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SANITARY AND HYGIENIC STATUS OF DRINKING WATER FROM CENTRALIZED AND PACKAGED SOURCES AND CRITERIA FOR ITS SAFETY ASSESSMENT

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Abstract

Background. Safe drinking water is a primary determinant of population health, yet urban consumers in Uzbekistan increasingly supplement or replace piped tap water with packaged water that is regulated by different legal instruments.

Aim. To compare the sanitary and hygienic status of drinking water supplied by the centralized system and packaged water marketed in Samarkand, and to substantiate an integrated set of criteria for assessing its safety.

Methods. Between September 2024 and August 2025, 156 samples were analysed: 96 from 24 points of the centralized distribution network, 36 from 12 brands of still water in polyethylene terephthalate (PET) bottles of 0.5–1.5 L, and 24 from six brands of water in 19-L returnable containers. Organoleptic, physicochemical and microbiological indicators were determined by standardized methods and evaluated against O'z DSt 950:2011, the World Health Organization guidelines and international benchmarks for packaged water. A weighted arithmetic water quality index (WQI) and an integrated sanitary-hygienic safety index (ISHSI) were calculated.

Results. All samples complied with toxicological limits for nitrates, nitrites and ammonium. Tap water was moderately mineralized (total dissolved solids 512 ± 86 mg/L; total hardness 5.42 ± 0.96 mmol/L), whereas 36.1% of PET and 45.8% of 19-L samples did not meet physiological adequacy criteria. Microbiological non-compliance was recorded in 13.5% of tap, 8.3% of PET and 33.3% of 19-L samples ($p = 0.023$), with a pronounced summer peak. Fluoride was below 0.7 mg/L in every sample. The WQI rated packaged water as excellent (11.5–16.4) and tap water as good (43.2), whereas the ISHSI ranked 19-L water lowest (77.5 versus 92.9 for tap water).

Conclusion. Chemical indices alone overestimate the safety of packaged water. A multi-criteria framework that combines microbiological stability, toxicological safety, organoleptic acceptability and physiological adequacy is recommended for routine sanitary surveillance.

Keywords: drinking water; centralized water supply; packaged water; 19-L containers; microbiological safety; physiological adequacy; water quality index; safety criteria; Uzbekistan

1. Introduction

Access to safe drinking water is a fundamental human right and one of the most cost-effective instruments of disease prevention. According to the WHO/UNICEF Joint Monitoring Programme, 2.2 billion people still lacked safely managed drinking water services in 2022 (World Health Organization [WHO] & United Nations Children's Fund [UNICEF], 2023). Inadequate water,

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sanitation and hygiene were responsible for an estimated 829,000 diarrhoeal deaths in low- and middle-income countries in 2016 (Prüss-Ustün et al., 2019). Importantly, access to an improved source does not guarantee safety: a systematic review showed that piped and other improved supplies are frequently contaminated with faecal indicator bacteria, particularly where intermittent supply, ageing networks and insufficient disinfection coexist (Bain et al., 2014). For this reason, the current WHO guidelines emphasize a preventive, risk-based approach that covers the whole chain from catchment to consumer (WHO, 2022).

Central Asian countries face a specific combination of water-related health risks, including salinization and agricultural pollution of surface and ground waters, deterioration of distribution infrastructure built several decades ago, and seasonal fluctuations in water availability (Törnqvist et al., 2011; Bekturganov et al., 2016). In Uzbekistan, the use of unsafe drinking water sources and poor household water handling have been identified as risk factors for diarrhoeal disease (Herbst et al., 2008). The quality of water supplied by centralized systems is regulated by the national standard O'z DSt 950:2011 “Drinking water. Hygienic requirements and quality control” (Uzstandard, 2011), and recent regional studies in Samarkand have highlighted the need for systematic evaluation of the organoleptic and chemical composition of drinking water supplied to the population (Utamuradova et al., 2024).

