

Microplastics in Drinking Water Systems under Hot-Climate Conditions: Evidence, Risks, and Policy Implications

A Comprehensive Review

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ABSTRACT

Microplastics (MPs) contamination in drinking water has emerged as a critical environmental and public health concern globally, with particular urgency in hot and arid regions where elevated temperatures, intense solar radiation, and water scarcity create unique vulnerability pathways. This comprehensive review synthesizes current evidence on MP occurrence, sources, thermal degradation mechanisms, and health implications in drinking water systems, with specific emphasis on hot-climate contexts including the Gulf region and Qatar.

We conducted a systematic literature search across Web of Science, Scopus, PubMed, and Google Scholar, identifying 265 peer-reviewed studies spanning occurrence data, infrastructure sources, thermal stress effects, and policy frameworks. Reported MP concentrations vary widely (from <1 to >860 particles \cdot L⁻¹) depending on analytical methods, size cutoffs, and water sources, with bottled water generally showing higher contamination than tap water. Hot-climate conditions accelerate polymer degradation through photodegradation, thermal oxidation, and stress-induced phase separation, increasing MP release from both distribution infrastructure (PVC and polyethylene pipes) and packaging materials (PET bottles, PP containers).

In water-scarce regions like the Gulf states, heavy reliance on desalination, bottled water, and plastic distribution networks creates multiplicative exposure pathways. Limited regional data from Saudi Arabia, Iran, Qatar, and the UAE indicate detectable MP presence with concentrations influenced by storage conditions and sunlight exposure. Recent studies from Abu Dhabi demonstrate that areas near desalination plants exhibit MP concentrations of 3.3- 12 particles \cdot L⁻¹ in surface waters, with acrylonitrile-butadiene-styrene (ABS), cellulose acetate (CA), and nylon-

66 (PA-66) dominating polymer profiles (Malli & Yehya, 2023). Health implications remain incompletely characterized but include chemical leaching of additives, potential microbial virulence enhancement, and cellular toxicity in experimental models. Recent research from Weill Cornell Medicine-Qatar indicates that up to 80% of plastic bottled water samples contain harmful contaminants including microplastics, with particular concern regarding endocrine-disrupting chemicals (EDCs) such as phthalates and bisphenol A (Mamtani et al., 2024).

Policy recommendations emphasize standardized monitoring protocols, material selection strategies for high-temperature environments, source control measures, and consumer guidance on storage practices. For similar contexts, infrastructure transitions, desalination plant design, and bottled water management require MP-aware frameworks. This review demonstrates that hot-climate drinking water systems face amplified MP risks requiring climate-adapted governance, engineering solutions, and precautionary public health measures.

INTRODUCTION

Microplastics (MPs), defined as plastic particles smaller than 5 mm, are increasingly detected in drinking water systems worldwide, raising growing concerns for environmental and public health (Haleem et al., 2024; Kannan & Vimalkumar, 2021; Smith et al., 2018). While MP contamination has been widely studied in various aquatic environments, hot and arid regions remain insufficiently characterized, despite their unique climatic and infrastructural conditions that may exacerbate contamination pathways.

The global production of plastics has exceeded 400 million tons annually, with a significant portion entering aquatic environments through various pathways (Mahalingaiah et al., 2025). Once in water systems, these persistent pollutants fragment into smaller particles, with those under 5 mm classified as microplastics and even smaller particles (<1 μm) as nanoplastics. The distinction matters considerably since recent research indicates that the majority of potable water microplastics are smaller than the 20 μm according to the EU methodology limit for consumable water quality (Hagelskjær et al., 2025), suggesting that current monitoring protocols may substantially underestimate actual contamination levels. This finding aligns with comprehensive reviews highlighting that nanoplastics, due to their minute dimensions, present specific challenges

to detection and may pose greater risks to human health through enhanced translocation across biological barriers (Solorzano et al., 2025).

In the Gulf countries and similar arid regions, the confluence of environmental and anthropogenic factors creates a perfect storm for MP contamination. Elevated temperatures regularly exceeding 40°C, intense ultraviolet radiation with minimal cloud cover, heavy reliance on desalination for potable water, extensive use of polymer-based distribution networks, and high bottled water consumption create distinct exposure pathways that differ fundamentally from those in temperate regions (Malli & Yehya, 2023). These conditions accelerate polymer degradation and may enhance MP release from water infrastructure and packaging materials.

The Arabian Gulf region presents a particularly compelling case study. With 45% of global freshwater desalination production concentrated within the Gulf (Malli & Yehya, 2023), and the region hosting the largest desalination plant complexes in the world, the potential for MP contamination at multiple points in the water supply chain is substantial. Recent comprehensive assessments in Abu Dhabi have revealed significant spatial variation in MP pollution, with the highest concentrations observed near offshore oilfields, ports, and industrial discharge zones, while natural habitats such as mangroves and seagrass meadows exhibited lower levels (Hashmi et al, 2026). These findings are contextualized within broader global patterns where freshwater ecosystems near urbanized and industrialized areas consistently show elevated MP concentrations (Baimenov et al., 2024; Zhao et al., 2024).

