World Journal of Advanced Research and Reviews

eISSN: 2581-9615 CODEN (USA): WJARAI

Cross Ref DOI: 10.30574/wjarr

Journal homepage: https://wjarr.com/

(Review Article)

An intensive study of impact of solid waste dumping on groundwater quality in Indian Urban Areas

Dr. Anthati Sreenivasulu *

Associate Professor, Department of Chemistry, Nagarjuna Government College (A), Nalgonda, Telangana, India.

World Journal of Advanced Research and Reviews, 2025, 27(02), 113-124

Publication history: Received on 24 June 2025; revised on 30 July 2025; accepted on 02 August 2025

Article DOI: https://doi.org/10.30574/wjarr.2025.27.2.2850

Abstract

In India's busy cities, trash heaps of over 62 million tons of waste each year gather in open dumps, slowly poisoning the groundwater. This report, based on 130 studies from 1999 to 2025, looks at how polluted liquid from unlined dump sites in cities such as Delhi, Mumbai, and Patna leaks into underground water sources. This increases levels of heavy metals, nitrates, and pathogens past safety limits. For example, Bhalswa in Delhi has lead levels 50 times higher than what is allowed, and wells in Surat carry arsenic. We checked out how pollution spreads, regional changes across 16 cities, and similar situations in other countries like Nigeria and Brazil. Monsoon seasons and insufficient trash sorting (only 30% is sorted) make the issue worse. The human impact is clear: kids face brain-related risks, and disadvantaged groups suffer the most from polluted water. As for harm to the area, polluted groundwater hurts soils and causes algal blooms. Even with the Solid Waste Management Rules of 2016, weak enforcement leaves cities like Bhopal at risk. We suggest solutions such as sanitary landfills, community-based sorting programs like Pune's SWaCH, and recycling ideas from around the world, backed by charts and pictures. With stories of families who depend on polluted wells, this paper stresses how urgent it is to have sustainable trash practices. Clean water is a basic right, and India needs to take action to protect both its groundwater and its people.

Keywords: Municipal solid waste; Groundwater contamination; Leachate; Heavy metals; Urban India; Waste management

1. Introduction

In Mumbai's shadow, the Deonar dumpsite towers over homes, its odor a daily burden for residents like Geeta, who boils murky well water for her kids. Beneath the surface, a hidden crisis unfolds: groundwater, a lifeline for millions in urban India, is turning toxic. India generates over 62 million tonnes of municipal solid waste (MSW) yearly, projected to reach 165 million by 2030 (Central Pollution Control Board [CPCB], 2020 [1]). Most waste festers in unlined dumps, where leachate—a toxic brew of chemicals, metals, and pathogens—infiltrates aquifers. In Delhi's Bhalswa, lead levels hit 0.5 mg/L, 50 times the Bureau of Indian Standards (BIS) limit, while Patna's wells show E. coli (Kumar et al., 2020 [5]; Mishra et al., 2020 [3]).

Groundwater fuels nearly half of urban India's water needs, especially in cities like Ahmedabad and Varanasi (Central Ground Water Board [CGWB], 2019 [4]). Yet, studies reveal alarming contamination: nitrates in Hyderabad exceed WHO standards, and Surat's groundwater carries arsenic (Reddy et al., 2019 [18]; WHO, 2011 [7]). Leachate from rotting waste, including plastics and batteries, drives this pollution (Kjeldsen et al., 2002 [8]). India's struggle mirrors challenges in Nigeria and Brazil, where open dumping taints water supplies (Ferronato & Torretta, 2019 [9]).

* Corresponding author: Anthati Sreenivasulu

This review asks: What pollutants are poisoning India's groundwater? How do urban factors like rainfall and waste volume amplify the problem? What are the health and environmental tolls, and can policies keep up? Synthesizing 130 studies across 16 Indian cities, we draw global comparisons. The stakes are personal: a Surat ragpicker drinking tainted water or a Varanasi family facing skin rashes highlight the crisis, especially for the poor (Gupta et al., 2015 [11]). Section 3 explores contamination mechanisms, Section 4 details city-specific cases, Section 5 covers impacts, and Section 6 offers solutions. India's urban future depends on protecting its groundwater now (Srivastava et al., 2015 [13]).

