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GROUNDWATER CRISISI IN HIMACHAL'S INDUSTRIAL HEARTLAND: A STUDY OF HEAVY METAL POLLUTIONIN BADDI-BAROTIWALA REGION

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Abstract

Groundwater, a lifeline for rural and urban India, is facing a silent crisis in the Baddi–Barotiwala–Nalagarh (BBN) industrial region of Himachal Pradesh. Once celebrated for its pristine natural resources, the area has witnessed rapid industrialization that has outpaced environmental safeguards. This study examines how unregulated effluent discharge, poor waste treatment, and weak institutional monitoring have led to heavy metal contamination of groundwater. The findings highlight the severe health risks posed by toxic elements such as lead, cadmium, chromium, and nickel, which are slowly accumulating in local communities dependent on groundwater for daily use. Beyond health impacts, the paper explores the governance deficits, institutional fragmentation, and limited community participation that have exacerbated the crisis. It argues that the BBN case is not just an environmental concern but also a question of social justice, as those least benefiting from industrial growth carry the heaviest burdens. The study underscores the urgent need for stricter regulatory enforcement, adoption of the "polluter pays" principle, community-based monitoring, and sustainable industrial planning. By situating Baddi–Barotiwala's water crisis within broader debates on development, environment, and equity, the paper calls for a transformative approach that balances industrial growth with ecological and human well-being.

Key words: *Groundwater pollution; Heavy metals; Industrialization; Baddi–Barotiwala–Nalagarh (BBN); Environmental governance; Public health; Social justice; Himachal Pradesh; Sustainability; Water management*

I

Introduction

Groundwater has long served as the backbone of India's water supply system, supporting agriculture, industry, and domestic consumption across both rural and urban areas. An estimated 85% of rural

drinking water and nearly 60% of agricultural irrigation in India relies on groundwater.[1] Despite its significance, this vital resource is under severe stress. Excessive withdrawal, combined with inadequate recharge and pollution from industrial, agricultural, and domestic sources, has led to widespread depletion and quality degradation of aquifers.

In Himachal Pradesh, a state often celebrated for its clean rivers and forest cover, the situation is no less alarming. While the hilly terrain and natural recharge mechanisms initially buffered the state from the groundwater crisis, recent trends indicate rising contamination levels, particularly in rapidly industrializing districts. [2] Areas experiencing urban sprawl and unregulated industrial growth are increasingly reporting chemical pollutants in groundwater, raising concerns for public health and environmental sustainability.

Overview of Baddi–Barotiwala industrial area

The Baddi–Barotiwala–Nalagarh (BBN) industrial belt in Solan district exemplifies this environmental shift. Once a relatively quiet rural area, BBN has transformed over the past two decades into one of North India's largest industrial corridors, housing hundreds of pharmaceutical, textile, plastic, and food processing units.This growth has created jobs and boosted the local economy, but it has also brought environmental challenges that were not anticipated in early planning stages.

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[1]Ministry of Jal Shakti, Govt. of India, *Ground Water Year Book – India 2022–23*, Central Ground Water Board (2023), https://cgwb.gov.in/.

[2]Central Pollution Control Board, *Status of Groundwater Quality in Industrial Clusters of Himachal Pradesh*, ENVIS Report (2021).

Numerous reports suggest that the expansion of industries in BBN has outpaced the development of environmental safeguards. [3] The BBN also figures in the list of 102 cities enlisted by the Central Pollution Control Board, which have failed to adhere to the National Ambient Air Quality Standards of the Air Prevention of Pollution Control Act. [4]Improper disposal of industrial effluents, inadequate waste treatment facilities, and limited regulatory enforcement have resulted in pollutants—including heavy metals—percolating into groundwater sources. For the residents of nearby villages who depend primarily on groundwater for drinking and domestic purposes, this has translated into potential long-term exposure to toxic substances.

Central Pollution Control Board (CPCB) in collaboration with Indian Institute of Technology (IIT), Delhi and other institutes formulated the concept for Comprehensive Environmental Pollution Index (CEPI) and has analysed the Environmental status of industrial clusters which were identified in consultation with the Ministry of Environment and Forests for CEPI analysis.Baddi is one of the severely polluted industrial clusters identified by CPCB and its CEPI Score is 69.07. This critically polluted industrial cluster needs further detailed study in terms of the extent of damage and formulation of appropriate remedial action plan.[5]

[3] Himachal Pradesh State Pollution Control Board (HPSPCB), ANNUAL REPORT ON INDUSTRIAL EFFLUENTS, Pollution Monitoring Division (2023).
[4]D.P. Gupta, *As Many as 195 Business Units Operating Without Pollution Consent: RTI Information*, Himachal Guardian, Mar. 31, 2025, https://himachalguardian.com/2025/03/as-many-as-195-business-units-operating-without-pollution-consent-rti-information/.
[5] Central Pollution Control Bd., Comprehensive Environmental Pollution Index (CEPI) Action Plan for Baddi, Himachal Pradesh,https://cpcb.nic.in/industrial_pollution/New_Action_Plans/(last visited June 11, 2025).

	A1	A2	A	B1	B2	B3	B	C1	C2	C3	C	D	Total
Air	6.00	5.00	30.00	7.00	0.00	0.00	7.00	3.00	3.00	0.00	9.00	10.0	56.00
	A1	A2	A	B1	B2	B3	B	C1	C2	C3	C	D	Total
Water	3.00	5.00	15.00	7.50	0.00	3.00	10.50	3.00	3.00	5.00	14.00	15.00	54.50
	A1	A2	A	B1	B2	B3	B	C1	C2	C3	C	D	Total
Land	3.00	5.00	15.00	7.50	0.00	3.00	10.50	3.00	3.00	5.00	14.00	15.00	54.50

Source: CPCB report: EIAS/5/2009-10

Significance of Studying Heavy Metal Contamination

Heavy metals such as lead, chromium, cadmium, nickel, and arsenic pose a serious risk when present in water. These elements do not degrade over time and can accumulate in human tissues, causing a range of health issues from kidney failure to neurological disorders and carcinogenic effects.[6]Over 80% of health issues in developing countries are linked to waterborne diseases, resulting in 1.5 million deaths annually from poor water quality and hygiene. [7] Unlike microbial contamination, which can often be treated through basic filtration, heavy metal pollution requires more complex and costly remediation measures.

