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Evaluating the Long-Term Impact of Privatization on Municipal Water Quality in Nagpur

Neeraj Kumar Dubey[1], Vipin Sharma[1], Vir Narayan[2], Pradeep Yadav[3], Pratiksha Sharma[2], Pratigya Darpe[2], Gyanendra Singh*[1]

[1]School of Pharmacy, Vikrant University, Gwalior, M.P, (Bharat)
[2]School of legal Studies, Vikrant University, Gwalior, M.P, (Bharat)
[3]School of Humanities and Culture, Vikrant University, Gwalior, M.P, (Bharat)

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Corresponding Author:
gyanileo@gmail.com

Abstract

The present paper assesses the effects of privatization or more precisely, public private partnership (PPP) led municipal water reform on the quality of drinking water in Nagpur over the long term. It uses secondary data to integrate operator water quality data, Nagpur Municipal Corporation data, and published research on intermittent and continuous supply. The indicators point toward qualified improvement rather than unqualified success or failure. Testing by operators indicates a negative trend in the percentage of samples that are unfit over time, declining from 21.0% in 2011–12 to 1.8% in 2024–25 and to a partial year record of 0.4% in 2025–26. Independent microbiological studies in Nagpur indicated a low risk of contamination in areas supplied continuously compared to areas supplied intermittently. Recent municipal indicators such as reduced tanker dependence from 346 (2016) to 78 (2024) and a partial decline in system losses to 41.91% confirm that trend of change, despite persistent dark zones and high residual losses. The paper argues that Nagpur cannot be regarded as pure privatization in the classical meaning since municipal ownership has remained governmental. Its principal contribution is the finding that the increase in water quality can best be attributed to changes in operations associated with increased continuity, pressure control, monitoring, and network rehabilitation. This long-term effect is consequential but imbalanced: both of which have apparent positive returns in terms of public health, accompanied by endemic issues of spatial inequity, leakage, and the city as a whole failing to fully consolidate gains.

1. Introduction

The discussion of urban water reform in India tends to reduce complex institutional arrangements to a simple publicversusprivate binary. Nagpur presents a more instructive case. The city implemented an operational model under a publicprivate partnership in the form of Orange City Water (OCW), while retaining full municipal ownership of assets. The central question for analysis is therefore not whether a private actor exists in the abstract, but whether the reform enhanced the quality of drinking water over time(Seppälä, 2002).

This distinction matters profoundly because water quality is directly influenced by the way a distribution system functions. Outages in supply increase the risks of contamination through loss of pressure, pipe intrusion, chlorine instability, and unsafe household storage all documented hazards of intermittent supply systems that were the norm across Indian cities before the reform era. More continuous and pressurized service can systematically reduce these risks. Nagpur is therefore not only a governance reform case but a publichealth case of direct relevance to the Sustainable Development Goal 6 agenda on universal safe water access.

India's urban water sector has long been characterized by institutional fragmentation, infrastructure deficits, and political economy constraints that militate against sustained reform. Nagpur's PPP represents one of the most closely documented urban water reform experiments in the country. Unlike the more contentious fullprivatization debates that surrounded Mumbai or Delhi, Nagpur's model retained public control of assets while contracting day to day operations to a private operator a structure known as an operations and maintenance (O&M) concession. This hybrid model is increasingly the preferred form in Indian urban water policy and in broader development finance guidance from the World Bank and Asian Development Bank(Tortajada, 2016).

The paper relies on secondary data to determine whether the reform in Nagpur resulted in credible long term water quality improvement, through what mechanisms, and to what extent. It blends official city documents, annual laboratory data of Orange City Water, and evidence from peerreviewed sources focused on Nagpur itself. The analysis situates Nagpur within the broader global literature on intermittent versus continuous supply and on the conditions under which PPPs generate or fail to generate publichealth improvements. Crucially, comparisons with pre reform conditions, with contemporaneous Indian cities, and with international benchmarks are drawn throughout, providing analytical depth beyond what a purely inward-looking case study could offer(Hastak, Labhasetwar, Kundley, & Gupta, 2017).

2. History of Nagpur Water Reform

Nagpur's pre reform water system epitomized the structural failure of Indian municipal water utilities. By the mid 2000s, the city of approximately 2.5 million people was receiving piped water supply for an average of two to four hours per day, with wide variation across neighborhoods depending on proximity to reservoirs and the political economy of water distribution. System losses were estimated to exceed 50% of treated water produced losses attributable to a combination of leaking distribution mains, unauthorized connections, and the inherent waste of intermittent operation itself. Extensive dependence on private water tankers numbering approximately 346 in 2016 supplemented the inadequate piped supply, at considerable cost to lower income households who could least afford to pay market rates for water of uncertain quality.

The city's treatment infrastructure was not itself the primary constraint. Nagpur operated surface water treatment plants drawing on the Kanhan and Pench rivers with substantial nominal capacity. The bottleneck was in the distribution network: aging cast iron and asbestos cement pipes, inadequate pressure zones, absent district metering, and a near total absence of routine network monitoring. Safe water produced at the treatment plant was routinely decontaminated in the distribution system before reaching the household tap a pattern extensively documented in the intermittent supply literature.

