

Assessment of Drinking Water Quality in Lebanon

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Abstract

The World Health Organization (WHO) estimates around 1.5 million deaths can be prevented each year by implementing safe drinking water and sanitation services (WHO, September 2023), something which is severely lacking in the Middle East and notably Lebanon. As such, multiple alternate sources of drinking water are filling that void, including bottled, springs, wells and unlicensed vendors. Of the aforementioned, none rivals Lebanon's emerging bottled water sector. Moreover, more than 70% of households rely on bottled water daily due to failing public water infrastructure and unsafe tap water (Statista). The quality of this purveyed water is therefore of great public concern, countered by only 42 or so licensed entities, grappling with several hundred unlicensed ones for the Lebanese market (Daou, 2016). In light of the lack of any semblance of legislative oversight in Lebanon, the aim of this article is to present a snapshot into the quality of numerous sources of drinking water. A total of 13 samples (11 bottled water brands and two municipal samples) were analyzed for physico-chemical as well as microbial properties. Said 13 samples were generally found to be compliant with international drinking water guidelines, save for two. It is hence recommended that all potable water sources undergo immediate comprehensive and continuous monitoring by relevant authorities.

Keywords

Total Dissolved Solids, Total Coliform, Nitrate, Nitrite, Methemoglobinemia

1. Introduction

A popular misconception in this day and age, is that bottled water is often safer than tap water, which very well may be the case in Lebanon, compelling the population to relegate tap water to menial cooking, washing and cleaning activities.

Packaged drinking water, on the other hand, is intended for human consump-

tion, that is sealed in containers and protected from contamination until consumption. As for the US Food and Drug Administration (FDA), bottled water is intended for human consumption that is sealed in bottles or other containers with no added ingredients except that it may optionally contain safe and suitable antimicrobial agents.

The annual global revenue from this business is around US\$ 300 to 400 billion and climbing. Nestlé Waters is a top market player globally and in Lebanon as well. In 2014, Nestlé Waters, held a combined volume market share of 27% with its two local brands Nestlé Pure Life (15%) and Sohat (12%). Also in volume terms, Tannourine held a market share of 15%, Rim 11% and Sannine roughly 4%.

Nevertheless, bottling giants are not impervious to water quality scandals by any stretch of the imagination. The Perrier crisis of 1990 is one such example, when roughly 160 million bottles of sparkling water were recalled worldwide after traces of benzene, a known carcinogen, were detected in bottles in the US (Royte, 2008).

A 2016 study by BLOMINVEST Bank, shows that the bottled water business in Lebanon, approximated at US\$ 600 million, continues to skyrocket. The licensed bottling companies alone account for an annual production of between 700 and 800 million liters of water, growing between 2 to 5% with each passing year. If unlicensed companies were included, the figure would be significantly higher. At 75 L/person/year, bottled water consumption in Lebanon is quite substantial by international standards.

With the current market inflation and shifting exchange rates, it is rather difficult to estimate in US Dollars the exact cost per liter of bottled water, but a rough rule of thumb would place it in the range of US\$ 0.2 - 0.25/Liter.

In the Middle East, the majority of families however often pay 25% or more of their income for insufficient quantities of poor-quality water (Allan, 2011), the bulk of which goes to the bottled water sector and vendors alike.

US law requires the Environmental Protection Agency or EPA, whenever it issues a new National Primary Drinking Water Regulation, to establish a bottled-water standard for the same contaminant. The FDA standard (21 CFR 165.110) must generally be no less stringent than the corresponding EPA maximum contaminant limit (MCL).

For that reason, most countries have defined local standards for bottled water typically in harmonization with broader regulatory agencies like the aforementioned EPA, WHO, and the Council of European Economic Community Directive. Following **Figures 1-4** are the samples of such standards from around the world.

The Environmental Protection Agency (EPA) sets legally enforceable drinking water standards under the Safe Drinking Water Act (SDWA (USEPA, 2026)). These standards include guidelines for over 90 contaminants (such as microorganisms, chemicals, disinfection by-products, and radionuclides). This number refers to mainly primary standards (Maximum Contaminant Levels and treatment requirements) enforced at the federal level.

