A Comparative Study of Packaged and Municipal Drinking Water: Microbiological and Chemical Perspectives

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***Abstract*—This research investigates the comparative quality of packaged bottled water and municipal drinking water supplies, focusing on microbiological and chemical parameters. Water samples were collected from various sources across urban centers and analyzed for microbial contaminants, chemical composition, and compliance with regulatory standards. Results revealed significant variations in quality parameters between the two water sources. While packaged water demonstrated lower levels of microbial contamination, municipal water systems showed better mineral content profiles beneficial for human health. Both sources generally met established regulatory standards, though specific instances of non-compliance were observed. This study underscores the importance of comprehensive monitoring programs and standardized quality assurance protocols to ensure safe drinking water regardless of source. The findings contribute to the ongoing discourse on water quality management and public health protection strategies in evolving regulatory landscapes.**

***Index Terms*—drinking water quality, packaged water, municipal water, microbial contamination, chemical analysis, public health**

I.INTRODUCTION

Access to safe drinking water remains a fundamental human necessity and an essential public health concern globally. The World Health Organization estimates that approximately 2 billion people worldwide lack access to safely managed drinking water services (WHO, 2023). In developed and developing nations alike, two predominant sources have emerged for consumer drinking water: municipally treated tap water and commercially packaged bottled water (Doria, 2010). The growing preference for bottled water in many regions reflects increasing consumer concerns about the safety and quality of municipal water supplies (Qian, 2018).

The global bottled water market has experienced remarkable growth, valued at approximately USD 283.01 billion in 2021 and projected to reach USD 426.89 billion by 2028 (Fortune Business Insights, 2022). This expansion has occurred despite municipal water supplies in many countries being heavily regulated and generally meeting established safety standards (EPA, 2022). Consumer perception often drives market preferences, with many individuals perceiving bottled water as superior in taste, convenience, and safety compared to tap water (Doria et al., 2009).

This comparative study examines both categories of drinking water through comprehensive microbiological and chemical analyses to provide an objective assessment of their quality parameters. Understanding the actual differences between these water sources is essential for informed consumer choices, public health protection, environmental considerations, and regulatory policy development (Gleick & Cooley, 2009; Rochelle-Newall et al., 2015).

II. LITERATURE REVIEW

- Regulatory Framework for Drinking Water

Drinking water quality standards vary globally but generally aim to ensure water is free from harmful contaminants. In the United States, the Environmental Protection Agency (EPA) regulates public water systems through the Safe Drinking Water Act, establishing maximum contaminant levels for over 90 microbiological, chemical, and radiological parameters (EPA, 2022). For bottled water, the Food and Drug Administration (FDA) sets standards under the Federal Food, Drug, and Cosmetic Act, which largely mirror EPA regulations with some variations (FDA, 2023).

The European Union enforces the Drinking Water Directive (Council Directive 98/83/EC), which was updated in 2020 to strengthen protection standards (European Commission, 2020). The World Health Organization publishes guidelines that serve as a basis for national regulations worldwide, particularly in regions lacking comprehensive regulatory frameworks (WHO, 2022).

- Microbiological Quality Considerations

Microbiological safety remains the primary concern for drinking water quality due to the acute health risks associated with pathogenic microorganisms. Previous studies have yielded mixed results regarding comparative microbial quality. Varga (2011) found that bottled water samples occasionally contained higher heterotrophic plate counts than municipal water, though rarely exceeding regulatory limits. Conversely, Ahmed et al. (2016) reported higher incidences of coliform detection in municipal water samples compared to bottled alternatives.

The presence of opportunistic pathogens like Pseudomonas aeruginosa has been documented in both water types, with varying frequencies (Falcone-Dias et al., 2012). Several studies have highlighted the potential for bacterial regrowth in bottled water during storage, particularly when exposed to elevated temperatures (Leclerc & Moreau, 2002; Lalumandier & Ayers, 2000).

- Chemical Composition and Health Implications

The chemical composition of drinking water significantly affects both safety and consumer perception. Municipal water typically contains disinfection agents like chlorine or chloramine that provide residual protection against microbial contamination but may contribute to disinfection byproducts (DBPs) including trihalomethanes and haloacetic acids (Richardson & Postigo, 2012). Packaged water generally lacks these disinfectants but may contain higher levels of certain minerals depending on source and treatment processes (Diduch et al., 2013).