The city responded to this crisis through a PPP design involving Nagpur Environmental Services Limited (NESL) as the special purpose vehicle and Orange City Water a joint venture of Veolia and Vishvaraj Infrastructure as the operator. The scheme focused on operational transformation, not on asset sales: network restoration, metering, pressure control, databasebased planning, customer service enhancement, and regular quality inspection (Ministry of Housing and Urban Affairs, 2021; Orange City Water, 2026a). The 24×7 continuous supply mandate was the defining operational goal.

This structural choice is analytically important. In Nagpur, the operational mechanisms that would be likely to enhance water quality improvement enhancement of

pressure continuity, reduction of leakage, improved chlorination, and enhanced monitoring did not require a change of ownership. They required operational discipline, capital investment in rehabilitation, and accountability for service outcomes: precisely the elements that an O&M concession was designed to introduce(Che-Ghani, Myeda, & Ali, 2023).

By way of comparison with the prereform era: Delhi's Jal Board (DJB), which remained a public utility, reported nonrevenue water of approximately 40% in 2022 and continued intermittent supply across much of the capital, demonstrating that public ownership alone does not solve distribution quality problems. Similarly, Mumbai's Brihanmumbai Municipal Corporation, also publicly operated, continued to provide only three to five hours of supply per day to many areas in 2023, with documented microbial contamination events. These comparisons underscore that the relevant variable is not ownership form but operational incentive structure and investment quality.

The organizational framework of the Nagpur water project reflects a complex Public Private Partnership (PPP) designed to streamline urban utility management. According to the structural model synthesized from Nagpur Municipal Corporation (NMC) and CARE Ratings (2024), the project operates through a Special Purpose Vehicle (SPV), which isolates financial risk and ensures dedicated project oversight. At the operational heart of this arrangement is Orange City Water (OCW), acting as a Joint Venture (JV) typically between Veolia and Vishvaraj Infrastructure responsible for the execution and maintenance of the city's 24x7 water supply initiative. This hierarchical alignment allows the NMC to maintain regulatory authority while leveraging the technical expertise and capital efficiency of private sector entities.The institutional structure of the Public Private Partnership (PPP) for water supply in Nagpur, which is organized into four distinct layers.Government Layer: At the top, the Nagpur Municipal Corporation (NMC) acts as the asset owner and contract authority, while the Maharashtra Government provides policy and regulatory oversight. Through a process of contract delegation, authority is passed to the next level.SPV Layer: The Nagpur Environmental Services Ltd (NESL) serves as the Special Purpose Vehicle (SPV). This layer is backed by creditworthy project finance, as indicated by CARE Ratings.

Operator Layer: An operations contract links the SPV to Orange City Water (OCW), a joint venture between Veolia and Vishvaraj. This operator is responsible for water treatment, distribution, quality monitoring, and the rollout. Beneficiary Layer: The final stage is service delivery to the residents. This layer encompasses 2.5 million residents across 229 water zones. The supply is divided into 36 zones receiving supply and 36 "dark zones" where supply is currently limited to less than 2 hours per day.

3. Review of Literature

3.1 Public Private Partnerships and Urban Water

The literature on urban water PPPs spans two decades of contested evidence. Reviews of developing country experience by Marin (2009) for the World Bank and by Lima et al. (2021) identify both positive and negative outcomes: where regulation is strong and contracts are well designed, private participation tends to improve operational efficiency and investment in distribution; where regulation is weak, accountability is low, or political will to enforce contracts is absent, PPPs can result in worse outcomes than the utilities they replaced. The broad conclusion that emerges from this literature is that institutional form public or private matters less than the incentive and accountability structures that institutional arrangements create.Comparative studies of water utility efficiency, including those from Portugal, Italy, and wastewater treatment globally, broadly confirm that well designed PPPs can improve technical efficiency and service quality, but that the effect is conditional on contract design, regulatory oversight, and political context. The Indian urban water sector presents a particularly challenging environment for PPP governance: democratic accountability is strong but institutional regulatory capacity is weak, and the distributional politics of water pricing constrain cost recovery(Walters, 2013).

3.2 Intermittent Supply, Water Quality, and Public Health

The second strand of literature, closer to the paper's empirical core, concerns the relationship between supply continuity and water quality. Extensive evidence establishes that intermittent supply is not simply an inconvenience: it is a systematic contamination mechanism. When pressure drops below zero during supply gaps, pipe intrusion draws in soil water, sewage, and surface contaminants at joints and corrosion points. Chlorine residual, which provides the disinfection barrier against faecaloral pathogens, decays during stagnation and cannot be maintained at safe levels across a network that refills intermittently. Biofilms that accumulate in pipes during dry periods are dislodged on resumption of flow,

generating turbidity spikes and pathogen loads.Household level coping behaviors under intermittent supply create additional contamination risks. Storage in open tanks and containers universal under intermittent systems provides conditions for bacterial regrowth, insect breeding, and cross contamination that are absent when supply is continuous and households do not need to store water. Studies from Jordan,Panama,Nepal, and China all document elevated microbial contamination in intermittent systems compared to continuous systems or to the same systems following continuity improvements.The global context is instructive. As of 2023, the WHO/UNICEF Joint Monitoring Programme estimated that approximately 2 billion people globally lacked access to safely managed drinking water services. India accounted for a disproportionate share of this burden, with a significant fraction attributable not to absence of treatment infrastructure but to distribution level contamination under intermittent supply. The SDG 6.1 target universal and equitable access to safe and affordable drinking water cannot be achieved while the predominant urban distribution model remains intermittent, regardless of treatment plant capacity(Arora & Mishra, 2022).