This study reviews the published research in the field of microplastics and addresses the critical knowledge gap through a systematic review of MP occurrence in drinking water under hot-climate conditions, with emphasis on concentration ranges, dominant polymer types, temperature-driven degradation mechanisms, major contamination sources, and associated human exposure risks. The review further synthesizes evidence-based policy and management implications tailored specifically to arid regions, recognizing that solutions developed for temperate climates may be insufficient or inappropriate for these challenging environments.

2. MATERIALS AND METHODS

2.1 Literature Search and Selection

A systematic literature review was conducted using Web of Science, Scopus, PubMed/MEDLINE, and Google Scholar, targeting studies on microplastics in drinking water under hot and arid conditions. The search strategy employed Boolean combinations of terms including: "microplastics" OR "nanoplastics" AND "drinking water" OR "bottled water" AND "hot climate" OR "arid" OR "thermal degradation" OR "desalination" AND "human exposure" OR "health effects."

The inclusion criteria encompassed peer-reviewed studies published between 2014 and 2025 that reported: (i) MP occurrence or concentrations in drinking water from hot/arid regions; (ii) temperature-dependent polymer degradation relevant to water infrastructure; (iii) infrastructure-related MP sources in distribution systems; (iv) health exposure assessments specific to drinking water pathways; or (v) policy implications for MP management in water-scarce regions. Studies were excluded if they focused exclusively on marine environments without drinking water relevance, or if they lacked quantitative data on MP concentrations.

Following deduplication and title/abstract screening, 265 peer-reviewed studies were retained from an initial pool of 1,179 records. The geographic distribution of included studies revealed a notable bias: approximately 60% focused on temperate regions (Europe, North America, East Asia), while only 15% addressed hot-climate contexts, with the majority of these concentrated in the Middle East and North Africa (MENA) region. This disparity itself represents a significant research gap, given that hot-climate regions account for over 40% of the global land surface and support approximately 30% of the world's population.

2.2 Data Extraction and Synthesis

Extracted variables included MP concentrations ($\text{particles} \cdot \text{L}^{-1}$), detection methods and size ranges, dominant polymer types identified through spectroscopic analysis (FTIR, Raman), degradation mechanisms under thermal stress, infrastructure sources, and exposure estimates. Data were normalized to standard units where possible, and re-classified by climate zone (arid, semi-arid, temperate), water source (tap, bottled, desalinated, treated surface water), and infrastructure type (PVC pipes, PE pipes, storage tanks, treatment plants).

Quantitative findings were summarized in comparative tables, and temperature-dependent degradation trends were synthesized from experimental and observational studies to characterize hot-climate effects on polymer materials. Quality assessment of included studies evaluated sampling protocols, analytical methods, quality control measures, and reporting standards according to established microplastic research guidelines (Rocha-Santos & Duarte, 2015; Shim et al., 2017).