In the context of Baddi–Barotiwala, understanding the nature and extent of heavy metal contamination is crucial for multiple reasons. First, the area serves as a case study for industrialization in ecologically fragile zones. Second, many of the affected communities are unaware of the invisible health risks they face daily. Lastly, regulatory action and pollution control mechanisms must be informed by scientific data that links pollution sources to public

[6] World Health Organization, GUIDELINES FOR DRINKING-WATER QUALITY,WHO Publication (4th ed. 2017) .

[7] Press Information Bureau, Ministry of Jal Shakti, Govt. of India, Carcinogenic Risks Were High for Adults, Mainly from Industrial Nick*el, Cobalt, and Barium*, PIB (May 23, 2024, 5:21 PM),https://www.pib.gov.in/PressReleasePage.asp?

health outcomes.[8] This study, therefore, seeks to fill an important gap in the literature by examining heavy metal contamination in groundwater within the BBN industrial region and assessing its implications for local communities and policy interventions.

II

Study Area: Baddi–Barotiwala Industrial Belt

(i) *Geographic and Industrial Profile*

Nestled in the Solan district of Himachal Pradesh, the Baddi–Barotiwala Industrial Belt is among the most prominent manufacturing clusters in North India. This region lies in the Shivalik foothills, strategically located close to the Punjab border, which offers logistical advantages for the movement of raw materials and finished goods to and from neighboring states.[9] Over the past two decades, this area has witnessed rapid industrialization, transforming from a quiet agrarian landscape into a bustling industrial corridor.

The industrial development was catalyzed by the Himachal Pradesh government's policy incentives in the early 2000 and Investment Policywhich included tax holidays and infrastructure support under the Central Government's industrial package.[10] As a result, numerous pharmaceutical, textile, food processing, and packaging units have been established, with Baddi alone emerging as a pharmaceutical hub housing over 300 drug manufacturing companies.[11] The influx of

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[8]Ramesh Kumar & Neha Sharma, *Groundwater Contamination and Health Impacts in Solan District*, 9(2) J. EARTH & ENVTL. SCI. 234, 239–40 (2022).

[9] Himachal Pradesh State Pollution Control Board, *Comprehensive Environmental Assessment of Industrial Clusters: Baddi-Barotiwala-Nalagarh (BBN)* (2018), https://hppcb.hp.gov.in

[10] Himachal Pradesh Industrial Investment Policy, 2019, *https://emerginghimachal.hp.gov.in*.

[11] Sunny Grack & Narender Singh Chauhan, *A Study on Challenges and Avenues of Pharmaceutical Industry in Himachal Pradesh*, 5 INT'L J. MGMT. & COMMERCE 84 (Apr. 24, 2023).

heavy industries, while economically beneficial, has placed substantial pressure on local resources, particularly groundwater.

a. Demographics and Water Usage Patterns

The demographic landscape of the Baddi–Barotiwala area has also evolved significantly. Originally inhabited by a relatively small, agrarian population, the region has seen a surge in migrant workers from across India, drawn by employment opportunities in the industrial sector. [12] This has led to the growth of semi-urban settlements with increased demand for housing, sanitation, and utilities.

With respect to water usage, the industrial belt heavily relies on groundwater, both for industrial processes and domestic consumption. [13] Many manufacturing units, especially those in the pharmaceutical and chemical sectors, require large volumes of water for production, cooling, and cleaning. [14] Unfortunately, the unregulated extraction of groundwater by industries, combined with a lack of efficient wastewater treatment, has not only lowered the water table but also introduced pollutants—particularly heavy metals—into local aquifers.[15]

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[12] BaddiBarotiwalaNalagarh Development Authority, *Draft Development Plan-2025 for Baddi-Barotiwala-Nalagarh Special Area* (2013),available at https://bbnda.hp.gov.in/DevPlan2025(last visited 12th June 2025).

[13] Kiran Thakur & Manish Sharma, *Groundwater Management in Industrial Belts of Himachal Pradesh: A Case Study of Baddi-Barotiwala*, 24(1) INDIAN J. ENV'T PROTECTION 46, 47 (2022).

[14]*Id.* at 48.

[15] Central Pollution Control Board, *Status of Groundwater Quality in Industrial Clusters of India (2020)*, available athttps://cpcb.nic.in(last visited 10th June, 2025).