3.3 Nagpur Specific Evidence

The third strand consists of Nagpur specific research. Hastak et al. (2017) documented measurable improvements in hours of supply, pressure, and coverage in Nagpur's demonstration zone following the 24×7 transition. Jayaramu et al. (2016) examined cost recovery trajectories. Jensen & Chindarkar (2019) studied the relationship between service quality, public trust, and political salience of the reform, arguing that the PPP's long term legitimacy depends on demonstrating quality gains across the full service area, not only in pilot zones.The strongest direct evidence is provided by Bivins et al. (2021), whose study in Water Research remains the most rigorous peerreviewed microbiological assessment of Nagpur's water quality. The authors sampled household tap water across zones as they transitioned from intermittent to continuous service and found significantly higher culturable Escherichia coli and pathogen gene target detection in intermittent supply zones(Bivins et al., 2021). The study directly attributes lower microbial risk to supply continuity within the same city, controlling for treatment plant quality. Earlier engineering work by Sakomoto et al. (2011) had identified bacteriological vulnerability from back suction and distribution level contamination in Nagpur, making the subsequent improvement under better continuity more plausible(Varela, André, Nunes, & Manaia, 2014).

4. Research Gap and Objectives

Despite this body of literature, a sustained long term synthesis focused specifically on water quality outcomes in Nagpur is sparse. Policy and academic discussion has focused primarily on governance, finance, tariffs, and the symbolism of 24×7 supply rather than on sustained quality evidence. This gap is consequential because quality and continuity outcomes are distinct: a city can achieve 24×7 supply without achieving safe water, if distribution infrastructure is inadequately maintained or chlorination is inconsistent. Conversely, measurable quality improvements can occur before the 24×7 mandate is fully citywide, if continuity increases in high risk zones reduce the most dangerous contamination pathways.

This paper fills that gap through five interconnected objectives:

To clarify what privatization means institutionally in the Nagpur case.

To trace the operator trend in fit and unfit samples over the long run.

To compare this trend with independent microbiological evidence.

To interpret it against service indicators including system losses, tanker dependence, and dark zones.

To generalize policy lessons for Indian municipal water reform.

The fifth objective generalization is the most novel, as it explicitly situates Nagpur's trajectory in comparison with prereform conditions, contemporaneous Indian cities, and international benchmarks, rather than treating the case as self contained(Singh, 2007).

5. Methodology

This is secondary data research. It is not based on field sampling or primary survey data. Rather, it cross tabulates four clusters of sources: Nagpur Municipal Corporation reports, Orange City Water annual water quality records, peer reviewed research on Nagpur and intermittent supply, and broader literature on PPP policy. The methodological approach is purposive triangulation: municipal documents provide service context; operator reports provide the only available long run annual quality series in the public domain; peer reviewed studies are used to test whether the series is consistent with independent evidence; and

comparative literature is used to interpret probable mechanisms and external validity.The analysis is built on three principles. First, it separates ownership reform from operational reform the institutional arrangement is analytically secondary to the service conditions it produces. Second, it treats operator data as useful but not sufficient in itself, requiring corroboration from independent microbiological evidence. Third, it evaluates water quality not through abstract institutional labels but through the concrete service parameters continuity, pressure, leakage, and microbial risk that the literature identifies as the proximate determinants of distribution level safety.Given the absence of standardized, publicly available longrun data adequate for controlled causal modeling, the paper is methodologically based on descriptive trend analysis and qualitative synthesis rather than econometric impact estimation. This is a deliberate choice, not a limitation: the available data support trend identification and mechanism interpretation, which are the appropriate analytical goals given the research questions(Patton, Sawicki, & Clark, 2015; Real-Dato, 2009).

6. Results and Analysis

Results are presented in five connected sections, proceeding from institutional clarification through long term trend analysis, independent microbiological evidence, service indicators, and an integrated synthesis. This sequence reflects the analytical logic of the paper: before interpreting quality outcomes, it is necessary to understand what kind of reform Nagpur represents; before assessing whether outcomes are sustained, it is necessary to triangulate the operator series with independent evidence.

6.1 The Institutional Character of Nagpur's Privatization

A review of the documentary record clarifies that Nagpur is not a privatized water system in the standard academic or policy sense. Water assets treatment plants, reservoirs, the distribution network remain the property of the Nagpur Municipal Corporation. Tariff setting authority and regulatory oversight nominally remain with NMC. What was privatized, in effect, is the operation and management of the system, delegated through a concession contract to NESL/OCW for a 25 year period.

