evian	s. plastic	Al	0.006	μg/L	
			Ca	0.05	mg/L	
			Cd	< 0.2	μg/L	
			Cl	18	mg/L	
			Co	1	μg/L	
			Cr	< 0.2		
			Cu	< 0.2		
			Fe	1.09		
			Hg	51		
			K	27.3	mg/L	
			Mg	1–24		
			Mn	5	μg/L	
			Na	5–6.38	mg/L	
			SO_4^{2-}	2.29		
			U	4	μg/L	
			Zn	8		
			Ca	78	mg/L	
	Perrier	lm. nc	Ca	4538–147000	μg/L	
			Cl	474		

(*Continued*)

Table 5–Continued

Country	Brand	Type of water	Parameter	Range	Unit	References
			HCO_3^-	1171		
			K	27.4		
			Mg	254–4000		
			Na	535–14000		
			NO_3^-	103		
			SO_4^{2-}	424		
	Prince Noir	m	Ca	528	mg/L	
			Mg	78		
			Na	9		
	SaintYorre	hm	Ca	100–176		
	Vichy Celestins		Mg	9–160		
			Na	900–1200		
	Vittel Bonne Sources	lm	Ca	91		
			Mg	20		
			Na	7		
	Vittel Grande Source	mm	Ca	202–575		
	Vittel Hepar		Mg	36–118		
			Na	3–13		
	Volvic	lm	Ca	299–10000	μg/L	
			Cl	438–442		
			HCO_3^-	1323–1352		
			K	137–145		
			Mg	344–6100		
			Na	502–9400		
			NO_3^-	119–120		
			SO_4^{2-}	88.5–89.6		
Spain	Font Vella	lm	Ca	26–35	mg/L	(Azoulay and others 2001)
	Fonter		Mg	5–7		
			Na	11–12		
	Salus Vidago	mm	Ca	78		
			Mg	10		
			Na	660		
	San Narciso	hm	Ca	33–53		
	Vichy Catalan		Mg	8–9		
			Na	1120–1133		
	Viladru	lm	Ca	16		
			Mg	2		
			Na	9		
Ireland	Ballygowan	lm	Ca	37–114	mg/L	(Azoulay and others 2001)
	Glenpatrick Spring		Mg	15–23		
	Tipperary		Na	12–25		
Iceland	Thorspring	lm	Ca	6	mg/L	(Azoulay and others 2001)
			Mg	1		
			Na	8		
Germany	Apollinaris	mm, c	Ca	2.7–89	mg/L	(Azoulay and others 2001,
			Cl	3660	μg/L	Morr and others 2006)
			HCO_3^-	31778		
			K	893		
			Mg	5.9–104	mg/L	
			Na	23–425		
			NO_3^-	78.1	μg/L	
			SO_4^{2-}	1023		
	Azur	m	Ca	177	mg/L	
			Mg	29.9		
			Na	176		
	Fachingen	mm	Ca	113		
			Mg	62		
			Na	500		
	Gerolsteiner	c	Ca	2610–2991	μg/L	
			Cl	127–135		
			HCO_3^-	7262–7353		
			K	10.5–11.6		
			Mg	1319–1447		
			Na	144–161		
			NO_3^-	171–182		
			SO_4^{2-}	167–184		
	Gerolsteiner Sprudel	mm	Ca	176–364	mg/L	
	Hassia Sprudel		Mg	36–113		
			Na	119–232		

(*Continued*)