TABLE 11: WATER QUALITY OF GROUND WATER UNDER NWMP IN HIMACHAL PRADESH – 2020

Station Code	Name of Monitoring Location	State Name	Temperature °C		pH		Conductivity (µmhos/cm)		BOD (mg/L)		Nitrate - N + Nitrite - N2 (mg/L)		Faecal Coliform (MPN/100ml)		Total Coliform (MPN/100ml)		Faecal Streptococci (MPN/100ml)		Total Dissolved Solids (mg/L)		Fluoride (mg/L)		Arsenic (mg/L)	
			Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1555	WELL AT KALA AMB,	HIMACHAL PRADESH	-	-	7.1	7.2	561	878	BDL	BDL	0.55	0.55	BDL	BDL	BDL	BDL	BDL	BDL	376	417	0.41	0.41	-	-
1556	WELL AT PAONTA SAHIB	HIMACHAL PRADESH	26	26	7.3	7.3	838	857	BDL	BDL	0.82	0.82	BDL	BDL	BDL	BDL	BDL	BDL	441	478	0.66	0.66	-	-
1561	GROUND WATER AT DAMTAL	HIMACHAL PRADESH	16	27	7.8	7.9	545	673	BDL	BDL	BDL	BDL	BDL	BDL	10	10	-	-	348	457	BDL	BDL	-	-
1562	WELL AT UNA	HIMACHAL PRADESH	-	-	8	8.3	417	526	BDL	BDL	-	-	BDL	BDL	21	21	-	-	257	357	BDL	BDL	-	-
1872	GROUND WATER AT SHIMLA D/S OF MSW DUMPING SITE	HIMACHAL PRADESH	18	18	7.1	7.6	535	5735	14	160	1.59	8.8	430	1600	1600	1600	-	-	241	325	0.53	1.58	-	-
1873	GROUND WATER AT DHARAMSHALA KANGRA D/S OF MSW DUMPING SITE	HIMACHAL PRADESH	15	15	7.4	7.4	339	339	BDL	BDL	BDL	BDL	BDL	BDL	130	130	-	-	216	216	BDL	BDL	-	-
1874	GROUND WATER AT SOLAN-D/S OF MSW DUMPING SITE SALOGRA	HIMACHAL PRADESH	18	18	7	8.5	207	738	BDL	BDL	-	-	BDL	BDL	BDL	2	BDL	BDL	112	432	BDL	0.65	-	-
1877	GROUND WATER AT BADDI INDUSTRIAL AREA	HIMACHAL PRADESH	25	25	7.4	7.6	560	743	BDL	BDL	-	-	BDL	BDL	BDL	BDL	BDL	BDL	336	422	BDL	0.48	-	-
1878	GROUND WATER AT BAROTIWALA INDUSTRIAL AREA	HIMACHAL PRADESH	25	25	7	7.3	569	702	BDL	BDL	-	-	BDL	BDL	BDL	BDL	BDL	BDL	341	412	0.75	0.75	-	-
1880	GROUND WATER AT KALA AMB INDUSTRIAL AREA	HIMACHAL PRADESH	-	-	6.9	8.1	693	900	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	398	603	BDL	BDL	-	-
1881	GROUND WATER AT PAONTA SAHIB INDUSTRIAL AREA	HIMACHAL PRADESH	20	20	6.6	7.1	663	909	BDL	BDL	0.81	0.81	BDL	BDL	BDL	BDL	BDL	BDL	418	438	0.67	0.67	-	-
1882	GROUND WATER AT MEHATPUR INDUSTRIAL AREA	HIMACHAL PRADESH	-	-	7.5	7.9	438	688	BDL	BDL	BDL	0.31	BDL	BDL	17	17	-	-	271	467	BDL	BDL	-	-
1883	GROUND WATER AT UNA INDUSTRIAL AREA	HIMACHAL PRADESH	-	-	7.7	7.7	542	662	BDL	BDL	BDL	BDL	BDL	BDL	21	21	-	-	340	450	BDL	BDL	-	-
2628	HAND PUMP AT SHAMSHI	HIMACHAL PRADESH	11	15	6.8	7	523	580	-	-	2.7	2.7	BDL	BDL	BDL	BDL	BDL	BDL	345	383	-	-	-	-
2629	HAND PUMP AT MANDI TOWN	HIMACHAL PRADESH	19	21	7.5	8	362	512	-	-	1.78	1.78	BDL	BDL	BDL	BDL	BDL	BDL	228	335	-	-	-	-
2630	HAND PUMP AT HAMIRPUR TOWN	HIMACHAL PRADESH	15.5	15.5	6.6	8.2	102	650	BDL	BDL	-	-	BDL	BDL	11	11	-	-	68	428	BDL	BDL	-	-
2631	HAND PUMP AT NADAUN TOWN	HIMACHAL PRADESH	15.7	27	7.7	7.7	622	824	BDL	BDL	BDL	BDL	BDL	BDL	20	26	BDL	BDL	379	560	BDL	BDL	-	-
2632	HAND PUMP AT BILASPUR TOWN	HIMACHAL PRADESH	19	20	7.8	8.6	426	804	-	-	2.35	2.35	BDL	BDL	BDL	BDL	BDL	BDL	282	526	-	-	-	-

Source: Central Pollution Control Board, *National Water Quality Monitoring Programme: NWMP Data 2020* (2020), https://cpcb.nic.in/wqm/2020/NWMP_DATA_2020.pdf. (See station code 1877 &1878)

Simultaneously, the residential demand for water has grown, straining the existing supply systems. Local communities, particularly those in peripheral villages, often depend on hand pumps and borewells, which are increasingly yielding contaminated or reduced water supplies. [16] This scenario has raised serious

[16]Kamaldeep, Madhuri S. Rishi, Naresh Kochhar & Nibedita Ghosh, *Impact of Industrialization on Groundwater Quality: A Case Study of Baddi–Barotiwala Industrial Belt, Distt. Solan, Himachal Pradesh, India*, 27 J. INDUSTRIAL POLLUTION CONTROL 153 (2011).

environmental and public health concerns, calling for urgent policy attention toward sustainable water management in the region.

b. Methodology

This study adopts a non-empirical, analytical approach aimed at understanding the complex issue of groundwater contamination in the Baddi–Barotiwala industrial belt of Himachal Pradesh. Rather than collecting fresh data through fieldwork or laboratory testing, the research relies on existing knowledge, documented findings, legal texts, and policy frameworks to build a comprehensive narrative of the environmental crisis in the region.

Given the scale of industrialization in Baddi–Barotiwala and the growing concerns over public health and environmental degradation, it becomes important to critically examine available scientific studies, government reports, judicial decisions, and regulatory actions. This allows the study to highlight patterns, gaps, and governance challenges related to heavy metal contamination of groundwater.

III

Regulatory and Legal Framework

Environmental protection in India, especially with respect to water pollution, is governed by a mix of overarching statutes, regulatory bodies, and judicial mechanisms. However, the case of the Baddi–Barotiwala industrial region reveals how even a strong legal framework can falter in the face of inadequate enforcement, fragmented governance, and unchecked industrial expansion.

(i) Statutory Provisions

There are two key environmental laws which form the backbone of water pollution regulation in India. Among these the Water (Prevention and Control of Pollution) Act, 1974 was among the first central legislations to address industrial water pollution. It established Pollution Control Boards at both the central and state levels, empowered to grant or revoke consents to industries, and

penalize violations.[17]However, the implementation often suffers from delays, insufficient staffing, and poor inter-agency coordination and according to some expert the law is further diluted by latest amendments bycentralizing the power. [18] The Environment (Protection) Act, 1986**,** enacted after the Bhopal Gas Tragedy, serves as an umbrella legislation allowing the central government to take necessary measures to protect and improve environmental quality.[19] Under this Act, rules relating to hazardous waste management, environmental clearance, and effluent discharge standards have been formulated. [20] Despite these tools, there remain gaps in real-time monitoring and compliance auditing.

Industrial areas like Baddi–Barotiwala, where effluent generation is high due to pharmaceutical and chemical processing, are supposed to be stringently regulated under these frameworks. Yet, enforcement is often weak due to the influence of vested interests, understaffing of local offices, and limited technological capability for pollution tracking.[21]

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[17]Water (Prevention and Control of Pollution) Act, No. 6 of 1974, §§ 16, 17, 21.

[18]Richi Verma, *Centralisation of Powers, Diluted Laws: Weak Water Act Further Diluted by Latest Amendments, Say Experts*, Down to Earth (Feb. 21, 2024), available at https://www.downtoearth.org.in/environment/centralisation-of-powers-diluted-laws-weak-water-act-further-diluted-by-latest-amendments-say-experts-94487 (last visited 8 June 2025).