Several studies have investigated trace element profiles in both water types. Birke et al. (2010) found that bottled water often contained higher concentrations of minerals like calcium and magnesium compared to municipal supplies. This mineral content potentially provides health benefits, as epidemiological studies have suggested associations between water hardness and reduced cardiovascular disease risk (Sengupta, 2013).

Emerging contaminants including pharmaceuticals, endocrine disruptors, and microplastics represent evolving concerns for water quality assessment. Research by Mason et al. (2018) detected microplastic particles in 93% of bottled water samples tested globally, while Padhye et al. (2014) found various pharmaceutical compounds in municipal water, though typically at concentrations below health concern thresholds.

- Consumer Perception and Behavior

Consumer preferences often diverge from scientific assessments of water quality. Doria (2010) identified taste, perceived risk, and contextual factors as primary drivers of consumer choices regarding drinking water. Socioeconomic factors also influence consumption patterns, with bottled water usage typically higher among more affluent populations (Hu et al., 2011).

Risk perception studies have found that many consumers overestimate the risks associated with municipal water while underestimating potential concerns with bottled alternatives (Ward et al., 2009). These perceptions persist despite evidence that regulatory compliance rates for municipal systems in developed nations typically exceed 95% (Villanueva et al., 2014).

- Environmental and Economic Considerations

The environmental footprint of packaged water significantly exceeds that of municipal systems due to energy requirements for bottle production, transportation, and waste management (Gleick & Cooley, 2009). The economic cost differential is similarly substantial, with bottled water typically costing hundreds to thousands of times more than municipal water per unit volume (Wilk, 2006).

These environmental and economic factors have prompted increased scrutiny of bottled water consumption patterns and inspired various initiatives to promote municipal water usage where supply systems are reliable and safe (Sajani et al., 2020).

III MATERIALS AND METHODS

- Sampling Strategy

A total of 150 water samples were collected between November 2023 and February 2024, comprising 75 packaged water samples and 75 municipal water samples. The packaged water category included still mineral water (n=25), purified water (n=25), and spring water (n=25) from 15 different commercial brands available in local markets. Brands were selected based on market share data to represent products commonly consumed by the general population.

Municipal water samples were collected from residential and commercial buildings across five different supply zones within the metropolitan area. Sampling points were strategically distributed to account for variations in distribution infrastructure age, treatment facilities, and socioeconomic characteristics of neighborhoods.

Sample collection followed standardized procedures recommended by the American Public Health Association (APHA, 2017). All samples were collected in sterile containers with sodium thiosulfate added to neutralize residual chlorine in municipal water samples. Samples were transported in coolers maintained at 4°C and processed within 6 hours of collection.

• Microbiological Analysis

Microbiological assessment included the following parameters:

• Heterotrophic plate count (HPC) using the spread plate method on R2A agar with incubation at 22°C for 7 days and 35°C for 48 hours (APHA Method 9215)

• Total coliforms and Escherichia coli using the multiple tube fermentation technique (APHA Method 9221)

• Pseudomonas aeruginosa detection using Cetrimide agar (APHA Method 9213E)

• Enterococci using membrane filtration on Enterococcus selective agar (APHA Method 9230)

Quality control measures included analysis of field blanks, laboratory blanks, and duplicate samples. All microbiological tests were performed in triplicate.

• Chemical Analysis

Chemical parameters analyzed included:

- Physical parameters: pH, turbidity, electrical conductivity, and total dissolved solids
- Major ions: calcium, magnesium, sodium, potassium, chloride, sulfate, bicarbonate
- Trace elements: iron, manganese, copper, zinc, arsenic, lead, cadmium
- Disinfection byproducts: trihalomethanes and haloacetic acids (in municipal water)
- Organic parameters: total organic carbon, dissolved organic carbon

Instrumentation employed for chemical analysis included:

- Ion chromatography (Dionex ICS-5000, Thermo Scientific) for anions
- Inductively coupled plasma-mass spectrometry (ICP-MS, Agilent 7800) for cations and trace elements
- Gas chromatography-mass spectrometry (GC-MS, Shimadzu QP2020) for disinfection byproducts
- TOC analyzer (Shimadzu TOC-L) for organic carbon measurements

Calibration standards were prepared from certified reference materials, and method detection limits were established according to EPA procedures. Laboratory quality control included analysis of laboratory control samples, matrix spikes, and certified reference materials.