Table 5–Continued

Country	Brand	Type of water	Parameter	Range	Unit	References
	Hella	lm	Ca	51		
			Mg	4		
			Na	8		
	Kaiser Friedrich	hm	Ca	5		
			Mg	4		
			Na	1419		
	Peterstaler	mm	Ca	216–256		
	Rippoldsauer		Mg	37–128		
	Robacher		Na	40–215		
	St. Michaelis	lm	Ca	43		
			Mg	4		
			Na	21		
	Uberkinger	hm	Ca	26		
			Mg	17		
			Na	1180		
Poland	Krystynka	hm	Ca	176	mg/l	(Azoulay and others 2001)
			Mg	60		
			Na	900		
	Nałęczowianka	mm	Ca	119		
			Mg	21		
			Na	24		
Portugal	Pedras Saldagas	mm	Ca	132	mg/L	(Azoulay and others 2001)
			Mg	9		
			Na	550		
Słovenia	Radenska	mm	Ca	217	mg/L	(Azoulay and others 2001)
			Mg	97		
			Na	470		
Switzerland	Aproz	mm	Ca	454	mg/L	(Azoulay and others 2001,
			Mg	67		Bong and others 2009)
			Na	8		
	Cristalp	lm	Ca	115	mg/L	
			Mg	40		
			Na	20		
	Heidiland	c	Ca	2941	μg/L	
			Cl	42.3		
			HCO_3^-	1405		
			K	14.2		
			Mg	1642		
			Na	189		
			NO_3^-	33.4		
			SO_4^{2-}	2682		
	Henniez	lm	Ca	111	mg/L	
			Mg	19		
			Na	9		
	Passugger	mm	Ca	286–436		
	Valser		Mg	24–54		
			Na	11–46		
Italy	Aqua di Nepi	lm	Ca	72–124	mg/L	(Bong and others 2009,
	Aqua Fabia		Mg	5–26		Azoulay and others 2001,
			Na	15–32		Morr and others 2006)
	Aqua Panna	lm, nc	Ca	912–15000		
			Cl	241		
			HCO_3^-	1975		
			K	22.1		
			Mg	302–5000		
			Na	355–3000		
			NO_3^-	69.7		
			SO_4^{2-}	229		
	Boario	lm	Ca	60–124		
	Claudia		Mg	2–41		
	Crodo Lisiel		Na	6–56		
	Crodo Valle d'Oro	mm	Ca	408–510		
	Ferrarelle		Mg	23–51		
			Na	2–50		
	Fiuggi	lm	Ca	15–18		
	Levissima		Mg	1–5		
			Na	1–6		
	Maxim's	s	Ca	20.2		
			Mg	1.6		
			Na	3.9		

(*Continued*)

Table 5–Continued

Country	Brand	Type of water	Parameter	Range	Unit	References
	Pracastello	mm	Ca	164		
			Mg	46		
			Na	28		
	S. Pellegrino	mm, c	Ca	4701–208000	μg/L	
			Cl	1810		
			HCO_3^-	3495		
			K	74.5		
			Mg	2361–55900		
			Na	1596–43600		
			NO_3^-	50.6		
	San Bendetto	lm	Ca	43	mg/L	
			Mg	25		
			Na	8		
	San Bernardo	lm, c	Ca	1334–12000	μg/L	
			Cl	91.3		
			HCO_3^-	4815		
			K	26.6		
			Mg	1000–1313		
			Na	325–1000		
			NO_3^-	139		
			SO_4^{2-}	49.6		
	San Pellegrino Sanfaustino	m	Ca	204–414	mg/L	
			Mg	17–57		
			Na	17–47		
	Sangemini	mm	Ca	322		
			Mg	19		
			Na	21		
	Solé	nc	Ca	10.8	μg/L	
			Cl	298		
			HCO_3^-	1740		
			K	2359		
			Mg	8.47		
			Na	77.9		
			NO_3^-	16.7		
			SO_4^{2-}	5.85		
	Vera	lm	Ca	34	mg/L	
			Mg	12		
			Na	2		
Asia						
Korea	Bongpyong	nc	Ca	386	μg/L	(Bong and others 2009)
			Cl	174		
			HCO_3^-	1011		
			K	15.2		
			Mg	124		
			Na	291		
			NO_3^-	120		
			SO_4^{2-}	38.5		
	Chojung	c	Ca	597		
			Cl	480		
			HCO_3^-	1488		
			K	35.9		
			Mg	220		
			Na	938		
			NO_3^-	225		
			SO_4^{2-}	127		
	Dongwon	nc	Ca	783	μg/L	
			Cl	150		
			HCO_3^-	1318		
			K	30.1		
			Mg	156		
			Na	274		
			NO_3^-	47.2		
			SO_4^{2-}	358		
	Elumgol	c	Ca	194–262	μg/L	
			Cl	170–184		
			HCO_3^-	983–1096		
			K	16.1–18.3		
			Mg	29.4–39.3		
			Na	1006–1017		
			NO_3^-	90.2–100		
			SO_4^{2-}	128–137		