[19] Environment (Protection) Act, No. 29 of 1986, INDIA CODE, § 3(1).

[20]Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016, Gazette of India, Extraordinary, Part II, Sec. 3(i) (Apr. 4, 2016); Ministry of Environment & Forests, S.O. 1533(E), Environmental Impact Assessment Notification, Gazette of India, Extraordinary, Part II, Sec. 3(ii) (Sept. 14, 2006); Environment (Protection) Rules, 1986, Gazette of India, Extraordinary, Part II, Sec. 3(i) (Nov. 19, 1986), Sch. VI; Environment (Protection) Act, No. 29 of 1986, § 3–6, (1986).

[21]*Enforce the Law in Baddi: NGT to Himachal Pollution Board*, TIMES OF INDIA(Jan. 24, 2022, 8:41 AM)*available at*https://timesofindia.indiatimes.com/city/shimla/enforce-the-law-in-baddi-ngt-to-himachal-pollution-board/articleshow/89103095.cms. (last visited 3 June 2025).

(ii) Regulatory Institutions: CPCB and HPSPCB

The Central Pollution Control Board (CPCB and its state counterpart, theHimachal Pradesh State Pollution Control Board (HPSPCB)**,** are the primary agencies tasked with environmental oversight. Their responsibilities include monitoring ambient water quality, ensuring industries comply with prescribed standards, reviewing environmental impact assessments (EIAs), and penalizing non-compliance through notices or closures.[22]

Despite their mandate, several independent reviews and official audits have pointed out systemic inefficiencies. For instance, a 2021 ENVIS report noted that in the Baddi–Barotiwala area, industrial compliance with zero-liquid-discharge and effluent treatment standards remains inconsistent. [23] Many industries reportedly discharge untreated or partially treated wastewater into open drains or percolation pits, contaminating groundwater with persistent pollutants like lead, cadmium, and chromium.

The HPSPCB, in particular, faces challenges of limited field staff and dependence on self-reporting by industries. [24] Monitoring is often

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[22] Central Pollution Control Board, *Functions of CPCB, available at*https://cpcb.nic.in/functions-of-cpcb/ (last visited June 9, 2025).

[23]Central Pollution Control Board, Comprehensive Environmental Pollution Index Action Plan for Baddi, Himachal Pradesh, App. A, List of industries complying/non-complying with effluent discharge standards (2021), *available at* https://cpcb.nic.in/industrial_pollution/New_Action_Plans/CEPI_HP_baddi%20.pdf (last visited June 11, 2025).

[24] Jacob Koshy, *Political Meddling Proves Toxic for Pollution Control Boards*, THE HINDU(Dec. 1, 2012), https://www.thehindu.com/news/national/Political-meddling-proves-toxic-for-pollution-control-boards/article12016818.ece.

sporadic, and punitive action is rare unless public outcry or media attention forces administrative intervention.[25]

(iii) Judicial Oversight and NGT Intervention

Given the gaps in administrative action, the National Green Tribunal (NGT) has emerged as a crucial institution in directing environmental compliance. In recent years, the NGT has passed several orders relating to industrial clusters with high pollution loads, including Baddi–Barotiwala, as part of its broader initiative on critically polluted areas. [26] The National Green Tribunal (NGT), Principal Bench, New Delhi, in Original Application No. 804/2017, has issued an order on industrial pollution in critically polluted areas, specifically concerning the case of Rajiv Narayan &Anr. v. Union of India & Ors. This orderfocuseson the need to implement specific recommendations, including the preparation of protocols for deciding on by-products based on chemical processes. The NGT's order addresses various aspects of environmental protection, including the enforcement of waste management rules, the identification of suitable sites for waste disposal and treatment, and the need for continuous monitoring of pollution levels. [27]

One notable case involved the NGT's 2020 order directing theMinistry of Environment, Forest and Climate Change (MoEFCC)and CPCB to undertake a comprehensive assessment of pollution levels in the BBN region and to develop a time-bound action plan. [28] The tribunal emphasized the need for regular

[25]Kuldeep Chauhan, *Pollution Regulator Needs Overhaul as Beas, Pabbar Rivers Face Toxic Threat ahead of High Court Hearing on July 4*, HIMBUMAIL (June 30, 2025), *available at* https://himbumail.com/latest/pollution-regulator-needs-overhaul-as-beas%2C-pabbar-rivers (last visited 25 May 2025).

[26] National Green Tribunal, *Order on Industrial Pollution in Critically Polluted Areas*, Original Application No. 804/2017, NGT PRINCIPAL BENCH, NEW DELHI (Dec. 18, 2020).

[27]Ibid.

[28] Id. at 10–12.

groundwater quality monitoring, public disclosure of contamination data, installation of real-time effluent monitoring devices, remediation plans under the "Polluter Pays Principle."[29]

However, while judicial directives have been strong on paper, their on-ground execution is often delayed due to bureaucratic red tape, lack of coordination, [30] and limited budgetary allocation for enforcement and remediation.[31]

(iv) The Missing Link: Public Participation and Transparency

Another critical shortcoming in the regulatory framework is the lack of meaningful community involvement**.** Local populations, despite being direct stakeholders, are rarely consulted during project clearances or in the aftermath of pollution events. Access to environmental information remains limited, and Grievance Redressal Mechanisms are underutilized due to lack of awareness and procedural complexity.[32]

Thus, while the legislative and regulatory architecture exists to prevent and control groundwater pollution, its poor implementation and accountability failures render it largely ineffective in industrial belts like Baddi–Barotiwala. Strengthening institutional capacity, ensuring transparency, and empowering local communities must be at the heart of any future regulatory reform.

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[29] Id. at 14–15.

[30]Dr. Vikas Sharma & Sachin Subhash Gore, *Enforcement of Environmental Law and Environmental Compensation by the National Green Tribunal (NGT): A Critical Analysis*, Vol. 27 No. 1S, AFRICAN J. BIOMED. RESEARCH (July 2024).

[31] S. Iyengar, Nives Dolšak& Aseem Prakash, *Selectively Assertive: Interventions of India's Supreme Court to Enforce Environmental Laws*, 11 SUSTAINABILITY 7234 (2019), https://doi.org/10.3390/su11247234.