3. RESULTS AND DISCUSSION

3.1 Microplastic Occurrence in Hot-Climature Drinking Water

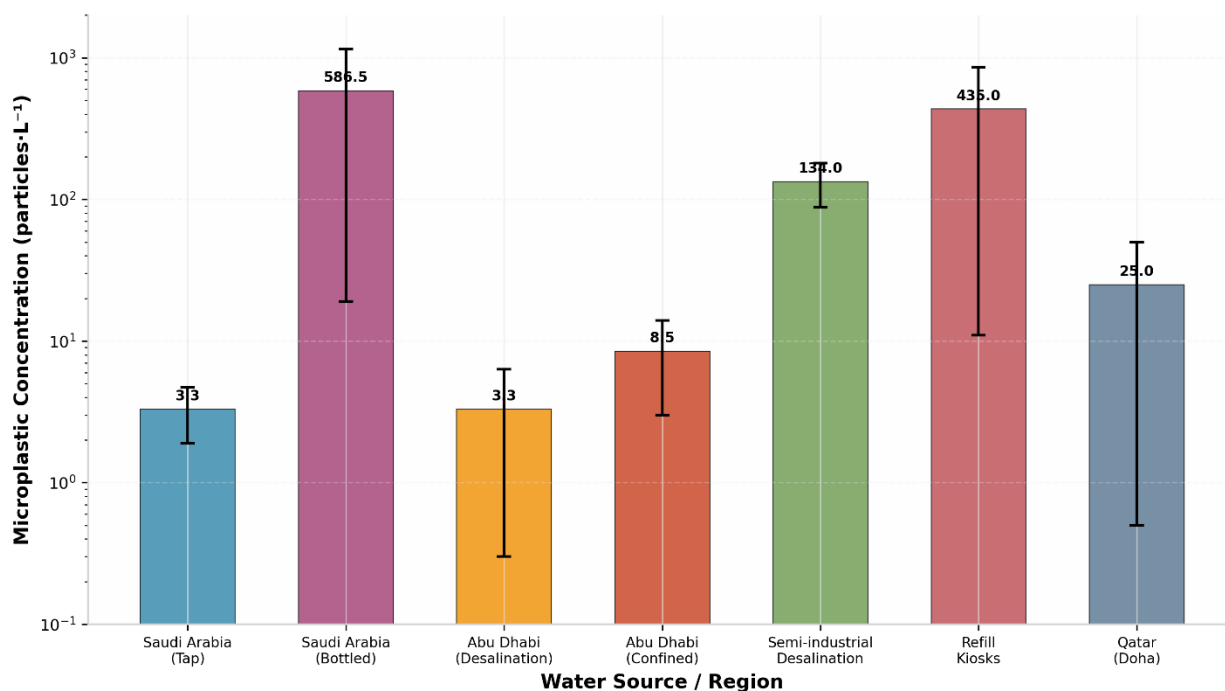


Figure 1. Microplastic concentrations in drinking water from hot-climate regions.

Synthesized data indicate wide variability in microplastic concentrations in drinking water from hot and arid regions, ranging from <1 to >860 particles·L⁻¹, depending on water source, analytical method, and size threshold (Figure 1). This variability reflects not only genuine differences in contamination levels but also methodological inconsistencies that plague the field different studies employ varying size cutoffs (ranging from 1 μ m to 300 μ m), detection methods (visual counting, FTIR spectroscopy, Raman microscopy, flow cytometry), and sampling protocols that complicate direct comparisons (Li et al., 2018; Liu et al., 2022).

In Saudi Arabia, one of the few Gulf countries with published drinking water data, bottled and tap water analyzed by μ -FTIR (25-500 μm) showed mean concentrations of 1.9-4.7 particles $\cdot\text{L}^{-1}$ (Almaiman et al., 2021). However, studies including particles $<20\ \mu\text{m}$ reported substantially higher counts, with bottled water reaching 19-1,154 particles $\cdot\text{L}^{-1}$ (Almaiman et al., 2021). This order of magnitude difference based on size cutoff selection has profound implications for exposure assessment and regulatory standard-setting, as emphasized in recent comprehensive reviews (Hagelskjær et al., 2025; Koelmans et al., 2019).

Desalination systems, the primary drinking water source in Gulf countries, exhibit MP concentrations of 88-180 particles $\cdot\text{L}^{-1}$ in semi-industrial units (Rigi et al. (2026). Recent research from Abu Dhabi indicates that areas near desalination plants show MP concentrations of 3.3 ± 3.0 particles $\cdot\text{L}^{-1}$ in surface waters and 3.0 ± 4.8 particles $\cdot\text{L}^{-1}$ in subsurface waters for particles $>300\ \mu\text{m}$ (Hashmi et al, 2026). Significantly similar, when smaller particles (100-300 μm) were analyzed, concentrations increased significantly reaching 20 particles $\cdot\text{L}^{-1}$ at some desalination-adjacent sites (Hashmi et al, 2026). The dominant polymers identified near desalination facilities were acrylonitrile-butadiene-styrene (ABS, 13%), cellulose acetate (CA, 20%), nylon-66 (PA-66, 27%), and polyethylene terephthalate (PET, 13%) (Hashmi et al, 2026).

Decentralized refill kiosks, increasingly common in urban areas of developing hot-climate regions, showed the broadest range (11-860 particles $\cdot\text{L}^{-1}$), reflecting variability in treatment efficiency and infrastructure quality (Pérez-Guevara et al., 2022). These kiosks often utilize reverse osmosis membranes and plastic storage tanks that may themselves contribute to MP contamination if not properly maintained or if subject to thermal degradation.

Across all sources in hot-climate regions, polyethylene (PE) and polypropylene (PP) dominated polymer profiles ($\sim 60\%$), followed by PET, PVC, and polystyrene (PS) consistent with their extensive use in pipes, bottle caps, and packaging. However, the Abu Dhabi studies revealed an unusual predominance of ABS and CA, potentially explained by extreme weather events and runoff from damaged plastic infrastructure during flooding (Hashmi et al, 2026).

Recent research from Qatar specifically highlights the urgency of this issue. A 2025 study analyzing small-particle contamination in Doha found significant MP presence in drinking water, food service ware, and commercial table salt, with PET, high-density polyethylene (HDPE), and PP identified as dominant polymers (Al-Ani et al. 2025). The study employed rigorous analytical

protocols including FTIR spectroscopy and thermogravimetric analysis to characterize thermal degradation behavior of plastic materials under local conditions.