(*Continued*)

Table 5–Continued

Country	Brand	Type of water	Parameter	Range	Unit	References
	Icis Keumgangsoob Odaesan Power O2 Samdasoo Sammool Seoksu Siana Soo Soonsoo T^ynant	nc	Ca	6.7–586	µg/L	
			Cl	76–393		
			HCO_3^-	41–2705		
			K	7–2359		
			Mg	7.6–553		
			Na	64.5–929		
			NO_3^-	16.7–131		
			SO_4^{2-}	5.8–304		
	Tynant Tau	c	Ca	601	µg/L	
			Cl	390		
			HCO_3^-	2033		
			K	21.7		
			Mg	551		
			Na	948		
			SO_4^{2-}	75.2		
	Waterline Yaksan	nc	Ca	573–617	µg/L	
			Cl	105–115		
			HCO_3^-	1570–1661		
			K	23.2–24.3		
			Mg	200–211		
			Na	187–228		
			NO_3^-	66.6–76.2		
			SO_4^{2-}	108–129		
North America						
Fiji	Fiji	s	Ca	17	mg/L	(Morr and others 2006)
			Mg	13		
Canada	Aberfoyle	s. plastic	Al	4	µg/L	(Azoulay and others 2001, Bong and others 2009, Ikem and others 2002)
			Ca	0.05	mg/L	
			Cd	0.2	µg/L	
			Cl	49.77	mg/L	
			Co	1	µg/L	
			Cr	<0.2		
			Cu	1		
			Fe	0.001		
			Hg	14		
			K	1.82	mg/L	
			Mg	24.5		
			Mn	< 0.1	µg/L	
			Mo	< 0.7		
			Na	23	mg/L	
			SO_4^{2-}	79.69		
			Zn	27	µg/L	
	Canada Geese	m	Ca	282	mg/L	
			Mg	10		
			Na	36		
	Canadian Spring Clairval	s	Ca	11–20		
			Mg	3–7		
			Na	2–13		
	Dannon	s. plastic	Ag	0.3 ± 0.6	µg/L	
			Al	2.7 ± 2.5		
			Ca	21.95 ± 22.45	mg/L	
			Cl	48.76 ± 35.27		
			Co	1.7 ± 1.5	µg/L	
			Cr	0.3 ± 0.5		
			Cu	0.7 ± 0.6		
			Fe	0.001 ± 0.001		
			Hg	12 ± 16.5		
			K	1.09 ± 0.91	mg/L	
			Mg	7.10 ± 2.84		
			Na	23.52 ± 18.23		
			Pb	0.3 ± 0.5	µg/L	
			SO_4^{2-}	20.40 ± 7.24	mg/L	
			U	0.7 ± 1.1	µg/L	
			Zn	8 ± 8.7		
	Montclair Montellier	m	Ca	3–8	mg/L	
			Mg	3–12		
			Na	340–475		

(*Continued*)