This distinction is not merely semantic. The literature on water PPPs consistently finds that the form of private participation full divestiture, lease, concession, and O&M contract matters for outcomes because it shapes risk allocation, investment incentives, and accountability structures. Full divestiture transfers commercial risk to the private sector but also weakens public oversight; O&M contracts retain public accountability while introducing private operational discipline and access to international technical expertise. Nagpur's model is closer to the latter.

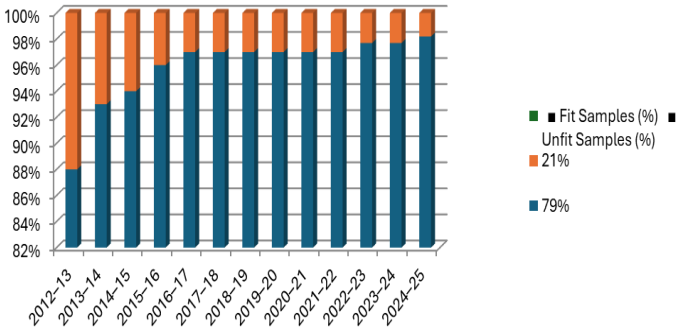
The CARE Ratings (2024) creditworthiness assessment of Orange City Water confirms that the project financing has been structured and serviced adequately, suggesting that commercial incentives are sufficiently aligned with continued operation. What this institutional structure implies analytically is that reform should be assessed by whether the PPP altered frontline service conditions pressure, continuity, monitoring rather than by the fact of private participation itself. Where rehabilitation and continuity advanced, quality improvement would be expected; where dark zones and unsteady supply persisted, improvements would be partial rather than general.

6.2 LongTerm Utility Reported Water Quality Trend

The most evident long term evidence is the data provided by Orange City Water in its annual laboratory reports, covering the period from 2011–12 through 2025–26. The proportion of unfit samples declined from 21.0% in 2011–12 to 12.0% in 2012–13, 7.0% in 2013–14, and 4.0% in 2015–16. From 2016–17 onwards it stabilized at approximately 3%, declining further to 2.3% in 2022–23 and 2023–24 and 1.8% in 2024–25. Partialyear data through February 2026 records an exceptional 0.4% unfit rate, the lowest in the series.This represents a substantial longterm improvement. The largest gains occurred in the early reform phase (2011–12 to 2015–16), which is consistent with the rectification of the most severe operational deficiencies: leakage hotspots, absent monitoring, and the contamination risks associated with fully intermittent supply. The plateau at approximately 3% from 2016 to 2022 suggests a stabilization phase in which incremental network improvements continued but the most acute problems had been addressed. The further decline after 2022 correlates with AMRUT 2.0 pipeline works and expanded metering.The credibility of this trend is reinforced by sample volume stability. Annual sample sizes consistently ranged from 15,000 to over 22,000 across the series, ensuring that the trend reflects genuine quality change rather than sampling variation. Nevertheless, as noted above, operator reported data must be treated with appropriate analytical caution and

corroborated by independent evidence rather than taken as definitive proof of systemwide safety.

Graph 1 : LongTerm Trend in Fit and Unfit Water Samples, Nagpur, 2011–12 to 2024–25



Author's visualization based on Orange City Water annual water quality data. Blue = Fit %; Red = Unfit %.

6.3 Independent Microbiological Evidence

The most compelling independent evidence is provided by Bivins et al. (2021), who sampled household tap water in Nagpur as zones transitioned from intermittent to continuous service. The study found significantly higher culturable E. coli and pathogen gene target detection in intermittent supply zones, with the improvement in continuous zones robust to controls for household and neighborhood characteristics. This is the pivotal finding for the present paper's argument: it directly attributes reduced microbial risk to supply continuity within the same city, using the same population and infrastructure, thereby providing a quasiexperimental validation of the operator trend data.

The Bivins et al. finding accomplishes three analytical tasks simultaneously. First, it confirms the direction of the operator trend: the system is genuinely getting safer, not merely generating more favorable test results through selective sampling or relaxed standards. Second, it identifies the probable mechanism of improvement continuity itself, rather than treatment plant upgrades or general infrastructure investment consistent with the broader intermittent supply literature. Third, it positions Nagpur within the global scientific consensus on intermittent supply risk, providing the external validity necessary for the Nagpur case to yield generalizable lessons.

It is equally important to note what the Bivins et al. study does not show. It does not demonstrate that water quality in Nagpur has reached WHO guideline levels zero E. coli per 100 mL at the point of consumption across the entire city. The study design compared zones with and without continuous supply within Nagpur; zones that remain on intermittent supply continue to carry the contamination risks that the broader literature documents. The 36 dark zones reported by NMC in 2023–24 represent communities where the microbiological risk reduction documented by Bivins et al. has not yet occurred.