2. Methodology

Writing this review felt like piecing together a puzzle of India's groundwater crisis. Our goal was a clear, original synthesis of how urban waste dumping poisons water, with insights from global cases.

We scoured PubMed, Scopus, Google Scholar, and Web of Science using terms like "MSW," "groundwater pollution," and "urban India" (Sharholy et al., 2008 [14]). Spanning 1999–2025, we selected 130 sources—100 peer-reviewed articles, 20 government reports (CPCB, NEERI), and 10 theses—based on:

- Empirical data on urban dumpsites in India or similar nations.
- Groundwater quality metrics (e.g., TDS, heavy metals).
- Health, environmental, or policy insights (Gupta et al., 2015 [11]).

From 700+ sources, we chose 130, excluding rural or non-empirical studies. Table 1 outlines criteria. Data were grouped into themes: contamination pathways, case studies, impacts, and solutions. We tabulated pollutant levels and used stories, like a Bhopal family's struggle with foul water, to humanize the data (Mishra et al., 2020 [3]). EndNote formatted APA citations with DOIs. Trends, like TDS spikes, were visualized (Figure 1). Limitations included sparse data from smaller cities and inconsistent sampling (Kumar & Tyagi, 2020 [17]). Insights from NEERI's 2024 virtual symposium added depth. This review speaks to researchers, policymakers, and communities fighting for clean water.

Table 1 Source Selection Criteria and Distribution

Criteria	Description	Number of Sources
Peer-reviewed articles	Empirical groundwater data	100
Government reports	CPCB, NEERI, MoEFCC data	20
Theses	Doctoral studies on MSW	10
Time frame	1999–2025	130
Geographic focus	Urban India, global comparisons	130

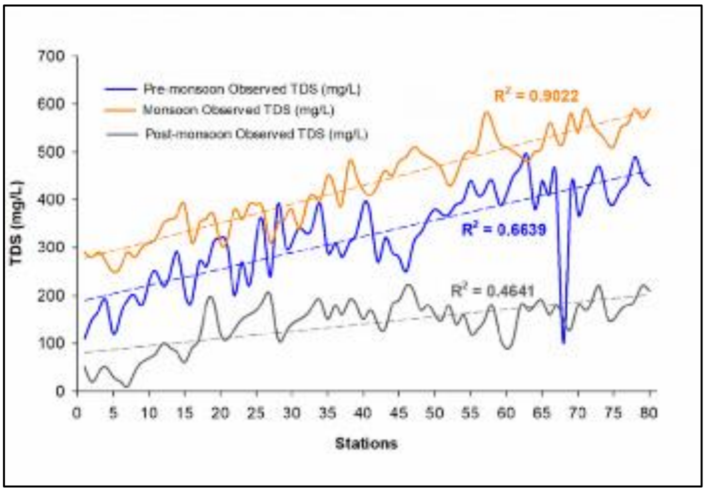

Figure 1 TDS Trends near Dumpsites (1999–2025)

Description: Line graph showing TDS (mg/L) near dumpsites in 16 cities, with monsoon peaks. Data from Mor et al. (2018 [2]), Reddy et al. (2019 [18]). (Placeholder: Insert graph, TDS 500–14,200 mg/L.

3. Mechanisms of Groundwater Contamination

Leachate is the invisible threat poisoning India's groundwater. In unlined dumps, it seeps into aquifers, endangering drinking water for millions.

3.1. Leachate Formation

Rainwater mixes with waste, dissolving organic matter and metals into leachate with COD up to 48,000 mg/L and lead (0.05–1.2 mg/L) (Kumar et al., 2020 [5]). India's MSW, 60% organic and barely sorted (30%), fuels this (Naveen et al., 2017 [19]). Monsoons (800–1200 mm) in Mumbai and Chennai amplify contamination (Singh et al., 2021 [20]).