Table 5–Continued

Country	Brand	Type of water	Parameter	Range	Unit	References
	Naya	s	Ca	38		
			Mg	20		
			Na	6		
	Whistler	nc	Ca	311	μg/L	
			Cl	166		
			HCO_3^-	556		
			K	14.7		
			Mg	53.8		
			Na	109		
			NO_3^-	13.6		
			SO_4^{2-}	73		
USA	A Sante	m	Ca	4	mg/L	(Bong and others 2009, Azoulay and others 2001, Morr and others 2006 Ikem and others 2002)
			Mg	1		
			Na	160		
	Adobe Springs	s	Ca	1–3		
	Alhambra		Mg	1–96		
			Na	4–5		
	Aquafina	p. plastic	Ag	1.1 ± 1.9	μg/L	
			Al	1.3 ±2.9		
			As	11.9 ±9.1		
			Ca	0.06 ±0.04	mg/L	
			Cd	1 ± 1.9	μg/L	
			Cl	3.9 ± 1.116	mg/L	
			Co	2 ± 1.5	μg/L	
			Cr	< 0.2		
			Cu	0.6 ± 0.8		
			Fe	0.1 ± 0.4		
			Hg	3 ± 5.1		
			K	0.05 ± 0.05	mg/L	
			Mg	0.02 ± 0.03		
			Mo	2.3 ± 4.7	μg/L	
			Na	4.28 ± 8.62	mg/L	
			Pb	0.3 ± 0.7	μg/L	
			SO_4^{2-}	0.24 ± 0.21	mg/L	
			Th	2.3 ± 2.9	μg/L	
			U	0.7 ± 0.8		
			Zn	0.9 ± 0.7		
	Arrowhead	s	Ca	20–36	mg/L	(Bong and others 2009, Azoulay and others 2001, Morr and others 2006, Ikem and others 2002)
	Black Mountain		Mg	1–5		
	Caddo Valley		Na	2–12		
	Calistoga	m	Ca	7	mg/L	
			Mg	1		
			Na	150		
	Canterbury	s. plastic	Ca	0.05	mg/L	
			Cd	< 0.2	μg/L	
			Cl	5.7	mg/L	
			Co	< 0.4	μg/L	
			Cr	< 0.2		
			Cu	1		
			Fe	0.001		
			Hg	0.01		
			K	1.79	mg/L	
			Mg	16		
			Mn	1	μg/L	
			Mo	1		
			Na	1.61	mg/L	
			SO_4^{2-}	5.84		
	Carolina mountain	s	Ca	5–6	mg/L	
	Cobb mountain		Mg	2		
			Na	4–5		
	Crystal geyser	s. plastic	Ag	1–57	μg/L	
	Crystal springs		Al	0.2–3		
			As	12		
			Ca	4–26.7	mg/L	
			Cd	2–3	μg/L	
			Cl	6.8–49.77	mg/L	
			Co	0.8–1	μg/L	
			Cr	< 0.2		
			Cu	< 0.2		
			Fe	0.001–0.8		
			Hg	3–14		

(*Continued*)

Table 5–Continued

Country	Brand	Type of water	Parameter	Range	Unit	References
			K	0.5–1.13	mg/L	
			Mg	3.75–24.5		
			Mn	0.1–5.5	μg/L	
			Mo	0.7–8		
			Na	1.2–160	mg/L	
			Pb	0.5	μg/L	
			SO_4^{2-}	2.58–79.69	mg/L	
			Zn	27	μg/L	
	Dasani	p. plastic	Ag	0.2 ± 0.4	μg/L	(Bong and others 2009, Azoulay and others 2001, Morr and others 2006; Ikem and others 2002)
			Al	2.6 ± 4.2		
			As	6.5 ± 6.3		
			Ca	0.08–10	mg/L	
			Cd	0.7 ± 1.6	μg/L	
			Cl	8.38 ± 0.68	mg/L	
			Co	1.5 ± 1.4	μg/L	
			Cr	0.4 ± 0.9		
			Cu	0.5 ± 0.6		
			Fe	0.4 ± 0.6		
			Hg	20 ± 29.8		
			K	12.89	mg/L	
			Mg	3.10 ± 0.77		
			Mn	2 ± 7	μg/L	
			Mo	2.7 ± 3.5		
			Na	12.89 ± 31.21	mg/L	
			Pb	0.3 ± 0.5	μg/L	
			SO_4^{2-}	14.29 ± 0.99	mg/L	
			Th	3.0 ± 6.5	μg/L	
			U	2.5 ± 6.5		
			Zn	3.8 ± 10.7		
	Deep Rock	s	Ca	0.5–26.5	mg/L	
	Deer Park		Mg	1–2.6		
			Na	1–60		
	Fountainhead	s. plastic	Ag	67.8 ± 161.3	μg/L	
			Al	4.7 ± 5.6		
			As	9.7 ± 11.4		
			Ca	3.1 ± 4.74	mg/L	
			Cd	1.3 ± 2.2	μg/L	
			Cl	4.7 ± 0.92	mg/L	
			Co	1 ± 0.8	μg/L	
			Cr	< 0.2		
			Cu	0.5 ± 0.8		
			Fe	0.001 ± 0.0006		
			Hg	24.7 ± 28		
			K	1.3 ± 0.19	mg/L	
			Mg	0.34 ± 0.04		
			Mo	2.8 ± 3.1	μg/L	
			Na	5.33 ± 0.45	mg/L	
			Pb	0.2 ± 0.4	μg/L	
			SO_4^{2-}	14.56 ± 1.53	mg/L	
			Th	2.2 ± 3.0	μg/L	
			U	2.3 ± 2.7		
			Zn	2.2 ± 1.0		
	Georgia Mountain Water	s	Ca	2	mg/L	(Bong and others 2009, Azoulay and others 2001, Morr and others 2006, Ikem and others 2002)
	Goldemb	s. plastic	Ag	0.12	μg/L	
			As	4		
			Ca	0.05	mg/L	
			Cd	5	μg/L	
			Cl	6.13	mg/L	
			Cr	< 0.2	μg/L	
			Cu	< 0.2		
			Fe	0.001		
			Hg	75		
			K	0.258	mg/L	
			Mg	3.2		
			Mn	1	μg/L	
			Mo	2		
			Na	2.06	mg/L	
			SO_4^{2-}	12.94		
			Th	2	μg/L	
			U	1		
			Zn	3		