In parallel, the consumption of packaged drinking water in PET bottles and in 19-L returnable containers for dispensers has grown rapidly. Consumer preference for packaged water is driven mainly by organoleptic properties, distrust of tap water and perceived health benefits rather than by objective quality data (Doria, 2006). However, packaged water is not intrinsically safer. Autochthonous and contaminating bacteria can multiply during storage (Rosenberg, 2003; Warburton, 1993), chemical quality varies considerably between brands (Diduch et al., 2011; Semerjian, 2011), antimony can migrate from PET, especially under warm storage (Shotyk & Krachler, 2007; Westerhoff et al., 2008), and microplastic particles have been detected in most bottled water products examined (Mason et al., 2018), with higher particle numbers in returnable plastic bottles (Schymanski et al., 2018). The safety of packaged water in Uzbekistan is governed by the General Technical Regulation on the safety of drinking water packaged in containers (Cabinet of Ministers of the Republic of Uzbekistan, 2019), while international benchmarks are provided by the Codex Alimentarius standard for bottled/packaged waters and the European drinking water directives (Codex Alimentarius Commission, 2001; Council of the European Union, 1998; European Parliament & Council of the European Union, 2020).

A further hygienic problem is the low mineral content of water produced by membrane technologies. Prolonged consumption of water with very low calcium and magnesium concentrations has been associated with adverse effects on mineral metabolism and cardiovascular health (Kozisek, 2005), yet few regulatory frameworks establish minimum levels of these elements (Kozisek, 2020). Integrative tools such as the water quality index (WQI) are widely used to communicate water quality (Brown et al., 1970; Tyagi et al., 2013), but most WQI models rely on physicochemical parameters and do not account for microbiological stability or physiological adequacy (Chidiac et al., 2023).

Comparative data on the hygienic quality of centralized and packaged drinking water consumed by the same urban population in Uzbekistan remain scarce, which limits evidence-based surveillance and consumer guidance. The aim of the present study was therefore to compare the sanitary and hygienic status of drinking water supplied by the centralized system and packaged water marketed in Samarkand and to substantiate an integrated set of safety criteria. The specific objectives were: (i) to characterize the organoleptic and physicochemical composition of the three water categories; (ii) to assess their microbiological quality and its seasonal dynamics; and (iii) to compare conventional WQI ratings with a multi-criteria safety index.

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2. Materials and Methods

2.1. Study area and design

A cross-sectional study with repeated seasonal sampling was conducted in Samarkand city between September 2024 and August 2025. The city is served by a centralized water supply system that abstracts water within the Zarafshan River basin and applies chlorination before distribution. Three categories of drinking water were compared: (1) tap water from the centralized distribution network; (2) still drinking water in single-use PET bottles of 0.5–1.5 L; and (3) drinking water in 19-L returnable containers delivered to households and offices for use with dispensers.

2.2. Sampling

Twenty-four sampling points were selected on the distribution network to represent its initial (n = 8), middle (n = 8) and peripheral dead-end (n = 8) sections, including public standpipes and taps in multi-storey residential buildings. Each point was sampled once per season, yielding 96 samples. Taps were disinfected by flaming and flushed for 2–3 min before collection in accordance with ISO 5667-5 (International Organization for Standardization [ISO], 2006b). Samples for microbiological analysis were collected in sterile 500-mL glass bottles containing sodium thiosulfate, and samples for chemical analysis in pre-cleaned polyethylene bottles.

Packaged water was purchased from retail outlets and home-delivery services. Twelve brands of PET-bottled water were each sampled in three production lots (n = 36; nine samples per season), and six brands of 19-L water were sampled once per season (n = 24). Production date and storage conditions at the point of sale were recorded, and only products within their declared shelf life were analysed. In total, 156 samples were examined. All samples were transported at 2–8 °C, and microbiological analyses were started within 6 h of collection or purchase.

2.3. Organoleptic and physicochemical analyses

Odour and taste were scored on a five-point scale at 20 °C and 60 °C, colour was determined on the platinum–cobalt scale and turbidity photometrically against a kaolin standard. The pH was measured potentiometrically; total dissolved solids (TDS) gravimetrically as dry residue; total hardness, calcium and magnesium by complexometric titration with EDTA; sodium by flame photometry; chlorides argentometrically; sulfates turbidimetrically; nitrates, nitrites and ammonium spectrophotometrically; fluoride with an ion-selective electrode; total iron photometrically; permanganate oxidizability by the Kubel method; and free residual chlorine with N,N-diethyl-p-phenylenediamine (DPD). Procedures followed the Standard Methods for the Examination of Water and Wastewater (Baird et al., 2017) and harmonized national methods. Every tenth sample was analysed in duplicate (relative percentage difference < 10%), and reagent blanks and certified reference solutions were run with each batch.