6.4 Municipal Service Indicators and Their Implications for Water Quality

The NMC Environment Status Reports for 2022–23 and 2023–24 provide the most recent official picture of Nagpur's service conditions. Billed volume increased from 377.454 MLD to 410 MLD, consistent with expanded metered connections and reduced unbilled water, though the increase also reflects overall consumption growth. Reported system losses declined from 47% to 41.91% over the same period a meaningful improvement, but still more than double the WHO recommended benchmark of under 20% for well managed distribution systems. The persistence of 41.91% losses implies that nearly half the water leaving treatment plants is not being billed, a proportion that includes genuine physical losses (leakage), commercial losses (unauthorized connections, meter error), and the inefficiency of the remaining intermittent zones.

Tanker dependence declined sharply and durably: from 346 tankers in 2016 to 193 in 2022–23 and 78 in 2023–24. This indicator is particularly significant as a quality proxy, because private water tanker supply in Indian cities is characterized by inconsistent and frequently unsafe water, stored in tanks of uncertain hygiene standards and delivered at prices that impose severe burdens on low income households. The substitution of metered piped supply for tanker supply therefore represents a direct population health gain, not only a service improvement. The reduction from 346 to 78 tankers over eight years is among the most concrete indicators of reform impact.Thedark zone data, however, complicate the positive picture. NMC reported 39 dark zones in 2022–23 and 36 in 2023–24 zones receiving fewer than two hours of supply per day. These zones remain on fully intermittent supply and therefore carry the full contamination risk profile documented by Bevin’s et al. (2021) and the wider literature. Citywide averages conceal this spatial inequity: a 98% fitsample rate at the aggregate level is consistent with nearsafe water in continuously supplied zones and

substantially unsafe water in intermittent zones, if the sampling is not representative of darkzone conditions.

Billed volume and reported loss share in Nagpur, 2022–23 and 2023–24. Reduction in tanker dependence reported by Nagpur Municipal Corporation

Analysisof the Nagpur Municipal Corporation (NMC) Environment Status Reports for the periods 2022–23 and 2023–24 reveals significant gaps in the implementation of national urban missions. Despite the city's strategic focus on water management, the reports indicate that AMRUT 1.0 and 2.0 (Atal Mission for Rejuvenation and Urban Transformation) were not executed within the specified timeframe. This lack of execution suggests a disconnect between high level policy frameworks and local level project delivery. Consequently, the city's environmental and water infrastructure remains reliant on existing frameworks such as the Orange City Water (OCW) joint venture without the anticipated systemic upgrades and financial influx promised by the AMRUT phases.

6.5 Overall Synthesis: Qualified Improvement

Taken together, the evidence supports a judgment of qualified improvement rather than either unqualified success or failure. The operator series documents a strong, sustained, and volumetrically robust decline in unfit samples over fourteen years. The Nagpur microbiological study independently confirms that continuous supply is substantially safer than intermittent supply within the same city. Municipal service indicators point toward lower dependence on emergency coping arrangements and toward gradual network rehabilitation. At the same time, high residual losses, persistent dark zones, and the absence of a comprehensive independent monitoring system show that reform remains uneven rather than fully consolidated. The reform trajectory also reveals an important temporal dimension that is often obscured in crosssectional comparisons. The most dramatic quality improvements occurred in the first five years of operations, as the most acute contamination hotspots were addressed. The subsequent period of slower improvement reflects the harder, more capital intensive work of extending continuous supply to areas with poor network condition, managing the political economy of tariff adjustment, and maintaining operational discipline in a complex urban environment. International comparisons Manila Water, Singapore PUB suggest that full consolidation of quality gains in large Asian cities typically requires sustained investment over 10–20 years, not a single reform moment.

Table 1: Key PeerReviewed Studies Informing Interpretation of Nagpur's Reform

Study	Location	Focus	Relevance to Nagpur
Bivins et al. (2021)	Nagpur, India	Continuous vs intermittent supply in Nagpur	Continuous supply areas had significantly lower E. coli and pathogen detection than intermittent areas
Hastak et al. (2017)	Nagpur, India	Service level benchmarks postreform	Documents measurable improvements in hours of supply, pressure, and coverage in Nagpur demo zone
Jensen & Chindarkar (2019)	Nagpur, India	Salience, trust, and reform sustainability	Links operational improvement to public trust; argues viability depends on reaching unserved areas

Note. Source: Compiled by the author from cited peer reviewed literature.

Table 2: Timeline of Nagpur Water Reform: Key Milestones and Water Quality Trajectory

Year	Key Development & Water Quality Milestone
2001	NMC identifies chronic water supply failure: intermittent delivery, aging pipes, 50%+ losses
2007	PPP model conceptualized; Government of India/World Bank engagement on urban reform
2011	Orange City Water (OCW) begins operations; baseline water quality testing initiated (21% unfit)
2012	POCSOaligned pilot zone launched in Dharampeth; first 24×7 zone operational
2013–14	Rapid improvement phase: unfit samples decline from 12% to 7%; network rehabilitation accelerated
2015–16	Unfit samples reach 4%; expansion of metered connections; AMRUT 1.0 pipeline works commence
2016–17	Stabilization at ~3% unfit; tanker dependence falls from 346 to ~200; dark zones persist
2021	Bivins et al. publish landmark study confirming microbial improvement in continuous supply zones

2022–23	Billed volume: 377 MLD; losses: 47%; 193 tankers; 39 dark zones; NMC ESR published
2023–24	Unfit rate: 2.3%; losses: 41.91%; tankers reduced to 78; AMRUT 2.0 (256 km) laid
2024–25	Unfit rate reaches 1.8% (full year); partial year data to Feb 2026 shows 0.4% — lowest on record

Note. Source: Compiled by the author from NMC Environment Status Reports, Orange City Water annual reports, and peer reviewed literature.