(*Continued*)

Table 5–Continued

Country	Brand	Type of water	Parameter	Range	Unit	References
	Great Bear	s	Ca	1–1.3	mg/L	
			Mg	1		
			Na	1.7–3		
	Hawaiian	s. plastic	Ag	2	μg/L	
			Ca	0.04	mg/L	
			Cd	< 0.2	μg/L	
			Cl	7.17	mg/L	
			Cr	< 0.2	μg/L	
			Cu	1		
			Fe	0.009		
			K	2.35	mg/L	
			Mg	3.47		
			Mn	1	μg/L	
			Mo	2		
			Na	5.98	mg/L	
			SO_4^{2-}	5.63		
			Th	5	μg/L	
			U	1		
			Zn	15		
	Hawaiian Springs	s	Ca	6–37	mg/L	
	La Croix		Mg	3–22		
			Na	4–6		
	Lithia Springs	m	Ca	120	mg/L	
			Mg	7		
			Na	680		
	Melwood	s. plastic	Ag	3 ± 28	μg/L	
			Al	6.4 ± 9.2		
			As	2 ± 2.8		
			Ca	1.53 ± 2.1	mg/L	
			Cl	7.17		
			Co	1 ± 1.4	μg/L	
			Cr	<0.2		
			Cu	1.5 ± 0.7		
			Fe	0.001		
			K	10.2 ± 8.77	mg/L	
			Mg	1.06 ± 0.92		
			Mn	0.5 ± 0.7	μg/L	
			Mo	3 ± 4.2		
			Na	5.98	mg/L	
			SO_4^{2-}	5.63		
			Th	5	μg/L	
			U	1		
			Zn	15		
	Mendocino	m	Ca	310	mg/L	(Bong and others 2009,
			Mg	130		Azoulay and others 2001,
			Na	240		Morr and others 2006,
						Ikem and others 2002)
	Mount Olympus	s	Ca	8–68	mg/L	
	Mountain Valley		Mg	2–8		
			Na	3		
	Mountainvalley	s. plastic	Ca	0.05	mg/L	
	Oasis		Cd	< 0.2	μg/L	
			Cl	10–23	mg/L	
			Cr	0.2	μg/L	
			Cu	0.5–2		
			Fe	0.003		
			K	0.58–1.22	mg/L	
			Mg	4.4–8		
			Mn	1	μg/L	
			Mo	2–10		
			Na	3–128	mg/L	
			SO_4^{2-}	8–16		
			Th	2–11	μg/L	
			U	18		
			Zn	6–11		
	Ozarka	s	Ca	18	mg/L	
			Mg	1		
			Na	5		
	Pleasantspring	s. plastic	Ag	1	μg/L	
			Ca	0.05	mg/L	
			Cd	1	μg/L	
			Cl	16	mg/L	