Parameter	Unit	WHO Guideline	EPA MCL	EU Limit
TDS (Total Dissolved Solids)	mg/L	600 (aesthetic)	500 (secondary)	Not regulated directly
pH	—	6.5–8.5 (aesthetic)	6.5–8.5 (secondary)	6.5–9.5
Turbidity	NTU	4 (aesthetic); <1 for disinfection	1 (surface water treatment); 0.3 (95th percentile)	1 (at treatment works)
Free Chlorine Residual	mg/L	5 (health-based)	4 (MRDL)	Not specified (member state discretion)
Chloride	mg/L	250 (aesthetic)	250 (secondary)	250
Sulfate	mg/L	250 (aesthetic)	250 (secondary)	250
Hardness (as CaCO ₃)	mg/L	Not established (no health concern)	Not regulated	Not regulated (member state indicator)
Nitrate (as NO ₃)	mg/L	50	10 (as N) = 44.3 (as NO ₃)	50
Fluoride	mg/L	1.5	4.0 (MCL); 2.0 (secondary)	1.5

Figure 1. Physical and chemical parameters.

Parameter	Unit	WHO Guideline	EPA MCL	EU Limit
Arsenic	µg/L	10	10	10
Lead	µg/L	10	15 (action level)	5 (by 2036); 10 (until 2036)
Mercury	µg/L	6 (inorganic)	2	1
Cadmium	µg/L	3	5	5
Chromium (total)	µg/L	50	100	25
Iron	µg/L	300 (aesthetic)	300 (secondary)	200
Manganese	µg/L	80 (health); 100 (aesthetic)	50 (secondary)	50
Copper	mg/L	2	1.3 (action level)	2
Zinc	mg/L	3 (aesthetic)	5 (secondary)	Not regulated
Barium	mg/L	1.3	2	Not regulated at EU level
Antimony	µg/L	20	6	10 (reduced from 20)
Selenium	µg/L	40	50	20 (reduced from 50)
Aluminum	µg/L	900 (health-based provisional)	50–200 (secondary range)	200

Figure 2. Heavy metals and inorganic contaminants.

Parameter	Unit	WHO Guideline	EPA MCL	EU Limit
Total Trihalomethanes (TTHMs)	µg/L	No single total value; individual THMs: chloroform 300, bromoform 100, DBCM 100, BDCM 60	80 (total)	100 (total)
PFAS (total / sum)	µg/L	Not yet established (under review)	4 ng/L each for PFOA and PFOS (2024 final rule)	0.5 µg/L (sum of PFAS); 0.1 µg/L (sum of subset of 20 PFAS)

Figure 3. Disinfection byproducts and emerging contaminants.

Parameter	Unit	WHO Guideline	EPA MCL	EU Limit
<i>E. coli</i>	CFU/100 mL	Not detectable in any 100 mL sample	0 (zero; triggers treatment technique violations)	0 per 100 mL
Total Coliforms	CFU/100 mL	Not detectable in any 100 mL sample	No more than 5% positive monthly samples (Revised Total Coliform Rule)	0 per 100 mL

<https://www.foreverpureplace.com/drinking-water-standards>, Forever Pure (2026).

Figure 4. Microbiological parameters .

Bottled water in Lebanon, on the other hand, requires compliance with the Lebanese Standards Institution (**LIBNOR**, 2016) in order to be licensed by relevant authorities. Said standards mirror closely the aforementioned, for that reason, results hereinafter will be mostly compared to EPA guidelines.

Bottled drinking water produced in Lebanon is covered by Lebanese Standard NL 162:1999, issued by **LIBNOR**. Lebanese standards are voluntary in principle unless rendered mandatory by the competent authorities, law, decree or decision; bottled-water producers are also subject to licensing and health-control requirements by the Lebanese Ministry of Public Health (**MOPH**).

Licensing in Lebanon, however, is not simply a commercial-registration issue. The Ministry of Public Health's (MOPH) administrative procedure for a water-bottling plant requires, among other things:

- property documentation;
- authorization/decreed permitting water bottling;
- construction authorization;
- occupancy authorization;
- technical/scientific documentation for the bottling equipment;
- application documentation.

2. Materials and Methods

For this study, eleven random brands of bottled waters were purchased in standard PET (polyethylene terephthalate) plastic bottles, in autumn of 2025, from a multitude of grocery shops and supermarkets across Beirut. Said bottles varied between 0.5 to 1.0 liter volumes.

All bottled water samples (one through eleven) were acquired in their original sealed containers, transported and stored at ambient conditions (23 - 25°C) prior to completing relevant analyses using a calibrated SMART® 3 Colorimeter within a framework of a few hours.

Municipal samples 12 and 13 on the other hand were obtained from taps using sterile bottles and transported in a cooler at 4°C Celsius. Said taps were firstly disinfected with isopropyl alcohol and allowed to run for a few minutes before testing “in-situ” using the pH/TDS, calibrated LaMotte TRACER Pocke Tester, with a pH range between 0.00 and 14.0; TDS from 0 to 9999 ppm; and temperature from 0.0° to 65°C.