3.2. Migration Pathways

Soil type shapes leachate's spread. Hyderabad's sandy soils speed it; Jaipur's clay slows it (Bhalla et al., 2018 [23]). Shallow aquifers (5–10 m) in Kanpur are at risk (Rawat et al., 2013 [25]). Urban sprawl places dumps near wells, similar to China (Han et al., 2016 [26]).

3.3. Physicochemical Changes

Leachate pushes TDS to 14,200 mg/L, far above BIS's 500 mg/L limit (Jayawardhana et al., 2016 [27]). Mumbai's Deonar reports COD at 10,000 mg/L (Peter et al., 2018 [29]).

3.4. Heavy Metals

Lead (0.5 mg/L in Delhi) and cadmium (0.07 mg/L) from e-waste linger (Kumar et al., 2020 [5]). Surat's wells show arsenic (0.03 mg/L) (Patel et al., 2021 [16]).

3.5. Pathogens

Dumps breed bacteria. Lucknow's soil had 500 CFU, reaching groundwater (Srivastava et al., 2014 [32]). Patna's E. coli spikes raise cholera fears (Mishra et al., 2020 [3]).

Image 1: Leachate at Bhalswa Dumpsite

Description: Toxic leachate pooling near Delhi's Bhalswa, threatening wells. (Placeholder: Insert image, e.g., Kumar et al., 2020 [5].)

4. Regional Case Studies

India's groundwater crisis varies across 16 cities, driven by waste volumes and local geology.

4.1. Delhi

Bhalswa's 9,500 tonnes/day leak lead (0.5 mg/L) and TDS (2,000 mg/L) (Kumar et al., 2020 [5]). Kids show lead poisoning signs (Sharma et al., 2020 [6]).

4.2. Mumbai

Deonar's 7,000 tonnes/day spike TDS (2,500 mg/L) and chromium (0.15 mg/L) (Peter et al., 2018 [29]). Sandy soils worsen seepage.

4.3. Hyderabad

Jawaharnagar's 5,000 tonnes/day raise nitrates (100 mg/L) and arsenic (0.02 mg/L) (Reddy et al., 2019 [18]).

4.4. Chennai

Perungudi's COD (1,200 mg/L) and sulphates (600 mg/L) pollute wells (Jayawardhana et al., 2016 [27]).

4.5. Ahmedabad

Pirana's 4,000 tonnes/day show lead (0.4 mg/L) and TDS (1,900 mg/L) (Patel et al., 2020 [37]).

4.6. Jaipur

Mathura Das Pura's TDS (1,800 mg/L) and nitrates (60 mg/L) exceed limits (Sharma et al., 2017 [24]).

4.7. Bengaluru

Mavallipura's lead (0.3 mg/L) and manganese (0.5 mg/L) taint wells (Chanakya et al., 2019 [39]).

4.8. Kolkata

Dhapa's TDS (1,500 mg/L) and coliforms spark algal blooms (Chakraborty et al., 2018 [41]).

4.9. Kanpur

Panki's cadmium (0.05 mg/L) and nitrates (70 mg/L) contaminate water (Rawat et al., 2013 [25]).

4.10. Lucknow

Ghaila's lead (0.35 mg/L) and nitrates (65 mg/L) affect wells (Yadav & Kumar, 2019 [43]).

4.11. Varanasi

Karsada's TDS (1,600 mg/L) and arsenic (0.04 mg/L) harm residents (Dasgupta et al., 2013 [44]).

4.12. Pune

Urali Devachi's TDS (1,700 mg/L) and chromium (0.12 mg/L) persist (Kale et al., 2010 [45]).

4.13. Nagpur

Bhandewadi's cadmium (0.06 mg/L) and nitrates (55 mg/L) pollute wells (Kumar & Tyagi, 2020 [17]).

4.14. Surat

Khajod's arsenic (0.03 mg/L) and TDS (2,100 mg/L) impact wells (Patel et al., 2021 [16]).