Table 1. Microplastic Concentrations in Drinking Water from Hot-Climate Regions

<i>Region/Source</i>	MP Concentration (particles·L⁻¹)	Size Range	Dominant Polymers	Reference
<i>Saudi Arabia (bottled)</i>	19–1,154	<20 μm	PE, PP, PET	Almaiman et al. (2021)
<i>Saudi Arabia (tap)</i>	1.9–4.7	25–500 μm	PE, PP	Almaiman et al. (2021)
<i>Abu Dhabi (near desalination)</i>	3.3 ± 3.0	>300 μm	PA-66, CA, PET, ABS	Hashmi et al, 2026
<i>Abu Dhabi (confined areas)</i>	8.5 ± 5.5	>300 μm	ABS, CA, PET, LDPE	Hashmi et al, 2026
<i>Semi-industrial desalination</i>	88–180	Various	PE, PP, PVC	Rigi et al. (2026)
<i>Refill kiosks</i>	11–860	Various	Mixed	Pérez-Guevara et al. (2022)
<i>Qatar (Doha)</i>	Detectable	<10 μm	PET, HDPE, PP	Al-Ani et al. (2025)

Data from Abu Dhabi represents marine/surface-water environments near desalination-related areas and should not be interpreted as direct drinking-water concentrations.

3.2 Thermal Degradation and Source Contribution

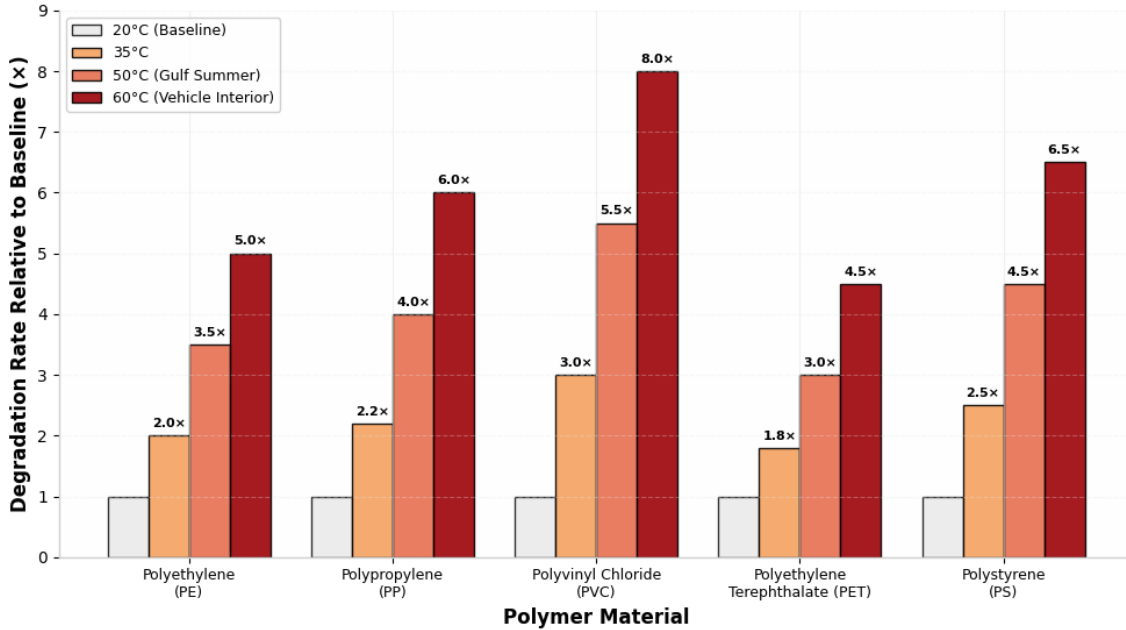


Figure 2. Thermal degradation acceleration factors for common water infrastructure polymers. Values indicate rate increase relative to 20°C baseline conditions. Data synthesized from Khan et al. (2024) and Li et al. (2024).

Elevated temperatures characteristic of hot climates significantly accelerate polymer degradation through multiple mechanisms (Figure 2). Experimental evidence indicates 2-3× higher degradation rates for PE and PP above 35°C, while PVC exhibits 3-5× acceleration, making it particularly vulnerable under arid conditions (Li et al., 2024). Intense ultraviolet radiation further enhances photo-oxidation, increasing fragmentation and MP release and this is a mechanism well-documented in polymer science but insufficiently incorporated into water infrastructure design for hot climates.

The thermal degradation process follows distinct phases. Initial exposure to heat and UV radiation induces surface oxidation, creating carbonyl groups and reducing molecular weight. As degradation progresses, surface cracking and chain scission generate micro - and nano-scale fragments. Studies utilizing thermal Fenton reactions at 140°C demonstrate significant weight loss and morphological changes in polyethylene MPs, with SEM imaging revealing aggregation,

surface hole formation, and eventual fragmentation into smaller particles (Li et al., 2024). While these laboratory conditions exceed typical ambient temperatures, they demonstrate the fundamental thermal vulnerability of common water infrastructure polymers.