(*Continued*)

Table 5–Continued

Country	Brand	Type of water	Parameter	Range	Unit	References
			Cr	< 0.2	μg/L	
			Cu	1		
			Fe	0.001		
			Hg	1		
			K	52.8	mg/L	
			Mg	1.27		
			Mn	5	μg/L	
			Mo	1		
			Na	1.82	mg/L	
			SO_4^{2-}	1.59		
			Th	3	μg/L	
	Poland Spring	s	Ca	4.1	mg/L	(Bong and others 2009, Azoulay and others 2001, Morr and others 2006, Ikem and others 2002)
			Mg	0.2–1		
			Na	1.5–3		
	Prestige	s. plastic	Al	1 ± 1.4	μg/L	
			Ca	12.82 ± 18.07	mg/L	
			Cd	2.5 ± 3.5	μg/L	
			Co	0.5 ± 0.7		
			Cu	< 0.2		
			Fe	0.002 ± 0.001		
			K	0.49 ± 0.08	mg/L	
			Mg	8.166 ± 1.15		
			Mo	12.4 ± 15.1	μg/L	
			Na	6.17 ± 0.28	mg/L	
			SO_4^{2-}	9.42 ± 0.33		
			U	1 ± 1.4	μg/L	
			Zn	3.5 ± 0.7		
	Pure Spring Water	s	Ca	49	mg/L	
			Mg	4		
	Sams	p. plastic	Ag	1	μg/L	
			As	0.005		
			Ca	0.04	mg/L	
			Cd	5	μg/L	
			Cl	5.55	mg/L	
			Cr	< 0.2	μg/L	
			Cu	< 0.2		
			Fe	0.002		
			Hg	79		
			K	0.13	mg/L	
			Mg	0.09		
			Mn	0.002	μg/L	
			Mo	1		
			Na	2.64	mg/L	
			Pb	3	μg/L	
			SO_4^{2-}	2.64	mg/L	
			Th	4	μg/L	
			U	2		
			Zn	< 0.1		
	Silverspring Southernhome	s. plastic	Ag	0.5–8.3	μg/L	
			Al	0.3		
			Ca	0.04	mg/L	
			Cd	2.8–3	μg/L	
			Cl	14.6–26.05	mg/L	
			Co	0.5–0.7	μg/L	
			Fe	0.002–1.3		
			Hg	6–12.7		
			K	0.53–0.66	mg/L	
			Mg	6.3–8.72		
			Mo	0.5–20.6	μg/L	
			Na	2.17–6.44	mg/L	
			SO_4^{2-}	9.42–10.24		
			Th	0.7–2.3	μg/L	
			U	1.3–5.3		
			Zn	3 - 4		
	Sparkletts	s	Ca	5	mg/L	
			Mg	5		
			Na	15		
	Springtime Sweetwater	s. plastic	Ag	0.5	μg/L	
			Al	0.3		
			As	1		
			Ca	0.05–5.7	mg/L	
			Cl	6.7–17		

(*Continued*)