7. Comparative Analysis: Nagpur in Global and Indian Context

A comparative lens sharpens the interpretation of Nagpur's trajectory. Within India, the contrast with Delhi and Mumbai is instructive. Delhi Jal Board, operating as a public utility, reported nonrevenue water of approximately 40% in 2022 and continued to serve much of the city intermittently, with documented contamination events in East Delhi (2023). Mumbai's Brihanmumbai Municipal Corporation provides 24hour supply to approximately 60% of its network, but the remaining 40% largely comprising informal settlements and periurbanareas receives intermittent supply with associated quality risks. Neither city has a comparable public longrun quality series to Nagpur's.

Internationally, the Philippines Manila Water concession (1997–2019) represents the most frequently cited comparator for an Asian urban water PPP. Manila Water achieved universal 24×7 supply in its eastzone concession area by 2007 and reduced nonrevenue water from 63% to under 11%, with documented water quality improvements throughout the period. The contrast with Nagpur is partly structural: Manila Water operated under a more complete concession (including asset investment obligations) and a more robust independent regulator (Manila Waterworks and Sewerage System), whereas Nagpur's operator faces weaker regulatory accountability and retains assets in NMC hands, creating split incentives for capital investment in network renewal.Singapore's Public Utilities Board (PUB) represents the international benchmark for continuous supply quality management: nonrevenue water below 5%, 24×7 universal supply, and compliance with WHO guideline values at the tap as a matter of routine. The Singapore model demonstrates that the technical achievement of safe continuous supply is feasible at urban scale, but it required several decades of sustained investment, a strong regulatory state, full costrecovery tariffs, and a degree of political insulation from waterpricing populism that is unlikely to be replicable in Nagpur's context.The European context provides additional benchmark data. Under the EU Drinking Water Directive (2020), member states are required to publish annual compliance reports with mandatory disaggregation by zone and supply system. UK water companies reported less than 0.03% of sample failures against drinking water standards in 2022 (Drinking Water Inspectorate). The contrast with Nagpur's 1.8% unfit rate (itself a major improvement from 21%) illustrates both how far Nagpur has come and how far it remains from universal safe water at the point of consumption.

Table 3: Comparative Assessment: Nagpur Pre and Post Reform versus International Benchmarks

Dimension	PreReform Era (Pre2012)	PostReform Era (2012–Present)	International Comparable
Ownership model	Municipal public utility (NMC)	PPP with delegated operations (OCW); municipal asset ownership retained	Manila Water (Philippines): full privatization; Delhi: DJB public utility
Water supply continuity	Intermittent, typically 2–4 hrs/day	Progressive rollout of 24×7 supply; ~36 zones transitioned	Singapore PUB: 24×7 universal; Mumbai: ~3–5 hrs/day (2023)
System losses (NRW)	>50% estimated losses	41.91% (2023–24); improving but still high	WHO target: <20%; Delhi DJB: ~40% (2022); Singapore: <5%
Unfit water samples	No systematic public tracking pre2011	21% unfit (2011–12) → 1.8% (2024–25)	UK water companies: <0.03% failures (DWI 2022)

Microbial contamination risk	High under intermittent supply; E. coli common in distribution	Lower in continuous zones; Bivins et al. (2021) confirm significant reduction	WHO guideline: zero E. coli per 100 mL; achievable only under pressurized continuous supply
Tanker dependence	~346 tankers/year (2016)	193 (2023); 78 (2024)	Tanker elimination is a key SDG 6 target indicator
Dark zones (< 2 hrs/day)	Citywide underservice prereform	39 (2022–23); 36 (2023–24)	Persistent inequity; lagging areas often low income
Monitoring & transparency	Ad hoc; no annual public quality series	Annual quality reports published; zone level monitoring improving	EU Drinking Water Directive (2020): mandatory public consumer reports

Note. Source: Compiled by the author. NMC = Nagpur Municipal Corporation; OCW = Orange City Water; NRW = Nonrevenue Water; DJB = Delhi Jal Board.

8. Discussion

8.1 Continuity as a Water Quality Intervention

Nagpur's case provides a correction to the prevailing binaries in water reform debates. The evidence does not demonstrate that private participation is invariably beneficial. Nor does it demonstrate that private participation is irrelevant. Rather, it implies that institutional form matters primarily through the service conditions it generates specifically, whether it produces operational improvements in continuity, pressure management, leakage control, and monitoring that are the proximate determinants of distributionlevel water safety.