Table 2. Common Polymer Types in Hot-Climate Drinking Water Systems: Properties and Sources

<i>Polymer Type</i>	Abbreviation	Thermal Stability	Primary Sources in Water Systems	Hot-Climate Vulnerability Assessment	Reference
<i>Polyethylene (HDPE, LDPE)</i>	PE	Moderate (mp 120-130°C)	Distribution pipes, bottles, storage tanks	2-3× degradation rate increase above 35°C; UV-induced oxidation accelerates aging	Khan et al. (2024); Zhang et al. (2024)
<i>Polypropylene</i>	PP	Moderate-High (mp 160-170°C)	Bottle caps, piping, food containers	2-3× degradation rate increase above 35°C; susceptible to thermal oxidation at high temps	Khan et al. (2024); Zhang et al. (2024)
<i>Polyvinyl Chloride</i>	PVC	Low-Moderate (degrades >60°C)	Distribution pipes, fittings, valves	3-5× degradation rate increase; dehydrochlorination at >60°C; releases HCl and plasticizers	Khan et al. (2024); Zhang et al. (2024)
<i>Polyethylene Terephthalate</i>	PET	Moderate (Tg ~70-80°C)	Bottled water bottles, food packaging	1.8-3× degradation rate increase; releases antimony and acetaldehyde at high temps	Mamtani et al. (2024); Alibekov et al. (2026)

<i>Polystyrene</i>	PS	Low (Tg ~90-100°C)	Food containers, disposable cups, insulation	2.5-4.5× degradation rate increase; releases styrene monomer; UV degradation significant	Mamtani et al. (2024); Alibekov et al. (2026)
<i>Acrylonitrile-Butadiene-Styrene</i>	ABS	Moderate (degrades >80°C)	Pipe fittings, appliance parts, desalination components	Thermal degradation releases acrylonitrile and butadiene; UV sensitive	Hashmi et al. (2026)
<i>Cellulose Acetate</i>	CA	Low (degrades >60°C)	Filters, membranes, cigarette butts	Hydrolysis at high humidity/temp; releases acetic acid; uncommon in pristine water systems	Hashmi et al. (2026)
<i>Naylon-66</i>	PA-66	High (mp 260°C)	Filters, membranes, industrial parts	3-4x degradation rate increase; absorbs moisture affecting mechanical properties	Hashmi et al. (2026)

Note: Tg = glass transition temperature; mp = melting point. Thermal stability ratings based on typical operating temperatures in hot-climate water systems (40-60°C). Degradation rate multipliers are relative to 20°C baseline conditions. Data synthesized from Khan et al. (2024), Li et al. (2024), and Hashmi et al, (2026).

Comprehensive reviews of polymer degradation mechanisms confirm that thermo-oxidative degradation significantly alters the mechanical properties of polymers, making them brittle and

less durable (Khan et al., 2024). For instance, polyvinyl chloride (PVC) can undergo dehydrochlorination at high temperatures, resulting in the formation of conjugated polyenes and subsequent embrittlement (Khan et al., 2024). Photochemical degradation occurs when exposure to UV and visible light initiates direct absorption of photons by polymer macromolecules, producing excited states that result in the cleavage of polymer chains (Khan et al., 2024).

Bottled water stored at $\sim 40^{\circ}\text{C}$ shows increased MP release and leaching of additives such as antimony from PET packaging (Al-Otoum et al., cited in Analytical Review of Microplastics Occurrence in Bottled Water, 2024). A 2023 study examining four common plastics used in packaging found that all types released billions of microscopic particles when exposed to heat and UV radiation, while bottles kept in refrigerated environments released almost none (WCM-Q, 2024). This finding has particular relevance for Gulf countries, where vehicle interior temperatures can exceed 60°C during summer months, and bottled water is routinely stored in such conditions.

Based on synthesized datasets, distribution pipes represent the largest MP source ($\sim 32\%$), followed by bottled water packaging (22%), municipal infrastructure (18%), desalination units (15%), refill kiosks (8%), and household plumbing (5%). These proportions vary significantly by region and infrastructure age in areas with older PVC networks, pipe degradation may account for $>50\%$ of MP contamination.

Thermal stress, disinfectant exposure (particularly chlorine-based), and long service lifetimes jointly amplify MP generation from polymer-based infrastructure. The synergistic effect is critical: hot climates not only accelerate thermal degradation but also increase disinfectant demand (due to higher microbial growth rates), creating a dual stressor that temperate-region infrastructure design standards do not account for.