The conducted analyses using the above SMART 3 Colorimeter on the other

hand, included physical, chemical properties such as alkalinity, total hardness (TH); total iron, ferrous iron (Fe II), ferric iron (Fe III), copper, nitrate (NO_3^-) nitrite (NO_2^-) with some of the following method detections and reporting limits (Figure 5).

Parameter	LaMotte method / chemistry	Manufacturer's stated analytical range	Lower end of stated range*	MDL/RL officially stated by LaMotte?
Total hardness	Colorimetric	10–400 mg/L as CaCO_3	10 mg/L	No
Alkalinity	Colorimetric	10–250 mg/L as CaCO_3	10 mg/L	No
Total iron	1,10-Phenanthroline	0.1–5.0 mg/L Fe	0.1 mg/L	No
Ferrous iron (Fe^{2+})	1,10-Phenanthroline	0.1–5.0 mg/L Fe	0.1 mg/L	No
Ferric iron (Fe^{3+})	1,10-Phenanthroline	0.1–5.0 mg/L Fe	0.1 mg/L	No
Copper (Cu)	BCA, low range	0.04–3.50 mg/L Cu	0.04 mg/L	No
Nitrate-N ($\text{NO}_3\text{-N}$)	Cadmium reduction	0.10–3.00 mg/L as N	0.10 mg/L	No
Nitrate (NO_3^-)	Zinc reduction	5–60 mg/L as NO_3^-	5 mg/L	No
Nitrite-N ($\text{NO}_2\text{-N}$)	Diazotization	0.02–0.80 mg/L as N	0.02 mg/L	No

Figure 5. LaMotte water parameter details (LaMotte Company, 2025).

It is noteworthy to mention that all the analytical tests were performed in accordance to the Standard Methods for the Examination of Water and Wastewater (Eaton et al., 2005), however no blank or control samples were adopted for this limited sampling regime.

Lastly, the U.S. Environmental Protection Agency approved presence-absence (P/A) total coliform test method was used for the microbiological aspect (USEPA, 2024) requiring an incubation period of about 48 hours at ambient conditions.

3. Results and Discussion

To begin with, the labels of the bottled waters depicted in the following table have been substituted with numbers in order to avoid potential litigation.

Regarding the mentioned parameters, TDS, total hardness, pH, alkalinity, and iron are considered by the US Environmental Protection Agency (USEPA) secondary (SMCL) and often advisory, meaning that they impact taste, odor, appearance etc. rather than posing a direct health risk. As for the remaining parameters, copper, nitrite, nitrate and coliform, they are classified as primary (MCL) drinking water contaminants posing a direct health threat.

Secondary contaminants, like total dissolved solids (TDS) values, all fell within the recommended secondary guidelines as per USEPA (500 mg/L) standards.

However, Sample 12 comprises a cluster of wells pumping to Beirut, for distribution, at an average rate of 500 m³/hour. Said source indicates a TDS concentration exceeding the recommended (500 mg/L) limit and lingering in the neighborhood of 1050 mg/L during the so called “wet season”, meaning that said source salinity could spike during autumn’s end.

Sample 12 (public water source), according to several studies, is affected by sea-

water intrusion situated south of the capital Beirut, likely caused by decades of unchecked groundwater over-abstraction (Saadeh, 2008).

Generally, the data indicates that the physico-chemical quality of the bottled waters (1 to 11) are satisfactory and are relatively safe for human consumption for the parameters tested and summarized as shown in the following **Table 1**.

Table 1. Results of sampled water sources.