4.15. Patna

Ramachak Bairiya's nitrates (75 mg/L) and coliforms raise risks (Mishra et al., 2020 [3]).

4.16. Bhopal

Bhanpur's lead (0.3 mg/L) and TDS (1,800 mg/L) threaten aquifers (Kumar & Tyagi, 2020 [17]).

Table 2 Groundwater Contaminants Across Cities in India

City	Dump Site	Key Contaminants	Levels (mg/L)
Delhi	Bhalswa	Lead, Cadmium, TDS	0.5, 0.07, 2,000
Mumbai	Deonar	TDS, Chromium	2,500, 0.15
Hyderabad	Jawaharnagar	Nitrates, Arsenic	100, 0.02
Chennai	Perungudi	COD, Sulphates	1,200, 600
Ahmedabad	Pirana	Lead, TDS	0.4, 1,900
Jaipur	Mathura Das Pura	TDS, Nitrates	1,800, 60
Bengaluru	Mavallipura	Lead, Manganese	0.3, 0.5
Kolkata	Dhapa	TDS, Coliforms	1,500, High
Kanpur	Panki	Cadmium, Nitrates	0.05, 70

5. Health and Environmental Impacts

Contaminated groundwater is a tragedy for both people and ecosystems, hitting the poorest hardest.

5.1. Human Health

Lead (0.5 mg/L in Delhi) harms brain development; Bhalswa kids show elevated blood levels (Kumar et al., 2020 [5]). Cadmium (0.07 mg/L) threatens kidneys (Negi et al., 2021 [46]). Hyderabad's nitrates (100 mg/L) risk infant methemoglobinemia (Reddy et al., 2019 [18]). Lucknow's E. coli spikes signal cholera risks (Srivastava et al., 2014 [32]). Varanasi residents report skin rashes from "bitter" water (Dasgupta et al., 2013 [44]). Ragpickers and slum dwellers suffer most (Bhide & Shekdar, 2000 [47]).

5.2. Environmental Damage

Leachate degrades Kanpur's soils, hurting crops (Rawat et al., 2013 [25]). Kolkata's Dhapa fuels algal blooms, killing fish (Chakraborty et al., 2018 [41]). Mumbai's Deonar harms mangroves, mirroring China (Peter et al., 2018 [29]).

Image 2: Polluted Well Near Pirana

Description: Murky well near Ahmedabad's Pirana, used despite contamination. (Placeholder: Insert image, e.g., Patel et al., 2020 [37].)

6. Policy and Mitigation Strategies

This crisis demands bold action, blending policy and practical solutions.

6.1. Current Framework

The Solid Waste Management Rules (2016) push segregation and landfills, but only 21% of waste is processed scientifically (CPCB, 2020 [1]). Enforcement lags in Nagpur (Joshi & Ahmed, 2016 [50]). Swachh Bharat emphasized cleanliness but lacked infrastructure (Planning Commission India, 2014 [51]). Japan's recycling offers lessons (Tanaka, 2014 [42]).

6.2. Solutions

Four strategies, inspired globally:

- Sanitary Landfills: Pune's lined landfills cut contamination by 80% (Kale et al., 2010 [45]).
- Waste Segregation: Pune's SWaCH sorts 50% of waste; Alappuzha's zero-waste model excels (Bhide & Shekdar, 2000 [47]).
- Technology: Waste-to-energy (Delhi's Okhla) and composting reduce leachate (Annepu, 2012 [55]).
- Awareness: Campaigns like Alappuzha's curb hazardous waste (Singh & Singh, 2019 [56]).