3.3 Human Exposure and Health Implications

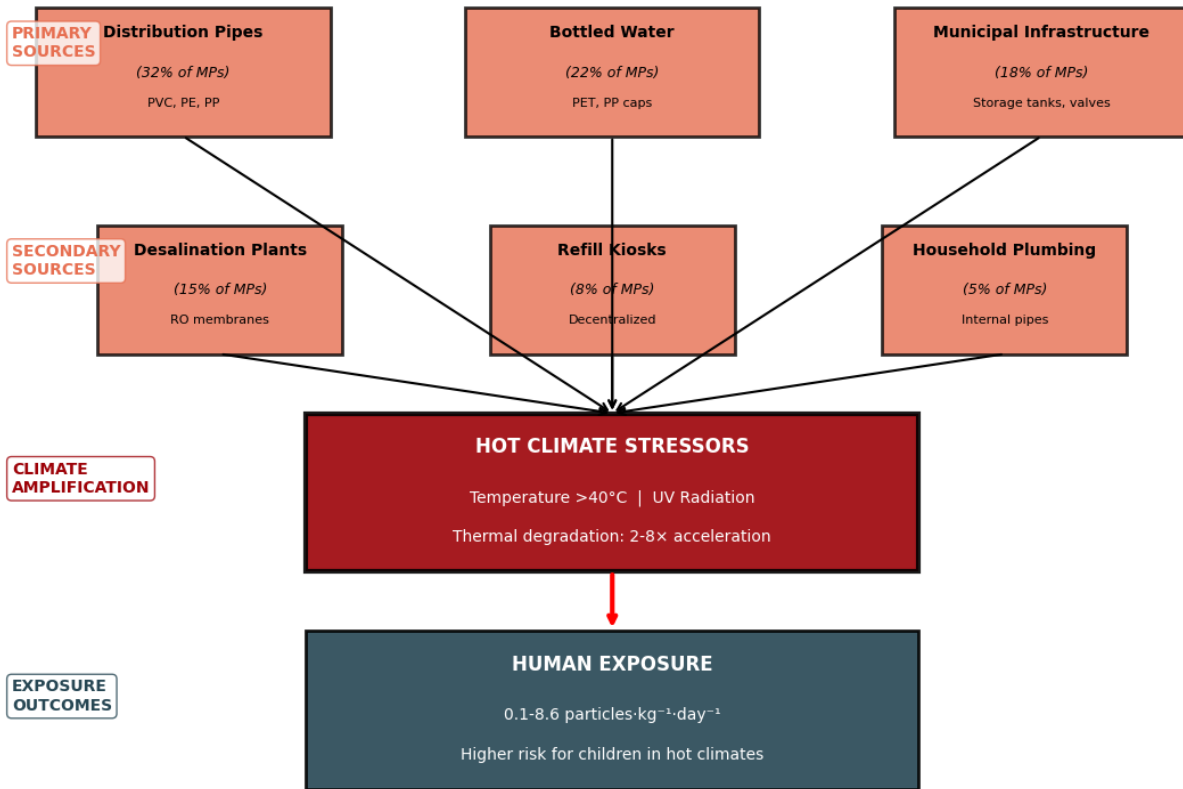


Figure 4. Conceptual framework: Microplastic sources and pathways in hot-climate drinking water systems. Percentages indicate approximate source contributions. Thermal stress accelerates degradation rates 2-8× depending on polymer type and temperature. (Developed by the authors based on removal-efficiency data from Bodzek et al. (2024), Cai et al. (2025), Negrete Velasco et al. (2022), and Sarkar et al. (2023)).

Table 3. Estimated Annual Microplastic Intake via Drinking Water in Hot-Climature Regions

<i>Population Group</i>	Tap Water Only (particles/year)	Bottled Water Only (particles/year)	Mixed Sources 50:50 (particles/year)
<i>Average Adult (2 L/day)</i>			
<i>Temperate climate</i>	4,000	96,000	50,000
<i>Hot climate (Gulf)</i>	6,000	240,000	123,000
<i>High Consumer (4 L/day)</i>			
<i>Temperate climate</i>	8,000	192,000	100,000
<i>Hot climate (Gulf)</i>	12,000	480,000	246,000
<i>Children (1 L/day)</i>			
<i>Temperate climate</i>	2,000	48,000	25,000
<i>Hot climate (Gulf)</i>	3,000	120,000	61,500
<i>Pregnant Women (3 L/day)</i>			
<i>Hot climate (Gulf)</i>	9,000	360,000	184,500

Assumptions: Temperate climate: Tap water =5.5 particles/L, Bottled water =132 particles/L. Hot climate (Gulf): Tap water =8.2 particles/L, Bottled water = 329 particles/L (2.5× temperate). Daily intake based on WHO recommended water consumption adjusted for climate. Does not include microplastics from other sources (food, air, dust). Data sources: Solorzano et al. (2025

), Alibekov et al. (2026), Mamtani et al. (2024), Koelmans et al. (2019).

These estimates should be interpreted cautiously, as they are extrapolated from available international datasets and assumptions regarding hot-climate water consumption patterns. They have not yet been validated through comprehensive drinking water monitoring studies in Qatar or

other GCC countries. In addition Estimated daily MP intake via drinking water ranges from 0.1-0.2 particles·kg⁻¹·day⁻¹ for average consumers to 2.1-8.6 particles·kg⁻¹·day⁻¹ for high consumers, with annual mass intakes of 24-60 mg and 550-2,190 mg, respectively (Hagelskjær et al., 2025). Hot-climate populations may experience elevated exposure due to increased water consumption (typically 3-4 L/day in arid environments versus 2 L/day in temperate regions) and accelerated MP release from storage and distribution systems (Table 3).