The most powerful message from the evidence is that continuity itself is a waterquality intervention. Safe water cannot be certified at the treatment facility; it is determined by what happens in the delivery system, particularly in systems historically characterized by low pressure, leakage, and intermittent flow. The Bivins et al. (2021) finding that E. coli detection was significantly lower in continuous supply zones than in intermittent zones within the same city provides perhaps the clearest empirical statement of this principle in the Indian context. It implies that the single most cost effectivepublic health intervention available to Indian municipal water utilities is the extension of continuous, pressurized supply not higher specification treatment technology, not advanced purification, but reliable daily delivery of water through maintained pipes.

8.2 Spatial Inequity and the Limits of Aggregate Improvement

A second discussion theme concerns the relationship between citywide improvement and spatial equity. Nagpur's aggregate quality data mask substantial internal variation. The 36 dark zones reported in 2023–24 areas receiving fewer than two hours of supply per day contain communities for whom the reform's benefits remain largely theoretical. The intermittent supply contamination risks documented by Bivins et al. and the wider literature are concentrated precisely in these zones. Any evaluation that relies solely on citywide averages will systematically overstate the reform's benefit to the most vulnerable populations.bThis point has direct implications for accountability and transparency. Chindarkar & Krishnamurthy (2021) document that water utility consumer confidence reports in India have poor accessibility and limited disaggregation, making it difficult for communities, civil society, or journalists to hold utilities accountable for zone specific quality failures. A PPP that improves conditions in well served central zones while leaving per urban and informal settlement zones on intermittent supply has not fulfilled the social contract implicit in a public essential service concession.

8.3 Interpreting the Operator Data: Credibility and Limits

The operator quality series fourteen years of annual data showing a consistent decline in unfit samples is a significant evidentiary resource. It is one of the few longrun utility quality datasets in the public domain for an Indian city. However, its credibility is conditional on the reliability of sampling and testing protocols, the representativeness of sampling locations, and the independence of analysis from the operator's commercial interests. The absence of an independent, publicly accessible microbiological surveillance programme for Nagpur means that the operator series cannot be independently verified on a routine basis.

The Bivins et al. (2021) study partially addresses this gap for the period of that study, and the directional consistency between the operator trend and the independent microbiological evidence provides reasonable grounds for treating the trend as genuine. But the broader point stands: in the absence of routine third party quality verification and public reporting disaggregated by zone, the strength of evidence for Nagpur's water quality remains dependent on a single operator controlled data stream, with all the credibility limitations that entails.

8.4 System Losses and Infrastructure Vulnerability

The persistence of 41.91% system losses in 2023–24 warrants specific discussion as a water quality risk, not only an economic inefficiency. Nonrevenue water at this level implies that a substantial fraction of the distribution network operates at suboptimal pressure for substantial periods. Pressure deficits create the conditions for pipe intrusion and backsiphonage that the intermittent supply literature identifies as the primary contamination pathways. Even in zones classified as receiving continuous supply, pressure transients associated with high leakage can momentarily generate the intrusion risks that the Bivins et al. study associates with intermittent supply.

The goal of reducing nonrevenue water to below 20% the WHO benchmark thus has direct public health significance beyond its economic rationale. AMRUT 2.0 pipeline works (256 km laid by 2023–24) are a positive indicator, but at the current rate of investment, achieving WHOlevel loss rates across the full Nagpur network would require sustained capital commitment over many additional years.

9. Policy Implications

Nagpur's reform experience yields several policy lessons that are transferable to other Indian cities and to the design of future urban water PPPs in comparable contexts.

First, reform should be evaluated in health relevant terms. Municipal and operator performance reporting in India typically emphasizes input metrics km of pipeline laid, treatment capacity installed, and number of connections rather than output metrics directly linked to public health: E. coli compliance at the tap, zone wise chlorine residual, hours of continuous supply per zone per day. Performance claims would be more credible, and more useful for policy learning, if routine public release of zone based microbial and chlorine data were backed by third party audits. The EU Drinking Water Directive (2020) provides a directly applicable international model: mandatory public consumer confidence reports with geographic disaggregation, accessible online, updated annually.

Second, the abandonment of intermittent supply should be regarded not only as an engineering objective but as an urgent public health priority. Indian cities account for a substantial share of the global intermittent supply burden, and the evidence from Nagpur, Hubli-Dharwar, and Panama is unambiguous that transition to continuous supply is the single most impactful distribution level intervention for reducing microbial contamination risk. AMRUT 1.0 and AMRUT 2.0 have funded pipeline expansion; the next generation of urban infrastructure programmes should make time boundphase out of intermittent supply a mandatory condition of funding.

Third, dark zones must be emphasized rather than masked by citywide averages. A PPP in an essential service can be legitimized only by demonstrating quality gains to the lagging and risk prone sections of the network. Performance linked payments and contract penalties should be calibrated specifically to dark zone coverage metrics, creating direct financial incentives for the operator to extend continuous supply to the most underserved communities.

Fourth, independent regulatory capacity must be strengthened. Nagpur currently operates without an independent water quality regulator: NMC simultaneously owns the assets, holds the concession contract, and is responsible for monitoring compliance. This conflict of interest is a structural weakness that no amount of operator goodwill can fully compensate. An independent state level or city level water regulator analogous to the Philippines' regulatory model for Manila Water would provide the accountability architecture necessary for long term reform sustainability.