2.4. Microbiological analyses

Heterotrophic plate counts (HPC) were determined by the pour-plate method on yeast extract agar after incubation at 36 ± 2 °C for 44 ± 4 h and at 22 ± 2 °C for 68 ± 4 h (ISO, 1999). Total coliform bacteria and Escherichia coli were enumerated by membrane filtration on chromogenic coliform agar (ISO, 2014), and intestinal enterococci on Slanetz–Bartley agar (ISO, 2000). Pseudomonas aeruginosa was determined in packaged water on cetrimide–nalidixic acid (CN) agar (ISO, 2006a). Filtered volumes were 100 mL for tap water and 250 mL for packaged water.

2.5. Assessment criteria and integrated indices

Tap water was evaluated against O'z DSt 950:2011 (Uzstandard, 2011) and the WHO guideline values (WHO, 2022). For packaged water, the microbiological benchmarks for water offered for sale in bottles or containers were applied: HPC ≤ 20 CFU/mL at 37 °C and ≤ 100 CFU/mL at 22 °C, and absence of E. coli, coliform bacteria, enterococci and P. aeruginosa in 250 mL (Codex Alimentarius Commission, 2001; Council of the European Union, 1998). Physiological adequacy was assessed

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using criteria established in hygienic practice for packaged water: TDS 100–1000 mg/L, total hardness 1.5–7.0 mmol/L, calcium ≥ 25 mg/L and magnesium ≥ 5 mg/L (Kozisek, 2005; Russian Federation, 2002). Because fluoride was deficient in all samples, it was analysed separately and was not included in the adequacy score.

Indicators were grouped into four criteria groups: microbiological safety, chemical (toxicological) safety, organoleptic acceptability and physiological adequacy. For each water category, the compliance rate C_i (%) of each group was calculated as the proportion of samples meeting all criteria of that group. The integrated sanitary-hygienic safety index was computed as $ISHSI = \Sigma w_i C_i$, with weights of 0.40, 0.25, 0.15 and 0.20, respectively, assigned by ranking of seven experts in environmental hygiene. ISHSI values ≥ 90 were classified as safe, 75.0–89.9 as conditionally safe and < 75 as unsafe. For comparison, a weighted arithmetic WQI was calculated from 11 parameters (pH, TDS, hardness, Na^+, Cl^-, SO_4^{2-}, NO_3^-, F^-, Fe, turbidity and permanganate oxidizability) as $WQI = \Sigma Q_i W_i / \Sigma W_i$, where $Q_i = 100 \cdot V_i / S_i$ (for pH, $Q_i = 100 \cdot |V_i - 7.0| / (8.5 - 7.0)$) and $W_i = K/S_i$; values of 0–25, 26–50, 51–75, 76–100 and > 100 indicated excellent, good, poor, very poor and unsuitable water, respectively (Brown et al., 1970; Tyagi et al., 2013).

2.6. Statistical analysis

Normality was checked with the Shapiro–Wilk test. Physicochemical data are presented as mean ± standard deviation (SD) and bacterial counts as median and interquartile range (IQR). Differences among the three categories were tested with the Kruskal–Wallis test followed by Dunn's post hoc test with Bonferroni correction; proportions were compared with the χ^2 test or Fisher's exact test. Statistical significance was set at $p < 0.05$. Analyses were performed in IBM SPSS Statistics 26.0.

