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Evaluation of Water Quality from Atmospheric Water Generators Deployed Across Multiple Indian Cities: A Comparative Study

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ABSTRACT

Atmospheric Water Generators (AWGs) represent an emerging decentralized water solution that extracts moisture from ambient air to produce potable water without reliance on conventional freshwater sources. This study evaluates AWG-produced water quality at three Indian deployment sites — Pune (October 2025), Sringeri (November 2025), and Chennai (October 2025) — against IS 14543:2024, the Indian Standard for packaged drinking water, and benchmarks results against the WHO Guidelines for Drinking-water Quality. Organoleptic, physical, chemical, toxicological, and microbiological parameters were analyzed at NABL-accredited laboratories. All three sites showed low total dissolved solids (10–32 mg/L), non-detectable heavy metals, and non-detectable pesticide residues. Two site-specific deviations were identified: elevated heterotrophic aerobic counts with yeast presence at Pune (56 CFU/mL at 22 °C), and an alkaline pH at Chennai (9.59), both outside IS 14543:2024 limits. The Sringeri site met all tested parameters. These results indicate that condensation-derived AWG water is intrinsically low in dissolved solids and free of the regulated toxicological and faecal-indicator contaminants, while microbial regrowth in storage/dispensing components and pH drift during mineralization are the principal, and correctable, risks. As this is a single-time-point, single-sample-per-site survey without seasonal replication, the findings should be read as an initial field snapshot rather than a statistically powered comparison; recommendations for routine post-treatment, monitoring, and future multi-season sampling are provided.

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Introduction

Global water stress, exacerbated by urbanization, pollution, and climate variability, has intensified the search for alternative freshwater sources. Atmospheric Water Generators (AWGs) offer a promising decentralized approach by harvesting water vapor from ambient air through condensation, filtration, and mineralization. Active condensation-based AWGs are reported to achieve yields ranging from roughly 15 L/day in small units to over 10,000 L/day in large-scale installations, alongside alternative approaches such as thermoelectric (Peltier) cooling, vapour-compression refrigeration, and recovery from air-conditioning condensate [1]. AWGs are particularly suited to regions with high relative humidity, such as coastal and monsoon-influenced areas of India, where atmospheric moisture availability supports sustainable water production.

Interest in AWG technology has grown internationally as a supplementary or emergency water source. The United States Environmental Protection Agency (US EPA) undertook a multi-year collaborative evaluation of commercial AWG units and found that elemental water quality was generally within drinking-water limits, but repeatedly identified elevated heterotrophic bacterial counts as the principal quality concern, attributing this to inadequate disinfection or microbial regrowth in storage and

distribution components rather than to the condensation process itself [2,3]. Field studies conducted in other geographies have reported broadly similar findings: AWG-produced water tends to be soft, low in dissolved solids, and low in salinity, making it suitable for both drinking and irrigation purposes, while pH has been observed to trend toward the alkaline end of acceptable ranges in some units [4]. Where AWG units are deployed in industrially polluted environments, comprehensive multi-parameter surveys have shown that ambient air quality can influence the profile of organic, inorganic, and microbial constituents in the condensate, underscoring the importance of site-specific evaluation rather than reliance on manufacturer specifications alone [5]. Parallel work in hot, humid climates has quantified the trade-off between water yield and energy consumption, both strongly dependent on ambient temperature and humidity, and recent review literature has proposed composite indices that jointly evaluate energy expenditure and water quality outcomes, reflecting a broader consensus that yield and purity must be assessed together rather than in isolation [6-8].

While AWGs are commercially promoted for residential, institutional, and industrial use, systematic water quality evaluations under real-world deployment conditions remain limited in the Indian context, where climatic zones range from humid coastal cities to drier inland regions and where the applicable regulatory benchmark — IS 14543:2024 — has not previously been used as the basis for a multi-site AWG comparison. This study addresses that gap by presenting a comparative water quality assessment of

commercial AWG systems deployed in three climatically distinct Indian cities — Pune (Maharashtra), Sringeri (Karnataka), and Chennai (Tamil Nadu) — conducted during October–November 2025. Water samples were analyzed in accordance with IS 14543:2024 and cross-referenced against WHO guideline values, to evaluate safety, potability, and regulatory compliance across differing climatic and environmental settings, and to identify which quality risks, if any, are generalizable across sites versus site-specific [9,10].