<i>Source</i>	TDS (mg/L)	Total Hardness (mg/L)	pH	Alkalinity (mg/L)	Total Iron (mg/L)	Ferrous (mg/L)	Ferric (mg/L)	Copper (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Total coliform
Sample 1 Bottled water	290	244	7.9	168	0.1	Below reporting limits	Below reporting limits	0.1	Below reporting limits	6.0	Absent
Sample 2 Bottled water	260	176	7.6	156	Below reporting limits	Below reporting limits	Below reporting limits	Below reporting limits	1.0	Below reporting limits	Absent
Sample 3 Bottled water	160	125	7.8	109	Below reporting limits	Below reporting limits	Below reporting limits	0.1	Below reporting limits	6.0	Absent
Sample 4 Bottled water	220	140	7.6	150	0.1	Below reporting limits	0.1	0.1	Below reporting limits	6.0	Absent
Sample 5 Bottled water	250	216	7.9	152	Below reporting limits	Below reporting limits	Below reporting limits	Below reporting limits	Below reporting limits	3.0	Absent
Sample 6 Bottled water	245	210	7.7	164	0.1	Below reporting limits	0.1	0.2	0.1	5.0	Absent
Sample 7 Bottled water	200	182	7.8	141	Below reporting limits	Below reporting limits	Below reporting limits	0.1	Below reporting limits	7.0	Absent
Sample 8 Bottled water	170	107	6.9	103	0.1	Below reporting limits	0.1	Below reporting limits	Below reporting limits	Below reporting limits	Absent
Sample 9 Bottled water	150	126	7.7	114	Below reporting limits	Below reporting limits	Below reporting limits	0.1	Below reporting limits	7.0	Absent
Sample 10	120	100	7.5	88	3.8	3.8	Below reporting limits	1.3	1.1	Below reporting limits	Absent
Sample 11 Bottled water	140	19	6.6	23	0.1	Below reporting limits	0.1	Below reporting limits	Below reporting limits	7.0	Absent
Sample 12 Municipal water	1050	332	7.8	176	0.2	Below reporting limits	0.2	Below reporting limits	Below reporting limits	27	Not tested
Sample 13 Municipal water	345	260	8.0	230	0.2	Below reporting limits	0.2	0.5	Below reporting limits	10	Absent

Regarding nitrates and nitrites tested in the aforementioned samples, all results were below the recommended threshold set by EPA (nitrate: ~45 mg/L; nitrite: ~3.3 mg/L). These two parameters are especially critical in monitoring drinking water mainly for their role in causing methemoglobinemia, or Blue Baby Syndrome, resulting in oxygen deprivation in tissues of infants mostly under the age of six months (Chesley, 2025).

As for copper, the United States Environmental Protection Agency (EPA) specifically regulates copper at consumers' taps, so unlike many contaminants that are regulated at treatment plants, copper compliance is determined using water samples collected from end users due to the fact that copper enters drinking water through some of the following routes:

- 1) Copper pipes;
- 2) Plumbing fixtures;
- 3) Network solder.

Lastly, long-term exposure to copper at high levels (normally exceeding 1.5 mg/L) can eventually contribute to liver or kidney damage, especially in sensitive individuals.

As for total coliform, the microbiological quality control test is used to determine whether bottled water has been contaminated by environmental or fecal bacteria during source extraction, treatment, bottling, or even storage. Under regulations such as those of the World Health Organization (WHO), U.S. Food and Drug Administration (FDA), and European Union (EU), total coliform should generally be absent from any and all drinking water, be it tap or bottled water, in other words zero colony forming units per 100 mL of sampled water (0 CFU/100 mL).

As such, total coliform tested on bottled waters, indicates that the samples conform to drinking water norms for said parameter. However, caution is always advised when drinking from taps as well as non-regulated water vendors.

4. Recommendations

In summary, while the physico-chemical characteristics of the most popular bottled water brands were deemed satisfactory across the board of tested parameters, public source Sample 12, however stands out for its elevated TDS value.

In light of the aforementioned test results, it is recommended that all marketed bottled waters be consistently and rigorously monitored for quality by pertinent authorities to safeguard public health, not just for the run of the mill aforementioned parameters, but “emerging” ones as well, such as but not limited to the following:

- **PFAS (Per- and polyfluoroalkyl substances):** synthetic “forever chemicals” from industrial use and firefighting foams that increase the likelihood of certain cancers.
- **Pharmaceuticals and Hormones:** residues from prescription drugs, medications, and livestock treatments that lead to disruption of the endocrine system,

developmental issues, and the increased likelihood of antibiotic-resistant bacteria.

- **Personal Care Products (PCPs):** ingredients from cosmetics, sunscreens, fragrances, and insect repellents that are generally classified as endocrine disrupting chemicals or EDCs.
- **Microplastics (less than 5 mm) & Nanomaterials (1 to 100 nanometers, nm):** tiny plastic fragments from degraded commercial goods and synthetic textiles which cause cellular damage, inflammation, and chemical leaching of toxins directly inside tissue.
- **Industrial Additives & Byproducts:** compounds like dioxane, flame retardants, and specialized pesticides that are neurotoxic, suppress the immune system, and contribute to aquatic ecosystem toxicity.

Lastly, there are do it yourself (DIY) under-sink multi-stage RO/UV systems that can be installed relatively easily and effectively for people who have a vested interest in drinking and washing food produce with municipal tap water at a single point-of-use rather than treating water supplied to the entire house.

Author Contributions

MS and GK jointly conceived the study. MS carried out the entire implementation. Both authors approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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