[32] See Kanchi Kohli & Manju Menon, *Transparent and Participatory Environmental Regulation in India: Still a Distant Dream*, 26(3) ECON. & POL. WKLY. 41, 43–44 (2021).

IV

Institutional and Governance Analysis

While India possesses an extensive legal framework for environmental protection, the effectiveness of environmental governance ultimately hinges on how institutions function on theground. In the case of the Baddi–Barotiwala–Nalagarh (BBN) industrial cluster, thegovernance deficit is not due to a lack of law, but rather due to institutional fragmentation, lack of coordination, and weak enforcement.[33]

(i) Multiplicity of Institutions, Minimal Accountability

Environmental governance in industrial zones like BBN is managed through a complex web of institutions, each with overlapping jurisdictions. The Ministry of Environment, Forest andClimate Change (MoEFCC**)** sets national policy, while the Central Pollution Control Board **(**CPCB) and the Himachal Pradesh State Pollution Control Board (HPSPCB)act as regulatory arms. In addition, departments such as Industries**,** Health**,** Urban Development, and Rural Development also play peripheral roles in environmental decision-making.[34]

However, this multiplicity often leads to diffused responsibility. For example, while HPSPCB is tasked with monitoring effluent discharge and issuing environmental consents, it lacks the authority

[33]Vandana Shroff & Ashish Jejurkar, *The Impact of Environmental Judgments at the Implementation Level*, India Law News (Sept. 1, 2011),*available at* https://indialawnews.org/2011/09/01/the-impact-of-environmental-judgments-at-the-implementation-level-2/ (last visited 27May 2025).

[34]Melissa Cyrill, *Environmental Compliance for Companies in India: Key Legislation and ESG Guidelines*, India Briefing (Apr. 12, 2024),*available at* https://www.india-briefing.com/news/environmental-compliance-for-companies-in-india-key-legislation-and-esg-guidelines-32012.html.; last visited 30 May 2025) Himachal Pradesh State Pollution Control Board, *Organisational Structure and Mandate*, https://hppcb.hp.gov.in.

to penalize larger industries without CPCB approval. [35] Similarly, local bodies are expected to manage waste infrastructure but are not adequately equipped, either in terms of personnel or finances, to deal with hazardous industrial waste.

This institutional disconnect often results in a "pass-the-buck" scenario**,** where no agency is held fully responsible for groundwater degradation, and response mechanisms are delayed or reactive rather than preventive.

(ii) Regulatory Capture and Industrial Lobbying

Another major obstacle is the influence of powerful industrial lobbies**.** The pharmaceutical and packaging industries in Baddi–Barotiwala have significantly contributed to the region's economic growth, generating employment and revenue. However, this economic leverage often translates into regulatory capture, where enforcement agencies may be pressured to overlook violations or delay punitive actions.[36]

Periodic inspections, especially in smaller units, are often either skipped or conducted perfunctorily. Reports suggest that some industries have installed effluent treatment plants(ETPs) only for display during inspections, bypassing them in day-to-day operations to cut costs.[37]Such practices continue due to a combination of lenient

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[35]Water (Prevention and Control of Pollution) Act, No. 6 of 1974, §§ 21, 25–26, 33A; Environment (Protection) Act, No. 29 of 1986, § 5.

[36] Ashwani Sharma, *Himachal Pradesh: How Spurious Drugs Have Brought Bad Name, Regulatory Spotlight On State's Famed Pharma Industry*, OUTLOOK INDIA (Feb. 13, 2023), https://www.outlookindia.com/amp/story/national/himachal-pradesh-how-spurious-drugs-have-brought-bad-name-regulatory-spotlight-on-state-famed-pharma-industry-news-261661;*Massive Failures of India's Drug Regulatory System*, Pulitzer Center (publication date not provided), https://pulitzercenter.org/stories/massive-failures-indias-drug-regulatory-system.

[37] Ambika Sharma, *Curbs on Polluting Units Hit Expansion Plans*, THE TRIBUNE (Chandigarh**)** (Aug. 24, 2019),

penalties, lack of whistleblower protection, and poor transparency in enforcement data**.**

(iii) Institutional Capacity Deficits

Even when there is willingness to act, many institutions suffer from severe capacity constraints. The HPSPCB, for instance, operates with limited field staff and outdated laboratoryinfrastructure**.** According to one study, the number of field inspections in Baddi–Barotiwala fell drastically between 2018 and 2022, despite an increase in pollution complaints.In March 2025, an RTI response obtained by Himachal Guardian disclosed that 195 business units in the BBN region were operating without pollution consent, and another 329 had pending consent renewals**,** indicating a significant oversight gap, likely due to insufficient inspections[38]

Further, there is a scarcity of hydrogeologists, environmental engineers, and data analysts within state-level institutions, making it difficult to conduct comprehensive impact assessments or track pollution pathways effectively. Without institutional strengthening and skill-based hiring, agencies are often unable to match the technological and operational scale of modern industries.

(iv) Weak Inter-Governmental and Community Interface

Another systemic flaw is the lack of coordination between state-level regulatory bodies and local governance institutions, such as Panchayati Raj bodies or municipal committees. [39] Groundwater

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https://www.tribuneindia.com/news/archive/himachal-tribune/curbs-on-polluting-units-hit-expansion-plans-822066/.

[38] Dharam Prakash Gupta, *As Many as 195 Business Units Operating Without Pollution Consent – RTI Information*, HIMACHAL GUARDIAN (Mar. 31, 2025),*available at* https://himachalguardian.com/2025/03/as-many-as-195-business-units-operating-without-pollution-consent-rti-information/.(last visited 20 May, 2025).

[39] The World Bank, INDIA: NATIONAL GROUNDWATER MANAGEMENT IMPROVEMENT PROGRAM – ENVIRONMENTAL AND SOCIAL SYSTEMS ASSESSMENT(Essa), Report No. P158119 (2018), *available*

ontamination affects rural households directly, yet local elected bodies often have little say in environmental planning or industrial clearance procedures.[40]

Additionally, community engagement in environmental governance remains minimal. Public hearings during Environmental Impact Assessments (EIAs) are frequently tokenistic, held without adequate information dissemination or meaningful participation.Research on hydroelectric projects in Himachal and Uttarakhand shows public hearings are treated as checkboxes rather than inclusive forums. Locals reported lack of detail in notifications, unfamiliarity with EIA norms, and hearings that occurred as mere procedures. [41]This top-down approach to governance contributes to mistrust, low awareness of pollution risks, and weak local surveillance over industrial activities.