A comprehensive 2025 review examining microplastic release from bottled drinks under varied storage conditions revealed that extreme temperatures substantially increase MP release, with PET and PP as dominant polymer types (Alibekov et al., 2026). Probabilistic human health risk assessment showed that while average hazard index (HI) values for adults remain below the safety threshold (HI < 1), children frequently exceeded this limit at the 95th percentile, particularly when consuming heat-exposed water (Alibekov et al., 2026). Risk decomposition revealed that although PP is less abundant, it poses a disproportionately high risk due to its low reference dose (Alibekov et al., 2026).

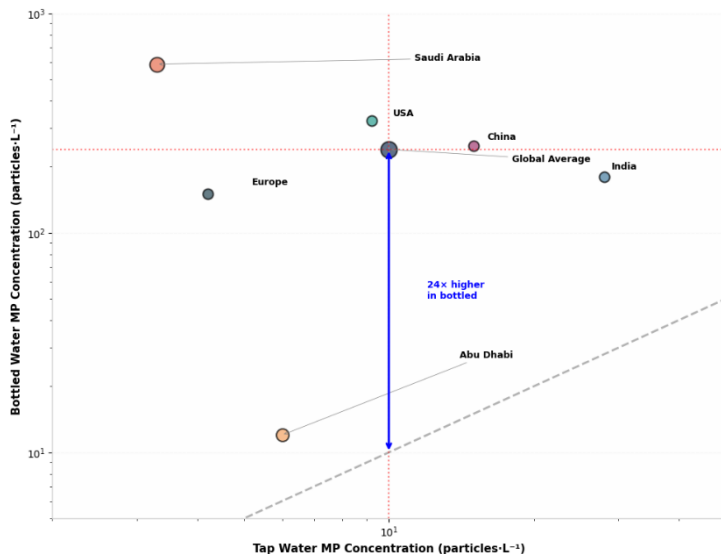


Figure 5. Global comparison: Microplastic contamination in bottled versus tap water.

Points above the diagonal indicate higher contamination in bottled water. Gulf region shows extreme bottled water contamination (Saudi Arabia: 586.5 particles/L bottled vs 3.3 particles/L tap)

Recent research from Weill Cornell Medicine-Qatar has highlighted particularly concerning findings regarding bottled water consumption. Their 2024 commentary in *BMJ Global Health* noted that up to 80% of plastic bottled water samples contain harmful contaminants including microplastics, with additional presence of endocrine-disrupting chemicals such as phthalates and bisphenol A (BPA) (Mamtani et al., 2024). Microplastic contamination has been associated with immune system dysregulation and oxidative stress, while BPA exposure is linked to cardiovascular

disease, diabetes, and obesity (Mamtani et al., 2024). The commentary emphasized that between 10% and 78% of bottled water samples contain various contaminants, and that the long-term effects of these exposures remain largely unknown (Mamtani et al., 2024).

A published 2025 review synthesized findings from over 140 scientific articles and found that bottled water can contain over 6,600 microplastic particles per liter (Solorzano et al., 2025). The review estimated that people who drink only bottled water may ingest up to 90,000 additional microplastic particles each year compared to those who drink tap water who ingest approximately 4,000 particles per year (Solorzano et al., 2025).

The cellular mechanisms of MP toxicity include physical damage to cell membranes, oxidative stress generation, inflammation, and potential translocation across biological barriers (Rahman et al., 2021; Wright & Kelly, 2017). MPs can act as vectors for chemical contaminants, including persistent organic pollutants (POPs), heavy metals, and plastic additives such as bisphenol A (BPA) and phthalates. In hot-climate storage conditions, the leaching of these additives accelerates studies show that antimony leaching from PET bottles increases with temperature and storage duration.

Comprehensive reviews of human health effects indicate that experimental and review-based evidence suggests that MPs may contribute to adverse effects in several biological systems., including gastrointestinal, nervous, hepatic, endocrine, respiratory, and reproductive systems (Snehamayee, et al., 2026; Li et al., 2024). These particles induce oxidative stress, alter metabolism, and affect gut microflora and gastrointestinal functions. Importantly, nanoplastics can translocate across biological barriers more easily than larger particles, posing potentially greater risks to human health, especially for vulnerable populations like infants and children who demonstrate higher exposure levels per body weight (Snehamayee, et al., 2026, Solorzano et al., 2026).