Materials and Methods
AWG System Description

The AWG units evaluated in this study operate on a multi-stage process common to condensation-based systems:

- Air intake and filtration, in which ambient air is drawn through particulate and activated-carbon filters to remove dust, volatile organic compounds (VOCs), and allergens
- Condensation, in which air passes over a chilled evaporator coil (4–10 °C) so that moisture condenses into liquid water, with extraction efficiency strongly dependent on ambient temperature and relative humidity
- Collection and storage, in which condensed water is held in a hygienic tank fitted with recirculation to limit stagnation
- Filtration and purification, comprising sediment, carbon block, reverse osmosis/ultrafiltration, and UV stages to remove residual microbes and chemical contaminants; and
- Mineralization and dispensing, in which optional remineralization cartridges add calcium, magnesium, and bicarbonates prior to dispensing. Commercial units of the class evaluated here typically produce 10–50 litres/day per unit depending on ambient conditions and rated capacity, with reported energy consumption in the range of 0.3–1.0 kWh per litre for comparable condensation-based systems [1,6].

Deployment Locations

- Pune (Maharashtra): A semi-urban, moderately humid city (RH ~60–70% during the monsoon) with moderate industrial activity.
- Sringeri (Karnataka): A rural, high-humidity temple-town setting (RH ~75–85%) with low industrial pollution.

Results

Physical and Chemical Parameters

Table 1: Summarizes The Organoleptic, Physical, and General Chemical Results Against the IS 14543:2024 Limit for each Parameter

Parameter	IS 14543:2024 Limit	Pune	Sringeri	Chennai
Colour (Hazen/TCU)	≤ 2	1.0	< 2.0	< 2.0
Turbidity (NTU)	≤ 2	0.1	< 1.0	< 0.5
TDS (mg/L)	≤ 500	10.0	24.0	32
pH @ 25 °C	6.0–8.5	7.3	6.90	9.59 *
Chloride (mg/L)	≤ 200	2.5	11.4	4.3
Sulphate (mg/L)	≤ 200	1.22	< 1.0	< 1.0
Alkalinity, HCO3- (mg/L)	≤ 200	2.97	25.0	21
Calcium (mg/L)	≤ 75	2.00	4	4
Magnesium (mg/L)	≤ 30	1.0	< 1.0	1.7
Nitrate, NO3- (mg/L)	≤ 45	0.77	1.8	< 1.0
Residual chlorine (mg/L)	≤ 0.2	0.1	< 0.1	< 0.1

* Non-compliant with IS 14543:2024.

- Chennai (Tamil Nadu): A coastal, high-humidity metropolis (RH ~70–80%) with elevated ambient temperatures and urban pollution.

Each site hosted a commercial AWG unit (rated capacity 20–30 L/day) installed indoors under controlled airflow. Samples were collected in sterilized 20 L containers, preserved at 2–8 °C, and transported to NABL-accredited laboratories for analysis.

Analytical Methods

Water samples were analyzed at two NABL-accredited laboratories: the FHHL Laboratory (Pune sample) performed chemical, biological, and pesticide-residue testing, while the Chennai Mettex Laboratory (Sringeri and Chennai samples) performed comprehensive testing across microbiological, toxicological, and organoleptic parameters. All testing followed IS 14543:2024 protocols. Parameters analyzed included: organoleptic/physical (colour, odour, taste, turbidity, pH, TDS); general chemical (alkalinity, hardness, chloride, sulphate, nitrate, fluoride, calcium, magnesium, sodium); toxic metals (barium, copper, iron, manganese, zinc, silver, aluminium, lead, cadmium, mercury, arsenic, chromium, nickel, uranium); pesticide residues (organochlorines, organophosphates, and herbicides including DDT, HCH, endosulfan, malathion, and chlorpyrifos); and microbiological indicators (E. coli, total coliforms, faecal streptococci, S. aureus, Pseudomonas, Salmonella, Shigella, total viable aerobic count, and yeast/mould).

Quality Assurance and Data Handling

Analyses were performed by third-party, NABL-accredited laboratories independent of Aeronero Solutions Pvt. Ltd., which supplies chain-of-custody separation between the manufacturer and the analytical result. Each site is represented by a single grab sample collected on the dates noted in Section 2.2; no replicate sampling or repeated-measures design was used within this dataset, and no statistical hypothesis testing (e.g., ANOVA) was therefore performed. Reported values are the single measured result issued on each laboratory's certificate of analysis, not a mean of replicates. This constraint is discussed explicitly in Section 4.6.

All heavy metals assessed (including lead, cadmium, arsenic, mercury, and uranium) were below detection limits (< 0.001–0.005 mg/L) at every site. The full panel of 20+ pesticide-residue compounds was undetectable (< 0.0001 mg/L) across all three samples.