3. Results and Discussion

3.1. Organoleptic and physicochemical composition

Odour and taste did not exceed 2 points in any sample; a faint chlorine odour (2 points at 60 °C) was noted in six tap samples (6.3%) collected close to the disinfection station. The physicochemical composition of the three categories differed significantly for all studied indicators (Table 1). Tap water was characterized by moderate mineralization of a sulfate–bicarbonate calcium type, with mean TDS of 512 ± 86 mg/L and total hardness of 5.42 ± 0.96 mmol/L. Hardness exceeded the 7.0 mmol/L limit in three samples (3.1%), all from peripheral sections of the network. Turbidity exceeded the standard in five samples (5.2%) and total iron in four samples (4.2%), which together made seven samples (7.3%) organoleptically non-compliant. Such episodes, concentrated at dead-end sections, are typical of corrosion and sediment resuspension in ageing networks (Liu et al., 2016).

Table 1. Organoleptic and physicochemical indicators of centralized and packaged drinking water (mean ± SD)

Indicator	Standard	Centralized (n = 96)	PET-bottled (n = 36)	19-L containers (n = 24)	p
Colour, degrees	≤ 20	6.8 ± 3.1	2.1 ± 1.0	2.9 ± 1.4	< 0.001
Turbidity, mg/L	≤ 1.5	0.62 ± 0.38	0.18 ± 0.09	0.27 ± 0.15	< 0.001
pH	6.0–9.0	7.48 ± 0.21	7.12 ± 0.34	7.26 ± 0.29	< 0.001
TDS, mg/L	≤ 1000	512 ± 86	238 ± 124	196 ± 88	< 0.001

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Indicator	Standard	Centralized (n = 96)	PET-bottled (n = 36)	19-L containers (n = 24)	p
Total hardness, mmol/L	≤ 7.0	5.42 ± 0.96	2.31 ± 1.28	1.86 ± 0.94	< 0.001
Calcium, mg/L	–	74.6 ± 12.8	31.4 ± 17.2	25.2 ± 12.6	< 0.001
Magnesium, mg/L	–	20.6 ± 4.9	9.0 ± 5.3	7.3 ± 3.8	< 0.001
Sodium, mg/L	≤ 200	38.5 ± 9.7	22.8 ± 14.1	15.6 ± 8.2	< 0.001
Chlorides, mg/L	≤ 350	46.2 ± 11.5	18.7 ± 9.8	14.2 ± 7.1	< 0.001
Sulfates, mg/L	≤ 500	142.8 ± 31.6	48.5 ± 27.3	36.9 ± 19.4	< 0.001
Nitrates (NO_3^-), mg/L	≤ 45	14.6 ± 6.8	5.2 ± 3.1	4.1 ± 2.6	< 0.001
Nitrites (NO_2^-), mg/L	≤ 3.0	0.021 ± 0.015	< 0.003	0.006 ± 0.004	< 0.001
Ammonium, mg/L	≤ 2.0	0.08 ± 0.05	0.03 ± 0.02	0.04 ± 0.03	< 0.001
Fluoride, mg/L	0.7–1.5	0.38 ± 0.09	0.21 ± 0.12	0.14 ± 0.07	< 0.001
Total iron, mg/L	≤ 0.3	0.14 ± 0.11	0.03 ± 0.02	0.05 ± 0.03	< 0.001
Permanganate oxidizability, mg O_2/L	≤ 5.0	1.84 ± 0.62	0.72 ± 0.31	1.12 ± 0.48	< 0.001
Free residual chlorine, mg/L	0.3–0.5	0.24 ± 0.12	–	–	–

Note: standards according to O'z DSt 950:2011 and WHO (2022); p – Kruskal–Wallis test. Post hoc comparisons: centralized water differed from both packaged categories for all indicators ($p < 0.01$); PET and 19-L water differed only in colour, total iron and oxidizability ($p < 0.05$). TDS – total dissolved solids.

Packaged waters were markedly less mineralized. Mean TDS was 238 ± 124 mg/L in PET-bottled and 196 ± 88 mg/L in 19-L water, and the wide dispersion reflected the coexistence of products made from naturally low-mineralized sources, products treated by reverse osmosis and products subsequently re-mineralized. The ionic profiles of the three categories are compared in Figure 1: calcium, sulfate and chloride concentrations in 19-L water were three to four times lower than in tap water. TDS below 100 mg/L was recorded in eight PET (22.2%) and seven 19-L samples (29.2%), and hardness below 1.5 mmol/L in 13 PET (36.1%) and 11 19-L samples (45.8%). When calcium and magnesium thresholds were also applied, 13 PET (36.1%) and 11 19-L samples (45.8%) failed the physiological adequacy criteria, compared with only the three over-hard tap samples (3.1%).