Fifth, the Nagpur case offers a model for other Tier1 and Tier2 Indian cities considering PPP arrangements for water supply: the O&M concession structure, with retained public asset ownership, appears to produce measurable operational improvements without the social and political risks of full privatization, provided that contract design, regulatory oversight, and investment commitments are adequate.

Table 4. Policy Recommendations for Nagpur Water Reform Consolidation

Policy Domain	Current Gap in Nagpur	Recommended Action
Water Quality Monitoring	Operator reported data lacks third party verification; zone level data not	Mandate quarterly independent sampling in all zones; publish zone wise chlorine

	publicly disaggregated	residual and E. coli results publicly
Equity & Dark Zones	36–39 dark zones persist; low income periurban neighborhoods disproportionately affected	Priorities pipeline extension and pressure zoning in dark zones; tie PPP performance payments to coverage equity metrics
Nonrevenue Water	41.91% NRW in 2023–24, well above WHO target of <20%	Accelerate district metered area (DMA) rollout; invest in pressure management and active leak detection
24x7 Transition	~36 zones with full continuous supply out of 220 zones	Develop time boundphase out plan for intermittent supply; fund AMRUT 2.0 pipeline completion with quality benchmarks
Accountability & Reporting	Consumer confidence reports not consistently published or disaggregated	Align with EU Drinking Water Directive 2020 standards; mandate annual plain language consumer reports
Regulatory Oversight	No independent regulator for Nagpur water quality; NMC acts as regulator and contract manager	Establish independent state level water regulator with enforcement powers over operator KPIs

Note. Source: Author's synthesis based on Nagpur Municipal Corporation data, Orange City Water reports, and comparative literature.

10. Limitations

This paper is subject to several methodological limitations that should be acknowledged explicitly. First, the primary long run quality series is operator generated rather than regulator generated or independently verified. While the directional consistency with the Bivins et al. (2021) study provides reasonable grounds for treating the trend as credible, the absence of a parallel independent data stream limits the strength of inference that can be drawn.

Second, the most recent municipal indicators billed volume, loss share, tanker numbers, dark zones are available only for 2022–23 and 2023–24, limiting the ability to trace service quality trends over the full reform period. Earlier years of the operator quality series are not matched by corresponding municipal service data at comparable detail.

Third, the Bivins et al. (2021) study, while of high methodological quality, was conducted over a specific period in a subset of Nagpur's zones. It is not a comprehensive citywide surveillance system, and its findings may not be fully representative of quality conditions across all 220 water zones.

Fourth, this paper does not attempt an economic evaluation of the reform: cost per unit of quality improvement, distributional incidence of gains and losses, or return on investment in infrastructure rehabilitation. Such an analysis would require data on tariff revenues, operator costs, and household water expenditure that are not available in the public domain.

Fifth, and most fundamentally, the paper is a synthesis based on evidence rather than a causal estimate. The methods employed descriptive trend analysis, triangulation across data sources, and qualitative synthesis support inference about direction and magnitude of change, and about probable mechanisms, but not the attribution of specific quality outcomes to specific reform interventions with the rigour of a quasi experimental design.

11. Conclusion

This paper concludes that Nagpur is more accurately characterized as an operations concession under a municipally owned PPP than as privatization in the classical sense, and that the evidence taken as a whole points to a significant and sustained improvement in municipal water quality over the reform period. The combination of a long run decline in operator reported unfit samples from 21.0% (2011–12) to 1.8% (2024–25), and the independent microbiological evidence of Bivins et al. (2021) confirming that continuous supply zones have significantly lower E. coli contamination than intermittent supply zones, constitutes the strongest available support for this conclusion.

The improvement is substantial but not complete. Residual system losses of nearly 42%, persistent dark zones in 36 areas, and an absence of routine independent quality verification mean that the reform cannot yet be characterized as a consolidation of universal safe water access. The spatial pattern of gains concentrated in better served, centrally located zones; less evident in peri urban and low-income areas raises questions of equity that citywide averages systematically obscure.

The broader lesson for urban water policy is that the legitimacy of public private partnerships in essential services is not established by institutional form but by demonstrated outcomes: continuity, network integrity, microbial safety, and improvement in the neighborhoods where intermittent supply has traditionally posed the greatest risk. Nagpur offers encouraging evidence that an O&M concession can produce meaningful quality improvements over time; it also offers a cautionary illustration of how much further consolidated reform must go before the most vulnerable communities achieve the reliable safe water that is their legal right under India's constitution and their entitlement under Sustainable Development Goal 6.

Future research: Future research should priorities three directions: independent, routine microbiological surveillance across all Nagpur zones to replace operator self reporting as the primary quality evidence base; a detailed equity analysis of quality outcomes across income and spatial dimensions; and systematic comparative analysis with Indian cities that have pursued alternative reform models, including remunicipalisation and communitybased management, to identify the conditions under which each model generates the most durable health and equity outcomes.

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