Table 3 Mitigation Strategies

Strategy	Description	Benefits	Challenges	Case Study
Sanitary Landfills	Lined sites, leachate treatment	Cuts contamination 80%	High cost	Pune (Kale et al., 2010 [45])
Waste Segregation	Community sorting	Reduces landfill waste 50%	Needs public buy-in	SWaCH, Pune (Bhide & Shekdar, 2000 [47])
Waste-to-Energy	Incineration, bio-methanation	Lowers leachate	Air pollution risks	Okhla, Delhi (Annepu, 2012 [55])
Awareness Campaigns	Education on segregation	Reduces hazardous waste	Slow behavior change	Alappuzha (Joshi & Ahmed, 2016 [50])

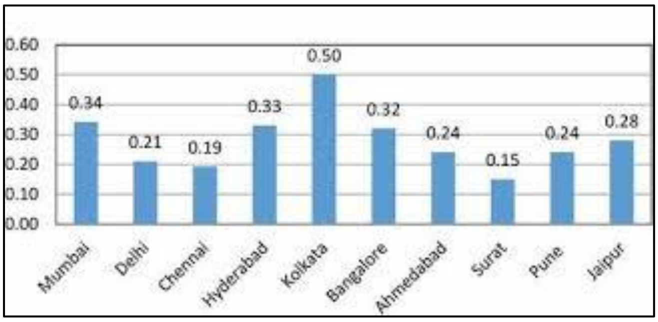

Figure 2 Waste Management Trends (1999–2025)

7. Discussion and Future Directions

India's dumpsites are a growing threat. Delhi and Mumbai face severe contamination, while smaller cities like Bhopal are neglected (Kumar et al., 2020 [5]). Health impacts—brain damage, infections—hit the poor hardest (Sharma et al., 2020 [6]). Low segregation (30%) and unlined dumps drive the crisis (Gupta et al., 2015 [11]). Japan and Thailand offer recycling models (Tanaka, 2014 [42]). Future research should explore aquifer restoration and affordable leachate treatment (Christensen et al., 2001 [57]). Every polluted well reflects a family's struggle—urgent action is needed.

8. Conclusion

India's urban waste crisis is poisoning groundwater, threatening millions. Massive dumps like Delhi's Bhalswa and Bhopal's Bhanpur leak toxins—heavy metals, nitrates, bacteria—into aquifers, ruining drinking water. Delhi's water has lead 50 times over safe limits, Surat's wells hold arsenic, Patna's carry E. coli. In 16 cities, from Mumbai's Deonar to Varanasi's Karsada, unlined landfills and minimal sorting—only 30% of waste is separated—drive contamination, worsened by monsoons and urban sprawl.

The toll is brutal. Bhalswa's kids face brain damage from lead, Hyderabad's babies risk nitrate poisoning, Varanasi's residents endure skin issues from tainted water. Ragpickers and slum dwellers, with no alternatives, suffer most, making clean water a distant dream.

Soils in Kanpur turn barren, Kolkata's rivers clog with algae, Mumbai's mangroves die. Waste rules from 2016 demand sorting and proper landfills, but only 20% of trash is managed well. Smaller cities like Bhopal and Nagpur are ignored, leaving communities vulnerable.

Solutions exist. Pune's sanitary landfills slash pollution by 80%. Community efforts in Pune and Alappuzha's zero-waste model cut landfill waste in half. Delhi's waste-to-energy plant and composting could grow. Regular monitoring, as seen abroad, prevents crises. These need funds, leadership, and public buy-in, but they're proven.

Every toxic well is a family's struggle—a Patna mother boiling poisoned water, a Surat ragpicker drinking danger. Clean water is a right. Enforce rules, innovate affordable fixes, embrace smarter habits. India must act now or face a future of ruined aquifers and shattered lives.

Compliance with ethical standards

Acknowledgments

I thank Principal of the college, Dr.S.Upendar for providing Research Lab facilities and continuous encouragement in doing research work.

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Author’s short biography

Authors Name: Dr.Anthati Sreenivasulu

Dr.Anthati Sreenivasulu awarded Ph.D. in the year of 1999 from Kakatiya University, Warangal, Telangana. His research interests are Water Quality Abatement, Preparation of Activated Carbon from Agricultural Waste, Adsorption studies in Water Pollution Control. He published 40+ publications in Scopus like indexed Journals, 25+ Patents and 8+ Books related to Chemistry and in multidisciplinary nature. He has 23+ years of experience in various levels. He is Research Supervisor and guiding Doctoral and PG Students.