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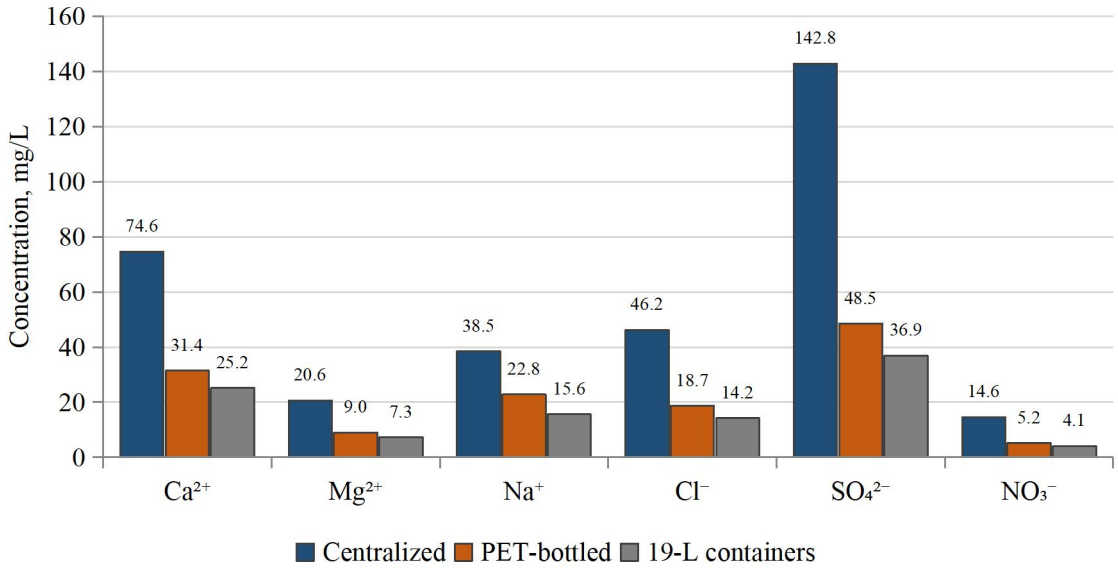


Figure 1. Mean concentrations of major ions in centralized, PET-bottled and 19-L drinking water, mg/L

These findings are consistent with international reviews showing wide variability in the mineral composition of bottled waters (Diduch et al., 2011; Semerjian, 2011). From a hygienic perspective, the problem is not a violation of maximum permissible concentrations but a deficiency of biologically essential elements. Water with very low calcium and magnesium content may contribute to a negative mineral balance, particularly in children and in people with low dietary intake, and demineralized water is more aggressive towards materials in contact with it (Kozisek, 2005). Since only a minority of regulatory frameworks establish minimum values for calcium, magnesium or hardness (Kozisek, 2020), labelling of mineral content and minimum levels for treated packaged water deserve consideration in national regulations.

All samples met the toxicological limits for nitrates, nitrites and ammonium. Nevertheless, mean nitrate concentration in tap water (14.6 ± 6.8 mg/L) was about three times higher than in packaged water, which reflects the agricultural pressure on water sources in the Zarafshan valley. Although this level is well below the limit of 45 mg/L, recent epidemiological evidence links long-term nitrate exposure below current standards with adverse outcomes, and continued monitoring is warranted (Ward et al., 2018). Fluoride was below 0.7 mg/L in every sample, with the lowest levels in 19-L water (0.14 ± 0.07 mg/L). Such a deficiency is relevant to the prevention of dental caries, particularly in children who drink packaged water exclusively (Fawell et al., 2006). Free residual chlorine in tap water averaged 0.24 ± 0.12 mg/L and was below 0.3 mg/L in 56 samples (58.3%), mainly in peripheral sections, which indicates insufficient residual disinfectant protection at the far ends of the network.