(v) ***Judicial Intervention as a Governance Substitute***

In the absence of effective executive action, judicial bodies such as the National GreenTribunal (NGT) have stepped in repeatedly to enforce environmental norms. [42] While this has led to short-term

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*at*https://ewsdata.rightsindevelopment.org/files/documents/19/WB-P158119.pdf. (last visited 07 July2025).

[40]Vikas Saini et al., *Groundwater Contamination with Special Reference to Chromium in the State of Uttar Pradesh: A Review*, 14(1) J. FAMILY MED. & PRIMARY CARE 3 1-10 (2021). *available at*https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7778406/. (last visited 07 July, 2025).

[41]Naveen Thayyil, *Public Participation in Environmental Clearances in India: Prospects for Democratic Decision-Making* (2017) (unpublished manuscript), available at *Academia.edu*, https://www.academia.edu/36893048/Public_Participation_in_Environmental_Clearances_in_India_Prospects_for_Democratic_decision_making (last visited 5 June, 2025).

[42] As per the report published,(retrieved on 12-6-2025) in 25th June,2021 in The Tribune, the NGT, on June 23, 2021, reproached HPPCB for allowing pharmaceutical units to discharge toxic effluents into the Sirsa River. It found antibiotic residues—like ciprofloxacin and ofloxacin—exceeding permissible levels by 1,139× and 348×, respectively. A joint inspection committee was mandated to report remedial steps; And as per the news published on 3rd March, 2025 (retrieved on 12th june, 2025)On March 3, 2025, the NGT ordered the Himachal Pradesh government to recover ₹1.08 crore in

compliance—such as sealing polluting units or ordering compensation—it reflects a deeper malaise: that core regulatory agencies are either underperforming or politically compromised. Reliance on litigation also makes pollution control a reactive mechanism [43] rather than a preventive one, and further burdens affected communities with the costs and complexities of legal processes.

As per various NGO reports the institutional and governance failures in the BBN region[44] exemplify how systemic inefficiencies, political economy, and weak public engagement together contribute to environmental crises. Strengthening regulatory independence, improving inter-agency coordination, building technical capacity, and ensuring citizen participation must be central to any long-term solution aimed at addressing groundwater pollution in industrial zones.

V

Health and Socio-Economic Implications

The impact of heavy metal contamination in the Baddi–Barotiwala region extends far beyond environmental degradation—it poses a direct threat to human health and disrupts the socio-economic fabric of local communities. While environmental policy debates often focus on regulatory mechanisms and industrial practices, the lived experiences of people consuming polluted water reveal a deeper, more urgent crisis that deserves equal attention.

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environmental penalties from 41 illegal soil-mining violators operating around Baddi. The tribunal directed the state to deposit funds from the District Mineral Fund if collection failed within 60 days, and instructed officials to appear before the tribunal.

[43]Polluter pays principle as adopted by Indian court in *M.C. Mehta* v *Union of India* case which states that the cost of pollution should be paid by those who caused it.

[44] Him Parivesh&Himdhara Collective, BBN INDUSTRIAL AREA: ENVIRONMENTAL VIOLATIONS, REGULATORY LAPSES AND COMMUNITY CONCERNS – A REPORT PRESENTED AT THE PUBLIC HEARING, https://www.himdhara.org(last visited 5thJune 2014).

(i) Chronic Health Risks from Heavy Metal Exposure

Scientific literature has established that exposure to heavy metals—such as lead, cadmium, chromium, and arsenic—can have long-lasting and irreversible health impacts. [45] In the Baddi–Barotiwala area, communities have reported rising instances of kidney disorders, gastrointestinal issues, skin ailments, and neurological symptoms—all of which are known to correlate with long-term ingestion of heavy metal-contaminated water.[46]

Children and pregnant women are especially vulnerable. Lead exposure, even in small quantities, is known to impair cognitive development and cause behavioral disorders in children.[47] In adult populations, chronic cadmium[48] and arsenic exposure [49]can lead to "bone demineralization, liver damage, and various forms of cancer"Sadly, these symptoms often go undiagnosed or are misattributed due to poor rural healthcare access and a lack of water quality awareness.

In an alarming revelation, assessment of groundwater by the Indian Institute of Technology (IIT), Mandi, and IIT-Jammu in the state's Baddi-Barotiwala industrial area has revealed high carcinogenic risks for adults, mainly from industrial nickel and chromium. Experts claim, "If left unattended, the lower Himalayan region is on a trajectory similar to south-western Punjab, which is considered the

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[45] World Health Organization, *Guidelines for Drinking-Water Quality*, WHO Publication (4th ed. 2017), at 89–90.

[46] Himachal Pradesh State Pollution Control Board (HPSPCB), ANNUAL REPORT ON GROUNDWATER MONITORING IN BBN REGION12–14(2022).

[47] Indian Council of Medical Research (ICMR), LEAD TOXICITY AND CHILD HEALTH: NATIONAL ASSESSMENT REPORT (2021) available at https://icmr.nic.in. (last visited on 8th June 2025).

[48] Faroon O, Ashizawa A, Wright S, et al. TOXICOLOGICAL PROFILE FOR CADMIUM. ATLANTA (GA): AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY (US); 2012 Sep. 3, HEALTH EFFECTS. Available from: https://www.ncbi.nlm.nih.gov/books/NBK158834/.

[49] I. Kostova, *Toxic Metals and Antidotes*, 4(1) J. CLINICAL IMAGES & MED. CASE REPS. 2240 (2023).

cancer belt of India.”“Industrialisation has contaminated groundwater with toxic metals, exceeding permissible limits. The reliance on untreated groundwater has caused numerous health problems, including cancer and renal disease between 2013 and 2018,” indicates the study.[50]

(ii) Healthcare Burden and Economic Insecurity

The financial burden of illness is magnified for poor and migrant communities living in the peripheries of industrial towns [51] .Most workers employed in Baddi’s factories are engaged in informal or contractual work, often without medical insurance or permanent housing.[52]When family members fall ill due to waterborne toxicity, households face high out-of-pocketexpenses for diagnosis, treatment, and travel to tertiary hospitals. Chronic diseases such as kidney failure or cancer can lead to debt cycles, job loss, and forced migration**.** Women, who are typically the primary caregivers, often reduce their income-generating work to care for sick relatives—deepening gendered inequalities.