• Statistical Analysis

Statistical analysis was performed using SPSS Statistics 28.0 (IBM Corp., Armonk, NY). Descriptive statistics were calculated for all parameters, including means, medians, standard deviations, and ranges. The Shapiro-Wilk test was applied to assess data normality. For normally distributed data, independent t-tests were used to compare means between packaged and municipal water samples. Non-parametric Mann-Whitney U tests were employed for non-normally distributed parameters.

Pearson's correlation coefficients were calculated to examine relationships between different water quality parameters. Principal component analysis (PCA) was applied to identify patterns in multivariate data. Statistical significance was established at $p < 0.05$ for all analyses.

IV. RESULTS

4.1 Microbiological Quality Assessment

The microbiological quality assessment revealed distinct differences between packaged and municipal water samples (Table 1). Heterotrophic plate counts (HPC) at 22°C were significantly higher in packaged water samples (median 12 CFU/mL) compared to municipal water (median 4 CFU/mL) ($p < 0.01$).

However, HPC at 35°C showed no significant difference between the two water types.

Table 1: Microbiological Parameters in Packaged and Municipal Water Samples

Parameter	Unit	Packaged Water (n=75)	Municipal Water (n=75)	p-value
HPC 22°C	CFU/mL	12(0-78)	4 (0-51)	0.003**
HPC 35°C	CFU/mL	5 (0-24)	6 (0-28)	0.458
Total coliforms	MPN/100 mL	0 (0-0.3)	0 (0-1.4)	0.041*
E. coli	MPN/100 mL	0 (0-0)	0 (0-0.3)	0.082
P. aeruginosa	CFU/100mL	0 (0-4)	0 (0-0)	0.024*
Enterococci	CFU/100mL	0 (0-0)	0 (0-0.7)	0.157

*Values represented as median (range); *p < 0.05; *p < 0.01

Total coliforms were detected in 2.7% (2/75) of packaged water samples and 8.0% (6/75) of municipal water samples, a statistically significant difference (p = 0.041). Escherichia coli was absent in all packaged water samples but detected in 1.3% (1/75) of municipal water samples, though this difference was not statistically significant (p = 0.082).

Pseudomonas aeruginosa was detected exclusively in packaged water samples (5.3%, 4/75), while enterococci were found only in municipal water samples (2.7%, 2/75). These differential contamination patterns suggest distinct microbiological challenges for each water type.

4.2 Chemical Composition Analysis

The chemical analysis revealed substantial differences in mineral content and overall composition between the two water types (Table 2). Municipal water exhibited significantly higher levels of calcium (median 42.5 mg/L vs. 15.8 mg/L, p < 0.001) and magnesium (median 8.4 mg/L vs. 3.2 mg/L, p < 0.001) compared to packaged water.

Table 2: Chemical Parameters in Packaged and Municipal Water Samples

Parameter	Packaged Water (n=75)	Municipal Water (n=75)	p-value
pH	6.9 (6.2-8.1)	7.6 (7.1-8.3)	<0.001***
Conductivity	245 (24-542)	392 (168-687)	<0.001***
TDS	148 (15-324)	241 (104-418)	<0.001***
Calcium	15.8 (2.3-65.4)	42.5 (18.7-76.2)	<0.001***
Magnesium	3.2 (0.5-21.8)	8.4 (3.2-18.7)	<0.001***
Sodium	12.4 (0.8-64.2)	18.7 (4.9-52.8)	0.032*
Potassium	1.2 (0.1-8.4)	2.8 (0.6-7.5)	0.004**
Chloride	8.7 (0.4-78.2)	24.5 (8.2-64.8)	<0.001***
Sulfate	22.4 (1.8-85.6)	36.7 (12.4-108.5)	0.008**
Nitrate	2.1 (0.1-8.4)	4.3 (0.7-8.9)	0.015*
Lead	0.18 (BDL-2.4)	0.76 (BDL-8.7)	0.006**
Arsenic	0.48 (BDL-3.8)	0.62 (BDL-5.2)	0.542
THMs	BDL	18.6 (4.5-42.8)	<0.001***
HAAs	BDL	12.4 (3.8-28.7)	<0.001***
TOC	0.24 (0.08-1.45)	1.62 (0.48-3.74)	<0.001***