3.2. Microbiological quality and seasonal dynamics

Microbiological results are summarized in Table 2. Overall non-compliance differed significantly among the categories ($\chi^2 = 7.56$, $p = 0.023$): it was lowest in PET-bottled water (8.3%), intermediate in tap water (13.5%) and highest in 19-L water (33.3%). Water in 19-L containers was significantly more often non-compliant than both PET-bottled water (Fisher's exact test, $p = 0.020$) and tap water ($p = 0.034$). HPC at 37 °C exceeded the respective criterion in 25.0% of 19-L samples, and P. aeruginosa was isolated from three 19-L samples (12.5%) but from only one PET sample (2.8%).

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Table 2. Microbiological indicators of centralized and packaged drinking water

Indicator	Criterion	Centralized (n = 96)	PET-bottled (n = 36)	19-L containers (n = 24)
HPC 37 °C, CFU/mL, median (IQR)	–	18 (7–42)	3 (1–8)	14 (4–46)
HPC 22 °C, CFU/mL, median (IQR)	–	31 (12–85)	6 (2–19)	42 (11–138)
HPC 37 °C above criterion, n (%)	> 100 (tap); > 20 (packaged)	7 (7.3)	2 (5.6)	6 (25.0)
HPC 22 °C above criterion, n (%)	> 100 (packaged)	n.r.	1 (2.8)	5 (20.8)
Total coliforms detected, n (%)	0 per 100/250 mL	9 (9.4)	1 (2.8)	4 (16.7)
E. coli detected, n (%)	0 per 100/250 mL	3 (3.1)	0 (0.0)	1 (4.2)
Intestinal enterococci, n (%)	0 per 100/250 mL	2 (2.1)	0 (0.0)	1 (4.2)
P. aeruginosa detected, n (%)	0 per 250 mL	n.d.	1 (2.8)	3 (12.5)
Any non-compliance, n (%)	–	13 (13.5)	3 (8.3)	8 (33.3)

Note: HPC – heterotrophic plate count; IQR – interquartile range; n.r. – not regulated; n.d. – not determined. Criteria: O'z DSt 950:2011 for tap water; Codex CXS 227-2001 and Directive 98/83/EC benchmarks for packaged water. Differences in any non-compliance: $\chi^2 = 7.56$, $p = 0.023$.

In tap water, total coliforms were detected in 9.4% and E. coli in 3.1% of samples; all E. coli-positive samples originated from peripheral points where residual chlorine was below 0.1 mg/L. The presence of faecal indicators in a chlorinated network points to post-treatment ingress through leaking joints, pressure drops during intermittent supply or cross-connections, which are recognized as leading causes of waterborne outbreaks in distribution systems (Craun et al., 2010). HPC values in tap water were moderate (median 18 CFU/mL at 37 °C). Although HPC bacteria have no direct health significance, their increase signals loss of disinfectant residual and biofilm development in pipes (Allen et al., 2004; Bartram et al., 2003).

A clear seasonal pattern was observed in all three categories (Figure 2). Non-compliance peaked in summer, reaching 25.0% in tap water, 22.2% in PET-bottled water and 50.0% in 19-L water, and was lowest in winter. Elevated water temperature accelerates chlorine decay and bacterial regrowth in the distribution network (Liu et al., 2016), while in packaged water, warm storage in shops, vehicles and on sunlit balconies promotes multiplication of heterotrophic bacteria and P. aeruginosa (Rosenberg, 2003).