Recent studies have detected microplastics in human tissues including blood, placenta, and lungs, confirming their bioavailability (Snehamayee, N). Experimental studies suggest that microplastics can alter gut microbial composition, disrupt intestinal mucosal integrity, and affect reproductive and metabolic functions (Snehamayee, et al., 2026). Some additives leached from microplastics, such as phthalates, are endocrine disruptors that impact reproductive health (Li et al., 2024). The interaction of microplastics with other pollutants in the environment induces varied hazards following synergistic or antagonistic effects (Li et al., 2024).

While epidemiological evidence linking MP exposure to specific health outcomes remains limited, the precautionary principle suggests that minimizing exposure, particularly for vulnerable populations (children, pregnant women, immunocompromised individuals), is warranted given the persistence and ubiquity of these contaminants (Mahalingaiah et al., 2025; Rahman et al., 2021).

3.5 Policy Implications and Management Strategies

Key policy priorities for hot and arid regions include: (1) strengthening baseline monitoring and data generation on microplastics in drinking water systems; (2) improving understanding of material performance under elevated temperatures; (3) promoting appropriate bottled water storage and handling practices; (4) evaluating the effectiveness of treatment technologies for microplastic removal under local conditions; and (5) enhancing regional collaboration on research, capacity building, and knowledge exchange.

For Hot Climate countries contexts, specific recommendations emerge:

Infrastructure Materials: Future research should further evaluate the long-term performance of water infrastructure materials under high-temperature conditions. Material selection for new infrastructure projects may consider thermal stability, durability, and potential microplastic release throughout the service life of the system. For desalination facilities, additional studies are needed to assess the implications of different treatment technologies and infrastructure configurations on microplastic occurrence and removal.

Storage Protocols: Develop voluntary temperature-awareness labeling for bottled water and promote storage below 25°C where feasible. Encourage best-practice storage and distribution measures during periods of high ambient temperatures, particularly in hot and arid regions. These recommendations are supported by evidence indicating that prolonged exposure of bottled water to sunlight and elevated temperatures can increase microplastic release and chemical leaching from packaging materials (Mamtani et al., 2024).

Monitoring Frameworks: Strengthen baseline monitoring and data generation efforts to improve understanding of microplastic occurrence in drinking water systems, particularly in hot-climate regions where data remain limited. Regional collaboration on analytical methods, monitoring approaches, and data sharing could improve comparability across studies while respecting national circumstances and available resources. Priority monitoring locations may include desalination

plant outputs, distribution networks, storage facilities, and representative household taps. Enhanced monitoring would support evidence-based policy development and help address existing knowledge gaps in Qatar and other GCC countries (Hagelskjær et al., 2025; Koelmans et al., 2019).

Regional Coordination: Strengthening regional cooperation on research, monitoring, capacity building, and knowledge exchange could support a better understanding of microplastic occurrence in drinking water systems across the GCC region. Collaborative initiatives may facilitate data sharing, improve methodological consistency, and help identify research priorities while respecting national circumstances and available resources.

4. CONCLUSIONS

This review demonstrates that microplastic contamination in drinking water systems of hot and arid regions has been reported across a range of water sources, with concentrations varying from <1 to >860 particles \cdot L $^{-1}$ depending on the water source, analytical methods, and particle-size thresholds applied. Recent studies from Abu Dhabi suggest elevated microplastic occurrence in marine and surface-water environments near desalination and industrial areas, with acrylonitrile-butadiene-styrene (ABS), cellulose acetate (CA), and nylon-66 (PA-66) among the detected polymers (Hashmi et al., 2026). Limited preliminary evidence from Qatar indicates detectable microplastic presence; however, comprehensive drinking water datasets remain unavailable (Al-Ani et al., 2025).

Elevated temperatures and intense ultraviolet radiation may accelerate polymer degradation, potentially increasing microplastic release from drinking water infrastructure and packaging materials. Available evidence suggests that distribution networks, bottled water packaging, and municipal infrastructure may represent important sources of contamination. Advanced treatment technologies, including membrane-based systems and dissolved air flotation, have demonstrated promising removal efficiencies; however, further research is required to evaluate their long-term performance and feasibility under hot-climate conditions.

Estimated human exposure through drinking water may be higher in arid regions due to increased water consumption and enhanced thermal stress on plastic materials. Although toxicological studies indicate potential risks associated with microplastic exposure, particularly for vulnerable

populations, epidemiological evidence remains limited and significant uncertainties persist regarding long-term health effects.

Important knowledge gaps remain, including the lack of hot-climate-specific drinking water datasets, limited understanding of temperature-dependent degradation processes, and insufficient assessment of microplastic occurrence across desalination-based water supply systems. Addressing these gaps will require strengthened monitoring efforts, improved analytical consistency, continued research, and enhanced capacity building to support evidence-based decision making.

Overall, the findings highlight the importance of generating robust baseline data and advancing scientific understanding of microplastics in drinking water systems under hot-climate conditions. As climate change intensifies thermal stress on water infrastructure globally, insights from arid regions may contribute to the development of more resilient and sustainable water management strategies.

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