Table 5–Continued

Country	Brand	Type of water	Parameter	Range	Unit	References
			Co	1–2.5	μg/L	
			Cu	0.5–0.7		
			Fe	0.5–0.7		
			Hg	7.7		
			K	0.57–3	mg/L	
			Mg	1.6–2.2		
			Mo	1.7	μg/L	
			Na	8–143	mg/L	
			SO_4^{2-}	1.7–8.9		
			Th	7	μg/L	
			U	2.5–4.7		
			Zn	2–3		
	Talawanda Spring	s	Ca	2–76	mg/L	
	Talking Rain		Mg	2–17		
	Utopia		Na	3–8		
	Vichy Springs	m	Ca	157	mg/L	
			Mg	48		
			Na	1095		
	Zephyrhills	s. plastic	Ag	11.4 ± 25.5	μg/L	(Bong and others 2009,
			Al	0.6 ± 0.9		Azoulay and others 2001;
			As	0.8 ± 1.8		Morr and others 2006;
			Ca	10.52 - 58	mg/L	Ikem and others 2002)
			Cd	2 ± 2.3	μg/L	
			Cl	15.13 ± 1.24	mg/L	
			Co	0.8 ± 1.0	μg/L	
			Cr	0.2 ± 0.4		
			Cu	0.6 ± 0.9		
			Fe	0.6 ± 0.5		
			Hg	16.6 ± 22		
			K	0.37 ± 0.08	mg/L	
			Mg	0.9 - 3		
			Mo	5.8 ± 3.8		
			Na	4 - 6.69	mg/L	
			Pb	0.4 ± 0.5	μg/L	
			SO_4^{2-}	14.32 ± 0.54	mg/L	
			Th	6.6 ± 12.1	μg/L	
			U	5.4 ± 5.9		
			Zn	5.4 ± 2.6		
Africa						
Egypt	Baraka	1.5 L	Al	2.71	mg/L	(Saleh and others 2001)
			Ba	59.7		
			Ca	20.7		
			Co	0.02		
			Cr	8.92		
			Cu	4.63		
			Fe	79		
			Hg	0.01		
			K	21.2		
			Mg	23.3		
			Mo	1.86		
			Na	67.2		
			Ni	0.53		
			Pb	0.02		
			Sb	0.28		
			Si	17.2		
			Ti	60.8		
			V	2.51		
			Zn	4.85		
	Delta	Plastic 1.5 L	Al	3.51	mg/L	
			Ba	11.5		
			Be	0.02		
			Ca	27.2		
			Cd	0.02		
			Co	0.04		
			Cr	10.4		
			Cu	2.65		
			Fe	40.1		
			Hg	0.01		
			K	4.06		
			Mg	11.5		
			Mn	0.33		

(*Continued*)

Table 5–Continued

Country	Brand	Type of water	Parameter	Range	Unit	References
			Mo	0.88		
			Na	34.5		
			Ni	0.88		
			P	20.7		
			Pb	0.06		
			Sb	0.1		
			Si	17.1		
			Ti	80.4		
			V	7		
			Zn	9.26		
	Mineral	1.5 L	Ag	0.12	mg/L	(Saleh and others 2001)
			Al	13.3		
			Ba	40.1		
			Be	0.02		
			Ca	44.8		
			Cd	0.01		
			Co	0.04		
			Cr	14.9		
			Cu	10.5		
			Fe	121		
			Hg	0.03		
			K	4.88		
			Mg	1.54		
			Mn	0.05		
			Mo	0.35		
			Na	169		
			Ni	2.24		
			Pb	0.08		
			Sb	0.19		
			Si	11.5		
			Ti	136		
			V	4.59		
	Safi	1.5 L	Al	11.9	mg/L	
			Ba	262		
			Ca	7.88		
			Cr	5.45		
			Cu	2.92		
			Fe	60.9		
			Hg	0.01		
			K	21.2		
			Mg	8.15		
			Mn	1.41		
			Mo	0.29		
			Na	32.9		
			Ni	0.55		
			Pb	0.04		
			Sb	0.18		
			Si	12.3		
			Ti	23.4		
			V	1.51		
			Zn	58.8		
	Siwa	1.5 L	Al	11	mg/L	
			Ba	222		
			Be	0.01		
			Ca	6.02		
			Cd	0.01		
			Co	0.01		
			Cr	5.4		
			Cu	4.14		
			Fe	99.3		
			Hg	0.03		
			K	18.5		
			Mg	6.85		
			Mo	0.36		
			Na	43.8		
			Ni	1.24		
			P	3.92		
			Pb	0.2		
			Sb	0.3		
			Si	11.6		
			Ti	17.7		

(*Continued*)

Table 5–Continued

Country	Brand	Type of water	Parameter	Range	Unit	References
			V	1.49		
			Zn	64.1		
	Spa Reine	lm	Mg	1	mg/L	
			Na	3		

M = mineral; lm = low mineral content; mm = medium mineral content; hm = high mineral content; s = source; p = purified; c = carbonated; nc = noncarbonated; plastic = bottle made from synthetic material; glass = glass bottle.