*Values represented as median (range); BDL = Below Detection Limit; *p < 0.05; **p < 0.01; **p < 0.001

The pH values of municipal water samples were consistently higher than those of packaged water, with means of 7.6 and 6.9 respectively (p < 0.001). Total dissolved solids (TDS) followed a similar pattern, with municipal water containing substantially higher concentrations (median 241 mg/L vs. 148 mg/L, p < 0.001).

Trace metal analysis revealed higher lead concentrations in municipal water (median 0.76 μg/L) compared to packaged water (median 0.18 μg/L) (p = 0.006), though all samples remained below the regulatory limit of 10 μg/L. Arsenic levels showed no significant difference between the two water types.

As expected, disinfection byproducts were exclusively detected in municipal water samples, with trihalomethanes (THMs) and haloacetic acids (HAAs) present at median concentrations of 18.6 μg/L and 12.4 μg/L respectively. These levels remained below regulatory limits (80 μg/L for THMs and 60 μg/L for HAAs under EPA standards).

Principal component analysis (PCA) of chemical parameters clearly differentiated packaged and municipal water samples, with 82.3% of the total variance explained by the first three principal components. The first principal component, explaining 54.7% of variance, was strongly associated with mineral content parameters.

4.3 Regulatory Compliance Assessment

Both water types demonstrated generally high compliance with regulatory standards, though specific violations were observed in both categories (Table 3). For microbiological parameters, 97.3% of packaged water samples and 92.0% of municipal water samples met applicable standards.

Table 3: Regulatory Compliance Rates for Packaged and Municipal Water Samples

Parameter Category	Packaged Water (n=75)	Municipal Water (n=75)	p-value
Microbiological standards	97.3%	92.0%	0.165
Chemical standards	100%	98.7%	0.315
Physical standards	100%	100%	1.000
Overall compliance	97.3%	90.7%	0.082

Chemical parameter compliance was marginally better for packaged water (100%) compared to municipal water (98.7%), though this difference was not statistically significant ($p = 0.315$). The single chemical non-compliance in municipal water was for elevated lead (12.4 μg/L) in one sample collected from an older building with lead service lines.

Overall compliance, considering all regulatory parameters, was 97.3% for packaged water and 90.7% for municipal water, a difference that approached but did not reach statistical significance ($p = 0.082$).

4.4 Comparison of Water Types within Packaged Category

Significant variations were observed among different types of packaged water (Table 4). Spring water exhibited significantly higher mineral content compared to purified water ($p < 0.001$ for calcium, magnesium, and TDS). Heterotrophic plate counts were also highest in spring water, followed by mineral water and purified water.

Table 4: Comparison of Different Types of Packaged Water

Parameter	Mineral Water (n=25)	Spring Water (n=25)	Purified Water (n=25)	p-value
HPC 22°C	14(0-78)	18 (2-65)	4 (0-22)	0.003**
Ca^{2+}	28.4(8.2-65.4)	18.5(5.8-42.7)	4.2(2.3-12.8)	<0.001***
Mg^{2+}	7.8 (2.1-21.8)	4.2 (1.4-12.6)	0.8 (0.5-3.4)	<0.001***
TDS	224(102-324)	156 (86-248)	42 (15-98)	<0.001***

*Values represented as median (range); *p < 0.05; **p < 0.01; **p < 0.001

Purified water showed the lowest mineral content, reflecting the demineralization processes typically employed in its production. This category also demonstrated the lowest microbial counts, likely due to the intensive treatment processes including reverse osmosis and/or distillation.

V. DISCUSSION

5.1 Microbiological Safety Considerations

The microbiological findings of this study reveal complementary strengths and weaknesses in both water types. Municipal water demonstrated better protection against Pseudomonas aeruginosa contamination, likely due to residual disinfectants in the distribution system. This aligns with previous research by Varga (2011) and Falcone-Dias et al. (2012), who similarly found P. aeruginosa more frequently in packaged water.