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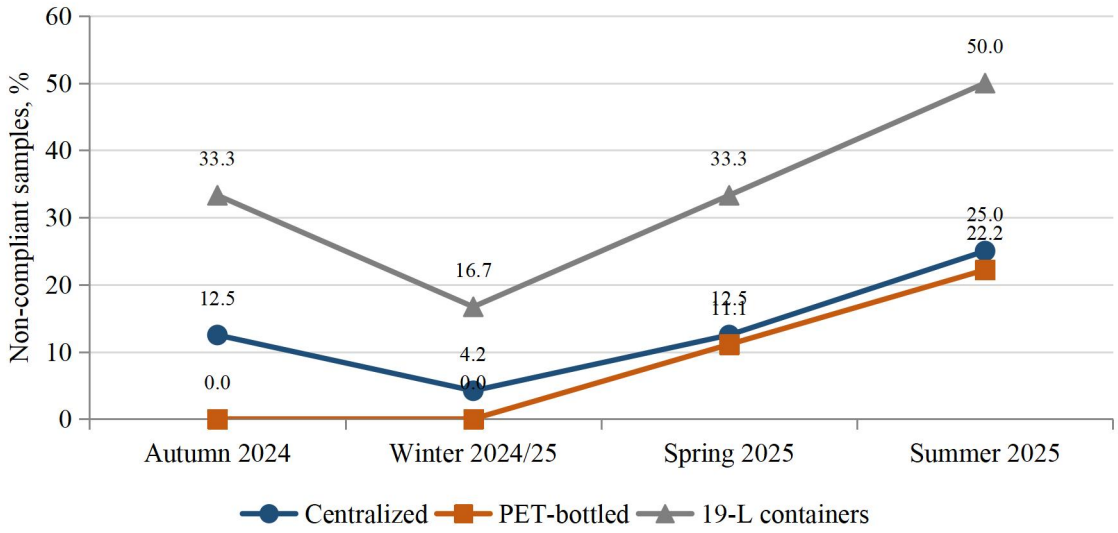


Figure 2. Seasonal dynamics of microbiological non-compliance of centralized and packaged drinking water, % of samples

The poor microbiological performance of 19-L water deserves particular attention. Unlike single-use PET bottles, returnable polycarbonate or PET containers are repeatedly washed, sanitized and refilled; scratches and inadequate sanitation favour the formation of biofilms, which protect bacteria from disinfectants (Flemming & Wingender, 2010). In addition, water in these containers is consumed over several days through dispensers, and each opening creates an opportunity for secondary contamination. Early reviews already called for stricter standards for bottled water because of the growth of bacteria during storage (Warburton, 1993), and our data suggest that the container washing process, the period between filling and consumption and the sanitation of dispensers should be treated as critical control points.

3.3. Integrated assessment of safety criteria

Compliance with the four criteria groups is shown in Figure 3. All categories fully met the toxicological criteria, but they differed in their weak points: tap water was limited mainly by microbiological (86.5%) and organoleptic (92.7%) compliance, whereas packaged waters were limited by physiological adequacy (63.9% for PET and 54.2% for 19-L water) and, in the case of 19-L water, by microbiological safety (66.7%). Only 79.2% of tap samples, 58.3% of PET samples and 33.3% of 19-L samples met all criteria simultaneously.

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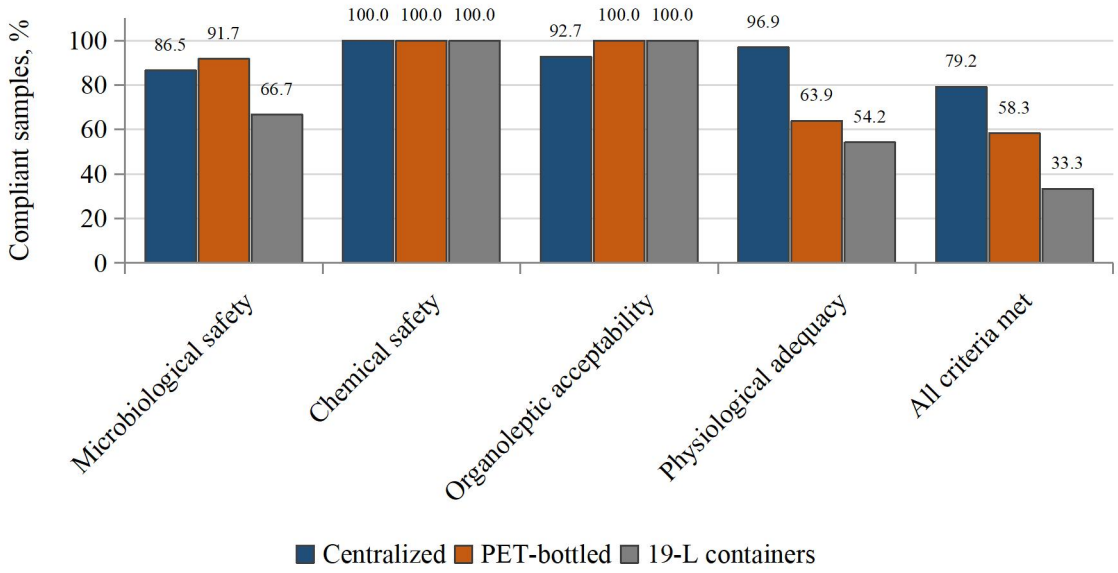