The healthcare system in the region is ill-equipped to address environmental diseases. Primary Health Centres (PHCs**)** andCommunity Health Centres (CHCs) lack the diagnostic tools to

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[50] “*Carcinogenic Content Found in Baddi-Barotiwala Groundwater*,” THE TRIBUNE. News Serv., June 14, 2024,*available at*https://www.tribuneindia.com/news/himachal/carcinogenic-content-found-in-baddi-barotiwala-groundwater-630507. (last visited 26 June, 2025).

[51]. Shiv Joshi & Abhishek Joshi, *Out-of-Pocket Health Expenditure Among Migrant Workers in India: A Narrative Review*, 14 CUREUS e30948 (2022),*available at* https://doi.org/10.7759/cureus.30948 (last visited on 23 June 2025).

[52]Ravi S. Chauhan, *Labour In-Migration in an Industrial Cluster of a Hill State: A Case Study of Tehsil Baddi of Himachal Pradesh***,** Vol 3 (7)INT’L J. HUMAN. & SOC. SCI. STUD. *394-397* (2015) https://www.internationaljournalcorner.com/index.php/theijhss/article/view/140234/98622 (last visited June 19, 2025).

detect metal toxicity or provide specialized care. [53] As a result, patients are either misdiagnosed or referred to distant urban centers, delaying treatment and increasing expenses.

(iii) Loss of Livelihoods and Land Devaluation

Beyond health, polluted groundwater threatens the livelihoods of small-scale farmers and daily wage workers**.** The Baddi–Barotiwala region still maintains pockets of agriculture, primarily for subsistence crops and vegetable farming. Irrigating fields with contaminated water can reduce crop yields, degrade soil quality, and even introduce metals into the food chain—posing another layer of health risk.[54]

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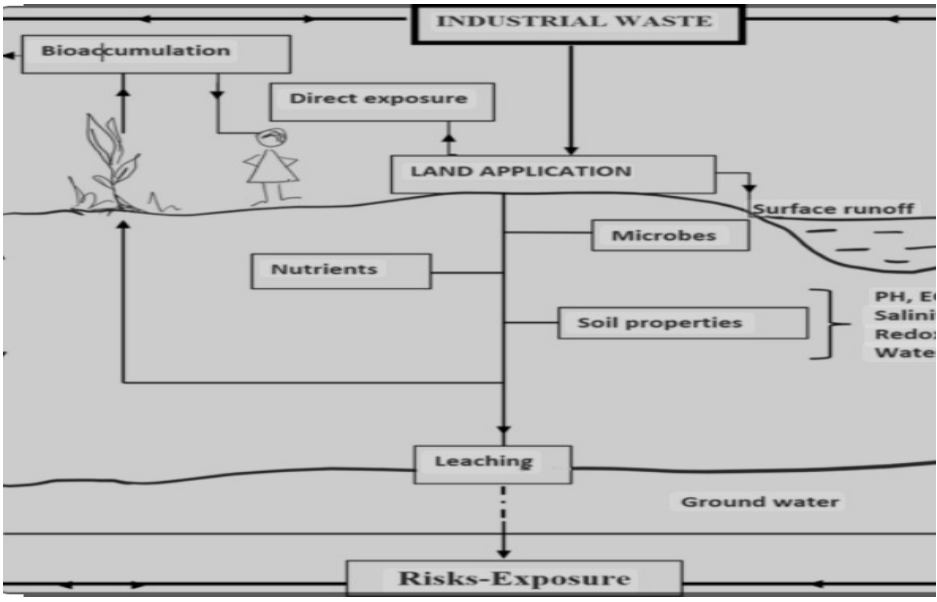
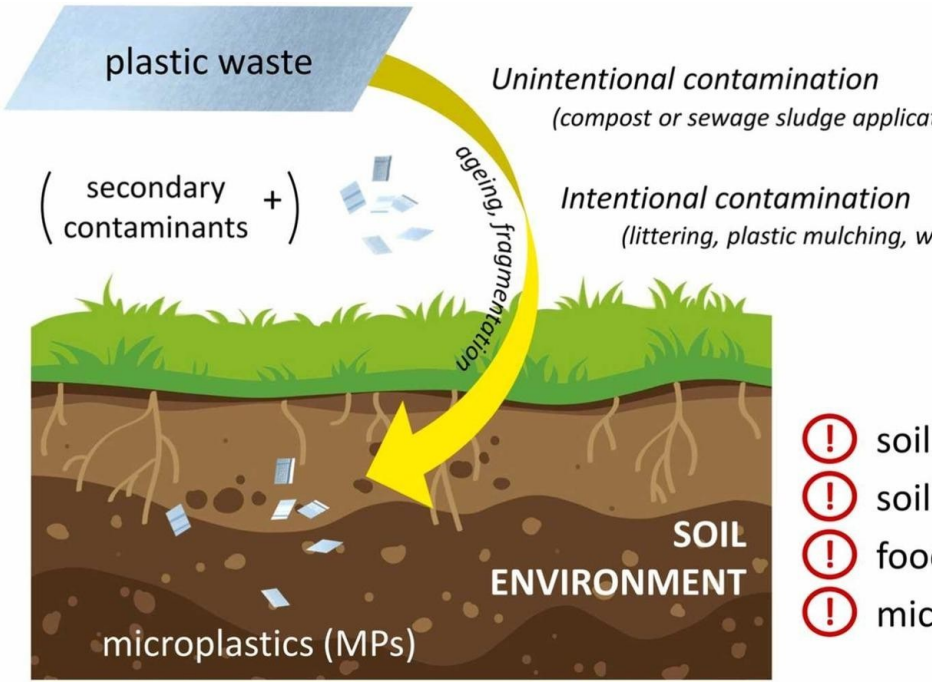
[53] Ministry of Health & Family Welfare, *National Rural Health Mission Report – Himachal Pradesh Chapter* (2023), at 35–36 and See *Health, Health Infrastructure and Health Policy of Himachal Pradesh*, PSCNOTES.COM , *available at*https://exam.pscnotes.com/health-health-infrastructure-and-health-policy-of-himachal-pradesh/.(last visited June 19, 2025).

[54] Central Ground Water Board, *Impact of Industrial Waste on Soil and Crops: Baddi–Barotiwala Study*, Technical Series No. 32 (2021).