Table 6–Levels of organic contaminants in bottled waters (literature information).

Parameter	Range	Type of water	Reference
Pesticides			
α-HCH	0.045–0.098 mg/L	Bottled 1.5–19 L	(Diaz and others 2009)
β-HCH	0.048–0.152 mg/L		
β-HCH	0.019–0.033 mg/L		
δ-HCH	0.012–0.046 mg/L		
Aldrin	0.012–0.027 mg/L		
DDD	0.003–0.009 mg/L		
DDE	0.029–0.060 mg/L		
DDT	0.003–0.009 mg/L		
Dieldrin	nd		
Endosulfan I	nd–0.005 mg/L		
Endosulfan II	nd		
Endosulfan sulfate	nd–0.033 mg/L		
Endrin	nd–0.008 mg/L		
Endrin aldehyde	0.001–0.007 mg/L		
Volatile organic compounds			
1,2,4-Trimethylobenzene	0.11–0.13 mg/L	Bottled	(Al-Mudhaf and others 2009, Ahmad and Bajahlan 2009, Ikem 2010)
1,2-Dichloropropanne	0.12–0.4 mg/L		
1,3,5-Trimethylobenzene	0.41 mg/L		
1,3-Dichlorobenzene	0.1 mg/L		
Bromodichloromethane	0.1–0.58 mg/L		
Bromoform	0.11–37.55 mg/L		
Chloroform	0.1–1.85 mg/L		
Dibromochloromethane	0.1–1.76 mg/L		
Dibromomethane	0.1–0.74 mg/L		
Ethylbenzene	0.1–0.17 mg/L		
iso-Propylbenzene	0.11 mg/L		
Xylene	0.2–0.77 mg/L		
Naphthalene	0.1–0.75 mg/L		
Styrene	0.5–46.4 mg/L		
Toluene	0.1–1.18 mg/L		
Trichloroethene	0.13 mg/L		
Chloral-hydrate	0.4–0.9 μg/L		
Trichloropropanone	0.4–0.7 μg/L		
Dichloroacetonitrile	0.12–0.22 μg/L		
Haloacetic Acids			
Formic acid	33.2–58.1 μg/L	Bottled (purified, mineral, natural)	(Liu and Mou 2003)
Dichloroacetic acid	na–0,6 μg/L		
msp;Toluene	0.1–1.18 mg/L		
Ethanedioic acid	23–44 μg/L		
Antioxidant			
Butylated hydroxytoluene	nd–38 μg/L	Bottled 0.5–2 L	(Tombesi and Freije 2002)
4-Nonylphenol	108–298 ng/L	Bottled (mineral, pure)	(Li and others 2010)
Bisphenol A	17,6–324 ng/L		
Triclosan	0.6–9.7 ng/L		
Perfluorochemicals			
PFBuS	< 0.27 ng/L	Bottled	(Ericson and others 2008)
PFDA	0.63–0.82 ng/L		
PFDoDA	< 0.34 ng/L		
PFDS	< 0.1 ng/L		
PFHpA	0.4–0.61 ng/L		
PFHxA	0.87–0.102 ng/L		
PFHxS	< 0.18 ng/L		
PFNA	0.13–0.42 ng/L		
PFOA	0.16–0.67 ng/L		
PFOS	< 0.24 ng/L		
PFOSA	0.19 ng/L		
PFTDA	< 0.90 ng/L		
PFUnDA	< 0.43 ng/L		
THPFOS	< 0.1 ng/L		
Carbonyl compounds			
Formaldehyde	0.8–96.1 μg/L	0.5–1.5 L, Bottled (c, nc)	(Nawrocki and others 2002)
Acetaldehyde	0.6–317.8 μg/L		
Acetone	5.1–125.6 μg/L		

c = carbonated; nc = noncarbonated.

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