Figure 3. Compliance of drinking water from different sources with groups of hygienic safety criteria, % of samples

Table 3. Integrated sanitary-hygienic safety index (ISHSI) and water quality index (WQI) of drinking water from different sources

Criteria group (weight)	Indicators	Centralized	PET-bottled	19-L containers
Microbiological safety (0.40)	HPC, coliforms, E. coli, enterococci, P. aeruginosa	86.5	91.7	66.7
Chemical (toxicological) safety (0.25)	NO_3^-, NO_2^-, NH_4^+, F^- (upper limit)	100.0	100.0	100.0
Organoleptic acceptability (0.15)	Odour, taste, colour, turbidity, Fe	92.7	100.0	100.0
Physiological adequacy (0.20)	TDS, hardness, Ca^{2+}, Mg^{2+}	96.9	63.9	54.2
ISHSI, points	$\Sigma w_i C_i$	92.9	89.5	77.5
Safety class (ISHSI)	–	Safe	Conditionally safe	Conditionally safe
WQI, points (class)	11 physicochemical parameters	43.2 (good)	11.5 (excellent)	16.4 (excellent)

Note: values of criteria groups are compliance rates, % of samples. ISHSI classes: ≥ 90 – safe; 75.0–89.9 – conditionally safe; < 75 – unsafe.

The comparison of the two integrated indices (Table 3) is instructive. According to the conventional WQI, both packaged categories were rated as excellent (11.5 and 16.4 points) and tap

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water as good (43.2 points), largely because the index rewards low concentrations of dissolved substances. The ISHSI, in contrast, ranked tap water first (92.9 points, safe), PET-bottled water second (89.5 points) and 19-L water last (77.5 points), both packaged categories being classified as conditionally safe. This discrepancy confirms that indices built on physicochemical parameters alone can give a misleading picture of safety when microbiological stability and physiological value are not considered (Chidiac et al., 2023). The proposed hierarchy of criteria follows the principle of the WHO guidelines that microbial hazards take priority over chemical ones (WHO, 2022), while explicitly recognizing that water that is too soft is not physiologically neutral.

Several practical implications follow. For the centralized system, maintaining free residual chlorine of at least 0.3 mg/L at peripheral points, flushing dead-end sections and implementing a water safety plan are priorities. For packaged water, surveillance should go beyond certification at the production stage and include post-market monitoring of 19-L water, validation of container washing and sanitizing regimes, control of storage temperature and requirements for minimum mineral content and its labelling. Consumer guidance should also address the regular sanitation of dispensers.

4. Conclusion

Centralized and packaged drinking waters consumed in Samarkand fully complied with toxicological requirements but showed different hygienic weaknesses. Tap water was moderately mineralized and physiologically adequate, yet 13.5% of samples were microbiologically non-compliant, with faecal indicators confined to peripheral sections of the network where residual chlorine was insufficient. Packaged waters were chemically purer but frequently deficient in calcium, magnesium and fluoride, and water in 19-L returnable containers showed the highest microbiological non-compliance (33.3%) with a pronounced summer peak. The conventional WQI rated packaged water as excellent, whereas the integrated sanitary-hygienic safety index, which combines microbiological, toxicological, organoleptic and physiological criteria, classified both packaged categories as only conditionally safe. We recommend that sanitary surveillance adopt such a multi-criteria framework, strengthen control of residual disinfectant in the distribution network, introduce post-market microbiological monitoring of 19-L water and consider minimum mineralization requirements for treated packaged water.

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