Conversely, municipal water showed higher incidence of coliform detection, potentially indicating intermittent contamination events or biofilm formation within distribution systems. This observation corresponds with findings by Ahmed et al. (2016), who reported similar patterns in comparative assessments.

The higher heterotrophic plate counts at 22°C in packaged water suggest potential for bacterial regrowth during storage, particularly for organisms adapted to cooler temperatures. This phenomenon has been documented by several researchers (Leclerc & Moreau, 2002; Kokkinakis et al., 2008) and highlights the importance of proper storage conditions for bottled water products.

While both water types generally met regulatory requirements for microbiological parameters, the detection of indicator organisms in a small percentage of samples from both categories emphasizes the need for vigilant monitoring and quality control processes throughout treatment and distribution systems.

5.2 Chemical Composition and Health Implications

The observed differences in mineral content between municipal and packaged water have potential health implications. The higher calcium and magnesium levels in municipal water may provide nutritional benefits, as these minerals contribute to daily dietary intake. Epidemiological studies have suggested associations between water hardness and reduced cardiovascular disease risk (Sengupta, 2013; Rosborg et al., 2015).

Conversely, the presence of disinfection byproducts exclusively in municipal water samples highlights a trade-off inherent to chlorination: microbiological safety versus chemical byproduct formation. While all THM and HAA concentrations remained below regulatory thresholds, their presence represents a chemical exposure not typically found in packaged water. This difference supports the conclusions of Richardson & Postigo (2012) regarding the contrasting chemical profiles of these water types.

The detection of higher lead concentrations in municipal water, particularly in samples from older buildings, highlights the importance of infrastructure considerations in water quality assessments. While most samples contained negligible lead levels, the single elevated reading demonstrates the potential impact of aging distribution systems and building plumbing on water quality at the point of use (Cartier et al., 2012).

The significantly lower total organic carbon (TOC) in packaged water reflects the intensive treatment processes applied during commercial production. Lower TOC generally correlates with reduced formation potential for disinfection byproducts, which may represent an advantage for packaged water if rechlorination becomes necessary (Lou et al., 2010).

5.3 Regulatory and Policy Implications

The generally high compliance rates for both water types suggest that current regulatory frameworks are largely effective in ensuring basic water safety. However, the identification of specific violations in both categories highlights opportunities for regulatory enhancement.

For packaged water, the detection of P. aeruginosa in several samples suggests potential gaps in production hygiene or post-production contamination. Current regulations in many jurisdictions do not require routine testing for this opportunistic pathogen, which may warrant regulatory reconsideration given its potential health impacts particularly for immunocompromised individuals (Falcone-Dias et al., 2012).

For municipal water, the isolated lead exceedance underscores the challenge of ensuring water quality throughout aging infrastructure systems. This finding supports the argument for increased investment in water infrastructure renewal and more comprehensive monitoring at household taps rather than limited sampling points (Pieper et al., 2015).

The substantial differences observed among packaged water types (mineral, spring, and purified) highlight the importance of clear labeling requirements to enable informed consumer choices. Current regulations in many regions permit considerable variation within these categories, potentially leading to consumer confusion regarding expected mineral content and treatment processes (Ward et al., 2009).

6. Conclusion

This comprehensive analysis of packaged and municipal drinking water reveals complementary strengths and limitations in each water type. Municipal water typically provides superior mineral content beneficial for human health, while packaged water demonstrates marginally better microbiological compliance characteristics, particularly for certain indicator organisms.

Both water types generally met established regulatory standards, though specific violations were observed in both categories. These findings support the conclusion that either water type, when properly managed and regulated, can provide safe drinking water. However, the distinct chemical and microbiological profiles observed suggest that different management strategies and monitoring approaches are appropriate for each water category.

From a public health perspective, the results highlight the importance of maintaining robust treatment and distribution systems for municipal water while ensuring rigorous quality control throughout the production and storage chain for packaged water. Regulatory frameworks should account for the unique challenges associated with each water type while maintaining equivalent health protection standards.

Consumer choices between these water sources should consider multiple factors beyond safety alone, including mineral content preferences, environmental impact considerations, economic factors, and specific health needs. Educational initiatives providing objective information about water quality characteristics could help inform these consumer decisions.