Microbiological Parameters

Table 2: Summarizes Microbiological Indicator Results

Parameter (per 250 mL unless noted)	IS 14543:2024 Limit	Pune	Sringeri	Chennai
E. coli	Absent	Absent	Absent	Absent
Total coliforms	Absent	Absent	Absent	Absent
Faecal streptococci	Absent	Absent	Absent	Absent
S. aureus / Pseudomonas / Salmonella / Shigella	Absent	Absent	Absent	Absent
Aerobic CFU, 22 °C, 72 h (/mL)	≤ 100	56	15	17
Aerobic CFU, 37 °C, 24 h (/mL)	≤ 20	12	5	5
Yeast & mould	Absent	Present *	Absent	Absent

* Non-compliant with IS 14543:2024.

Comparison with WHO Guideline Values

Table 3 places the same chemical results alongside the corresponding WHO Guidelines for Drinking-water Quality values, where a numerical guideline value exists, to situate the IS 14543:2024 comparison within an internationally recognized benchmark [10].

Parameter	WHO Guideline Value	Pune	Sringeri	Chennai
pH	No health-based guideline; 6.5–8.5 typically targeted for acceptability	7.3	6.90	9.59
TDS (mg/L)	No health-based guideline; ≤1000 mg/L for acceptable taste	10.0	24.0	32
Nitrate, NO ₃ ⁻ (mg/L)	50	0.77	1.8	< 1.0
Fluoride (mg/L)	1.5	[insert]	[insert]	[insert]
Lead (mg/L)	0.01	< 0.005	< 0.005	< 0.005
Arsenic (mg/L)	0.01	< 0.005	< 0.005	< 0.005

Discussion

Chemical Purity and Desirability

The consistently low TDS (10–32 mg/L) observed across all three sites reflects the capacity of condensation-based AWG systems to produce demineralized water comparable to distilled water, essentially free of dissolved salts, hardness, and ionic contaminants. This characteristic is particularly advantageous in areas served by high-TDS groundwater or saline sources. The absence of detectable heavy metals, pesticide residues, and organic pollutants is consistent with prior evaluations reporting that elemental and toxicological parameters of AWG condensate generally fall within, or well within, drinking-water limits, and underscores the efficacy of multi-stage filtration together with the inherent purity of atmospheric moisture when captured in a controlled indoor environment [2,3,4].

The Sringeri site's near-neutral pH (6.90) and moderate alkalinity (25 mg/L) suggest either limited remineralization or natural atmospheric CO₂ dissolution during condensation. In contrast, Chennai's elevated pH (9.59) most likely reflects post-condensation neutralization — for example, calcium/magnesium dosing cartridges — or a calibration deviation in the mineralization stage, and falls outside the IS 14543:2024 range of 6.0–8.5. A tendency toward alkaline pH in AWG-produced water has similarly been reported in other field evaluations, reinforcing the need for routine pH verification as a standard operating check rather than a one-time commissioning parameter [4].

Microbiological Considerations

The elevated CFU count at the Pune site (56 CFU/mL at 22 °C) together with detectable yeast is indicative of post-condensation microbial regrowth, most plausibly originating in storage tanks, dispensing taps, or under-performing UV treatment rather than in the condensation process itself. This finding is consistent with the pattern documented by the US EPA's multi-year evaluation of commercial AWG units, in which elemental water quality met drinking-water standards but heterotrophic bacterial counts were repeatedly elevated, attributable to inadequate disinfection or biofilm-associated regrowth downstream of treatment, even though indicator organisms of faecal contamination were not detected [2,3]. The Sringeri and Chennai samples, both within the CFU limit, indicate that routine tank hygiene and appropriately dimensioned UV/ozone disinfection can keep microbiological parameters within compliance even in high-humidity, high-yield environments.

Site-Specific Performance

- Pune: Moderate humidity and urban aerosol load may contribute to microbial pressure on storage components; enhanced post-treatment and more frequent tank servicing are recommended.

- Sringeri: High humidity combined with low ambient pollution and fully compliant results affirms AWG viability in rural, humid settings with minimal intervention.
- Chennai: Coastal humidity supports strong yield, but pH correction in the mineralization stage is necessary to achieve full compliance.

Comparison with International Literature

Benchmarking against the WHO Guidelines for Drinking-water Quality (Table 3) confirms that the toxicologically regulated parameters — nitrate, lead, arsenic, and the broader heavy-metal panel — sit well within internationally accepted health-based limits at all three sites, reinforcing that the IS 14543:2024 compliance picture is not an artefact of a comparatively lenient national standard [10]. The two deviations identified in this study — heterotrophic regrowth and alkaline pH drift — mirror, respectively, the principal concern raised in the US EPA's cooperative AWG evaluation and the alkaline-pH tendency reported in a South African commercial AWG assessment, suggesting these are recurring, technology-level risk categories for condensation-based AWG rather than issues specific to the Indian deployments studied here [2-4]. This convergence across independent studies and geographies strengthens the case that post-condensation handling — not the condensation process itself — is the primary quality-control lever for this technology class.