(Conceptual diagram of the fate and behaviour of contaminants in industrial wastes applied to land)

Source: Central Ground Water Board, *Impact of Industrial Waste on Soil and Crops: Baddi–Barotiwala Study*, TECHNICAL SERIES NO. 32 (2021).



Source: Attila Bodor et al., *Soils in Distress: The Impacts and Ecological Risks of (Micro)plastic Pollution in the Terrestrial Environment*, 269 Ecotoxicology & Env't Safety 115807 (2024), https://doi.org/10.1016/j.ecoenv.2023.115807.

Moreover, real estate and agricultural land prices in affected areas have reportedly declined, as residents increasingly seek to relocate. Those unable to move—due to lack of alternative housing or financial means—find themselves locked in a cycle of exposure and impoverishment. [55] Such communities are often overlooked in industrial policy discussions, which focus more on investment inflows than on equitable development.

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[55]Central Ground Water Board**,***Impact of Industrial Waste on Soil and Crops: Baddi–Barotiwala Study*, Technical Series No. 32, at 35–37 (2021) and D.P. Gupta, *As Many as 195 Business Units Operating Without Pollution Consent: RTI Information*, HIMACHAL GUARDIAN**,** Mar. 31, 2025, https://himachalguardian.com/2025/03/as-many-as-195-business-units-operating-without-pollution-consent-rti-information/.

(iv) Erosion of Community Well-being and Environmental Justice

In a broader sense, the water crisis in Baddi–Barotiwala has led to an erosion of community trust and collective well-being**.** Conflicts over shared water resources, increasing dependence on bottled or tanker-supplied water, and the fear of invisible contaminants have all contributed to a sense of helplessness and disempowerment.This reflects a deeper environmental justice issue, where those who benefit least from industrial development are forced to bear the highest environmental and health burdens. [56] It raises ethical questions about policy priorities and whether current development models adequately account for human welfare, particularly in marginalized communities.

VI

Sustainability and Policy Recommendations

The groundwater contamination crisis in the Baddi–Barotiwala industrial belt is not just a result of industrial growth—it is a symptom of institutional neglect, planning gaps, and fragmented environmental governance. While addressing the current situation requires urgent measures, long-term resilience can only be built through sustainable, inclusive, and enforceable policies that bridge the gap between industrial development and environmental stewardship.

(i) Strengthening Environmental Regulation and Monitoring

The first step toward sustainability is enhancing the institutional capacity of the Himachal Pradesh State Pollution Control Board (HPSPCB) and ensuring real-time water quality monitoringin and around industrial clusters. Currently, groundwater monitoring in

[56] Rahul Bhandari, *Baddi's Groundwater Pollution: High Court Orders Detailed Study by IIT Mandi*, THE NEWS HIMACHAL (18thJun. 2024).

Himachal including BBN region is periodic and reactive, leaving room for prolonged undetected contamination.Installation of automated sensors and GIS-based water mapping should be mandated for industries handling hazardous substances.Moreover, regulatory frameworks like the Environment (Protection) Act, 1986**,** and theWater (Prevention and Control of Pollution) Act, 1974**,** must be implemented with stringent penalties for violations**.**Industries violating consent conditions or operating without valid treatment systems should faceclosure notices, financial penalties, and public disclosure of violations to create deterrence. Thus, transparency and data availability are essential tools to rebuild community trust and ensure regulatory accountability.

(ii) ***Polluter Pays and Extended Producer Responsibility***

Enforcement alone will not drive sustainability unless polluters are made to internalize the costs of their environmental damage. A strict application of the "polluter pays" principle must be adopted, holding companies financially accountable for groundwater remediation, health screenings, and compensation to affected communities.Further, the concept of Extended Producer Responsibility (EPR**)**—already in place for plastic waste—should be extended to industries producing chemical effluents. Pharmaceutical and chemical units must be made responsible not just for waste treatment but also for post-discharge environmental safety**,** including regular third-party audits.

(iii) ***Community-Based Water Management***

One of the most overlooked aspects of groundwater governance is the exclusion of local communities from water management decisions**.** Creating community water user associations (WUAs)and village-level groundwater watch groups can foster participatory monitoring, reduce over-extraction, and enable early detection of contamination.

Such mechanisms have been effective in parts of Maharashtra and Rajasthan and can be adapted to Himachal's semi-urban settings with state facilitation and NGO support. Additionally, capacity-building programson water testing, waste segregation, and reporting

mechanisms should be launched for schoolteachers, health workers, and gram panchayat members.

(iv) Sustainable Industrial Planning and Green Zoning

The current industrial planning in Baddi–Barotiwala is reactive and infrastructure-driven. For long-term sustainability, green zoning and eco-sensitive mapping must guide future industrial growth. New industries should only be permitted after comprehensive Environmental Impact Assessments (EIAs), not as a formality but as a decision-making tool.

Industries should also be incentivized to adopt zero-liquid-discharge (ZLD) systems**,** reusetreated water**,** and invest in bioremediation technologies for in-situ groundwater recovery. Industrial estates should include common effluent treatment plants (CETPs**)** with community oversight and third-party verification of discharge quality.

(v) Health Surveillance and Emergency Response

Given the chronic exposure risk in the Baddi–Barotiwala region, the health department must set up special environmental health cells in local Primary Health Centres. These cells should conduct baseline health surveys, track illness patterns, and create public health advisories in coordination with pollution control boards.

Emergency response protocols must also be formalized—particularly for contamination spikes or accidental leaks. This includes setting up a state-level environmental disaster response fund that can be activated in the event of mass contamination incidents or industrial accidents.

(vi) Legislative Innovation and Judicial Monitoring

To support these efforts, Himachal Pradesh should consider enacting a state-level WaterProtection and Groundwater Safety Act, incorporating rights-based provisions, precautionary principles, and decentralized governance mechanisms. This can also help align local action with national frameworks like the Draft National Water

Framework Bill, 2016**.**Further, judicial monitoring by the National Green Tribunal (NGT**)** or the Himachal High Court should be continued on identified hotspots like Baddi-brotiwalaand other alike industrial area of state of Himachal Pradesh. Regular status reports, community hearings, and court-mandated implementation audits can also maintain pressure on regulatory bodies and industries alike.

True sustainability in Baddi–Barotiwala must go beyond compliance checklists. It demands a transformative shift in how we view water, pollution, and community rights. By linking ecological responsibility with industrial planning, and empowering local communities, the region can become not just a case of crisis—but a model for environmental resilience in India's fast-growing industrial landscapes.