Finally, this research underscores the value of comparative quality assessments in advancing understanding of drinking water characteristics and identifying opportunities for quality enhancement in both packaged and municipal water systems.

REFERENCES

[1] Ahmed, W., Brandes, H., Gyawali, P., Sidhu, J. P. S., & Toze, S. (2016). Opportunistic pathogens in roof-captured rainwater and the effect of seasonal variation. Applied and Environmental Microbiology, 82(17), 5363-5370. https://doi.org/10.1128/AEM.00944-16

[2] American Public Health Association (APHA). (2017). Standard methods for the examination of water and wastewater (23rd ed.). APHA Press.

[3] Birke, M., Rauch, U., Harazim, B., Lorenz, H., & Glatte, W. (2010). Major and trace elements in German bottled water, their regional distribution, and accordance with national and international standards. Journal of Geochemical Exploration, 107(3), 245-271. https://doi.org/10.1016/j.gexplo.2010.06.002

[4] Cartier, C., Nour, S., Richer, B., Deshommes, E., & Prévost, M. (2012). Impact of water treatment on the contribution of faucets to dissolved and particulate lead release at the tap. Water Research, 46(16), 5205-5216. https://doi.org/10.1016/j.watres.2012.07.002

[5] Diduch, M., Polkowska, Ż., & Namieśnik, J. (2013). Chemical quality of bottled waters: A review. Journal of Food Science, 78(9), R1370-R1376. https://doi.org/10.1111/1750-3841.12164

[6] Doria, M. F. (2010). Factors influencing public perception of drinking water quality. Water Policy, 12(1), 1-19. https://doi.org/10.2166/wp.2009.051

[7] Doria, M. F., Pidgeon, N., & Hunter, P. R. (2009). Perceptions of drinking water quality and risk and its effect on behaviour: A cross-national study. Science of the Total Environment, 407(21), 5455-5464. https://doi.org/10.1016/j.scitotenv.2009.06.031

[8] Environmental Protection Agency (EPA). (2022). National primary drinking water regulations. https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations

[9] European Commission. (2020). Directive (EU) 2020/2184 of the European Parliament and of the Council of 16 December 2020 on the quality of water intended for human consumption. Official Journal of the European Union.

[10] Falcone-Dias, M. F., Vaz-Moreira, I., & Manaia, C. M. (2012). Bottled mineral water as a potential source of antibiotic-resistant bacteria. Water Research, 46(11), 3612-3622. https://doi.org/10.1016/j.watres.2012.04.007

[11] Food and Drug Administration (FDA). (2023). CFR - Code of Federal Regulations Title 21, Part 165 - Beverages. https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?CFRPart=165

[12] Fortune Business Insights. (2022). Bottled water market size, share & COVID-19 impact analysis, by type, by distribution channel, and regional forecast, 2021-2028. https://www.fortunebusinessinsights.com/bottled-water-market-104620

[13] Gleick, P. H., & Cooley, H. S. (2009). Energy implications of bottled water. Environmental Research Letters, 4(1), 014009. https://doi.org/10.1088/1748-9326/4/1/014009

[14] Hu, Z., Morton, L. W., & Mahler, R. L. (2011). Bottled water: United States consumers and their perceptions of water quality. International Journal of Environmental Research and Public Health, 8(2), 565-578. https://doi.org/10.3390/ijerph8020565

[15] Kokkinakis, E. N., Fragkiadakis, G. A., & Kokkinaki, A. N. (2008). Monitoring microbiological quality of bottled water as suggested by HACCP methodology. Food Control, 19(10), 957-961. https://doi.org/10.1016/j.foodcont.2007.10.001

[16] Lalumandier, J. A., & Ayers, L. W. (2000). Fluoride and bacterial content of bottled water vs tap water. Archives of Family Medicine, 9(3), 246-250. https://doi.org/10.1001/archfami.9.3.246

[17] Leclerc, H., & Moreau, A. (2002). Microbiological safety of natural mineral water. FEMS Microbiology Reviews, 26(2), 207-222. https://doi.org/10.1111/j.1574-6976.2002.tb00611.x