Study Limitations

This study should be read as an initial, cross-sectional field snapshot rather than a statistically powered comparison, for four reasons. First, each site is represented by a single grab sample collected on a single date; no within-site replicates were taken, so no measure of analytical or sampling variability (e.g., standard deviation, confidence interval) can be reported, and no inferential statistics (ANOVA, t-tests) are applicable to the three-site comparison presented in Tables 1-3. Second, sampling was confined to October–November 2025, a single seasonal window; AWG condensate composition is expected to vary with ambient temperature and humidity, so the results reported here may not represent performance in other seasons (e.g., pre-monsoon or winter conditions) at the same sites. Third, only one commercial AWG unit was sampled per site, so unit-to-unit manufacturing or maintenance variability within a given deployment class was not assessed. Fourth, two different accredited laboratories were used across sites (FHHL for Pune; Chennai Mettex for Sringeri and Chennai), and while both operate under IS 14543:2024 protocols, inter-laboratory method differences cannot be fully excluded as a contributor to the observed site differences. These constraints do not undermine the qualitative findings — namely, that the toxicological and faecal-indicator profile of AWG condensate is consistently favourable while pH and heterotrophic counts are the parameters requiring routine operational control — but they do mean the specific numerical values reported here should not be extrapolated as representative annual or fleet-wide averages without the longitudinal, replicated sampling programme proposed in Section 6.

A further consideration for the reader is that the authors are affiliated with the manufacturer of the AWG units tested; this is addressed directly in the Conflicts of Interest statement, and is one reason the analytical work itself was routed through independent, third-party NABL-accredited laboratories rather than in-house testing.

Conclusions

Across all three deployment sites, AWG systems delivered chemically pure, low-TDS water essentially free of the heavy metals, pesticide residues, and faecal indicator organisms regulated under IS 14543:2024, supporting the technology's suitability for decentralized water supply in humidity-rich regions of India. However, this study also identifies two recurring risk categories that warrant standard operating attention: microbial regrowth downstream of condensation (as observed at Pune) and pH drift introduced during mineralization (as observed at Chennai). Neither issue reflects a limitation of the condensation process itself; both are addressable through site-specific post-treatment, namely UV/ozone disinfection and pH balancing, alongside routine monitoring. With these controls in place, and subject to the single-sample, single-season scope described in Section 4.5, AWG technology represents a promising, climate-resilient water source for urban and semi-urban deployment across diverse Indian climatic zones, warranting the longitudinal, multi-unit follow-up study proposed below.

Recommendations and Future Work

- **Post-Treatment Enhancement:** Integrate UV/ozone disinfection modules and automated pH-adjustment systems into unit design.
- **Routine Monitoring:** Conduct quarterly microbiological and chemical testing at each deployment site, with more frequent checks in the first months following installation.
- **User and Operator Education:** Train site operators on tank cleaning, filter replacement schedules, and general hygiene protocols for dispensing components.
- **Policy Support:** Incentivize AWG adoption in water-scarce, high-humidity zones under national water-security missions, contingent on demonstrated compliance monitoring.

Future research should extend this comparative approach across a wider range of Indian climatic zones, incorporate longitudinal (multi-season) sampling with within-site replicates at each location to enable formal statistical comparison, and examine the long-term health implications of sustained consumption of low-mineral, AWG-derived water, alongside further optimization of the energy-quality trade-off characteristic of condensation-based systems [6-8].

Institutional Review Board Statement

Not applicable. This study did not involve human participants, human data, or animals; it involved analytical testing of water samples only.

Informed Consent Statement

Not applicable, as the study did not involve human subjects.

Data Availability Statement

The data presented in this study (laboratory certificates of analysis for the Pune, Sringeri, and Chennai samples) are available from the corresponding author on reasonable request.

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Conflicts of Interest

All authors are affiliated with Aeronero Solutions Pvt. Ltd., the manufacturer of the AWG units evaluated in this study. To mitigate

this conflict, all analytical testing was performed by independent, NABL-accredited third-party laboratories (FHHL Laboratory and Chennai Mettlex Laboratory) rather than in-house, and the raw certificates of analysis underlie every value reported in Tables 1-3.

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