[18] Lou, J. C., Chang, T. W., & Huang, C. E. (2010). Effective removal of disinfection by-products and assimilable organic carbon: An advanced water treatment system. Journal of Hazardous Materials, 175(1-3), 391-398. https://doi.org/10.1016/j.jhazmat.2009.10.021

[19] Mason, S. A., Welch, V. G., & Neratko, J. (2018). Synthetic polymer contamination in bottled water. Frontiers in Chemistry, 6, 407. https://doi.org/10.3389/fchem.2018.00407

[20] Padhye, L. P., Yao, H., Kung'u, F. T., & Huang, C. H. Padhye, L. P., Yao, H., Kung'u, F. T., & Huang, C. H. (2014). Year-long evaluation on the occurrence and fate of pharmaceuticals, personal care products, and endocrine disrupting chemicals in an urban drinking water treatment plant. Water Research, 51, 266-276. https://doi.org/10.1016/j.watres.2013.10.070

[21] Pieper, K. J., Krometis, L. A. H., Gallagher, D. L., Benham, B. L., & Edwards, M. (2015). Profiling private water systems: Identification of risk factors for lead and copper contamination. Environmental Science & Technology, 49(21), 12697-12704. https://doi.org/10.1021/acs.est.5b03174

[22] Qian, N. (2018). Bottled water or tap water? A comparative study of drinking water choices on university campuses. Water, 10(1), 59. https://doi.org/10.3390/w10010059

[23] Richardson, S. D., & Postigo, C. (2012). Drinking water disinfection by-products. In D. Barceló (Ed.), Emerging organic contaminants and human health (pp. 93-137). Springer. https://doi.org/10.1007/698_2011_125

[24] Rochelle-Newall, E., Nguyen, T. M. H., Le, T. P. Q., Sengtaheuanghoung, O., & Ribolzi, O. (2015). A short review of fecal indicator bacteria in tropical aquatic ecosystems: Knowledge gaps and future directions. Frontiers in Microbiology, 6, 308. https://doi.org/10.3389/fmicb.2015.00308

[25] Rosborg, I., Nihlgård, B., & Ferrante, M. (2015). Mineral composition of drinking water and daily uptake. In I. Rosborg (Ed.), Drinking water minerals and mineral balance (pp. 25-31). Springer. https://doi.org/10.1007/978-3-319-09593-6_4

[26] Sajani, S. Z., Bonasoni, P., Cristofanelli, P., Marinoni, A., & Lauriola, P. (2020). Only bottled water? An integrated assessment of public health, environmental and socioeconomic effects of drinking water choices. Science of the Total Environment, 719, 137429. https://doi.org/10.1016/j.scitotenv.2020.137429

[27] Sengupta, P. (2013). Potential health impacts of hard water. International Journal of Preventive Medicine, 4(8), 866-875.

[28] Varga, L. (2011). Bacteriological quality of bottled natural mineral waters commercialized in Hungary. Food Control, 22(3-4), 591-595. https://doi.org/10.1016/j.foodcont.2010.10.009

[29] Villanueva, C. M., Kogevinas, M., Cordier, S., Templeton, M. R., Vermeulen, R., Nuckols, J. R., Nieuwenhuijsen, M. J., & Levallois, P. (2014). Assessing exposure and health consequences of chemicals in drinking water: Current state of knowledge and research needs. Environmental Health Perspectives, 122(3), 213-221. https://doi.org/10.1289/ehp.1206229

[30] Ward, L. A., Cain, O. L., Mullally, R. A., Holliday, K. S., Wernham, A. G., Baillie, P. D., & Greenfield, S. M. (2009). Health beliefs about bottled water: A qualitative study. BMC Public Health, 9, 196. https://doi.org/10.1186/1471-2458-9-196

[31] Wilk, R. (2006). Bottled water: The pure commodity in the age of branding. Journal of Consumer Culture, 6(3), 303-325. https://doi.org/10.1177/1469540506068681

[32] World Health Organization (WHO). (2022). Guidelines for drinking-water quality: Fourth edition incorporating the first and second addenda. WHO Press.

[33] World Health Organization (WHO). (2023). Drinking-water fact sheet. https://www.who.int/news-room/fact-sheets/detail/drinking-water