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Sustainable Solutions for Ground Water Requirements and Its Availability for Various Industries

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Abstract: Groundwater serves as a critical lifeline for numerous industries, yet its unsustainable extraction has led to alarming depletion levels worldwide. This research investigates forward-looking, sustainable solutions to meet groundwater demands while ensuring long-term availability for diverse industrial sectors. The study emphasizes a systems-based approach integrating advanced water-saving technologies, managed aquifer recharge (MAR), and circular water use within industrial processes. It further explores the role of policy frameworks, cross-sectoral water sharing models, and data-driven groundwater monitoring tools in promoting equitable and efficient usage. By analyzing case studies across energy, manufacturing, agriculture-based, and pharmaceutical industries, the research identifies scalable practices that reduce dependency on non-renewable groundwater reserves. The findings underscore the importance of aligning industrial water strategies with regional hydrogeology and climate resilience goals. This paper aims to provide a roadmap for industries and policymakers to shift from exploitative water use patterns to sustainable groundwater stewardship.

Keywords: Groundwater sustainability; industrial water management; managed aquifer recharge (MAR); circular water use; reuse and recycle of water, including zero liquid discharge (ZLD); decision support systems (DSS)

I. INTRODUCTION.

- Groundwater is necessary for industrial, agricultural and household uses.
- UNESCO (2024): Industrial aquifer water withdrawals constitute 40% of industrial freshwater use.
- Industrialization and climate change no longer make extraction viable. India (CGWB 2025): 70% of industrial clusters located in semi-critical or over-exploited areas.
- Main concerns: depletion, salinization, contamination and lower water security.
- Purpose: Develop technology and policy solutions to sustainably meet industrial water needs.

II. TRENDS IN INDUSTRIAL WATER USE AND DEPLETION.

Global Scenario
- Industrial water demand rose by 22% (2015–2024).
- Major users of ground water: energy, manufacturing, textiles, pharmaceuticals.
- Globally, more than 150 of the world's major aquifers are over-pumped.

Indian Context
- The annual withdrawal of groundwater is over ~260 billion cubic meters in India.
- Industry: ≈ 8% of total, but with severe local impact.
- Areas of major impact: Gujarat, Maharashtra, Tamil Nadu, Rajasthan.

Effects:
- Water table decline.
- Heavy metal contamination.
- Soil salinity.

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• Production disruptions.

III. SUSTAINABLE TECHNOLOGICAL APPROACHES.

❖ **Managed Aquifer Recharge (MAR)**

Replenishes ground water artificially by means of treated wastewater, rain or runoff.
• MARVI project (2024): 15–20% increment in groundwater in Rajasthan; and Gujarat.
• Recharge basins using treated effluent can be implemented near plants.

❖ **Zero Liquid Discharge (ZLD)**

• No liquid waste goes out of the plant — water is processed and reused.
• Technologies: RO (Reverse Osmosis), MBR (Membrane Bioreactor).
• Provides 95% water recovery. • Reduction in losses with IOT monitoring is 30-35%.
• Example: The pharmaceutical industries in Hyderabad achieved 90% reuse.

❖ **Circular Water Economy**

• Fosters the reuse of reclaimed water between industries. Example: Gujarat – reuse of textile wastewater by cement plants.
•Conserves 1.5 million cubic meters of groundwater each year.
• Joint treatment, distribution infrastructure urged.

❖ **Rainwater Harvesting**

• Captures rooftop and surface runoff for industrial reuse.
• Example: Tamil Nadu SIPCOT industrial parks decreased extraction by 25 %.
• MAR used in conjunction with other mar or CR for continuous recharge cycle.

IV. POLICY FRAMEWORKS AND GOVERNANCE

• Government practices control sustainable groundwater use.
• CGWA (2024): • Digital permits for groundwater abstraction.
• Annual water audits for industries.
• National Water Policy (2025 draft):
• Principe "Reutilizar y reciclar antes que extraer".
• Incentives for certified water-neutral industries.
• Public–Private Water Partnerships (PPWP): Co-funding mechanisms for MAR and wastewater treatment.
• NAQUIM (2025): GIS and RS are applied to locate recharge zones.

V. DATA-DRIVEN GROUNDWATER MONITORING.

• Technology enables real-time groundwater management.
• Water4Industries Initiative (2025):
• Monitors aquifers with satellite, IoT sensors and AI.
• Predicts contamination and optimizes pumping.
• Instance: The Panipat refinery (Haryana) cut the intake by 18 per cent using an AI-based system.
• AI models reproduce aquifer response to the heterogeneous patterns of industrial withdrawal.

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VI. CASE STUDIES BY INDUSTRY SECTOR.

Industry Sector	Location / Region	Sustainable Practice / Approach	Key Outcomes / Impacts	Remarks / Insights
Agriculture / Agro-Processing	Saurashtra, Gujarat	Construction of ~27,000 check-dams for rainfall–runoff capture and storage enhancement	Increased groundwater storage during wet years; improved seasonal water availability	Demand rose again over time—highlighting the need to pair recharge with water- use efficiency
Rural / Small-Scale Farming	Chotuppal Mandal, Telangana	Managed Aquifer Recharge (MAR) using percolation tanks	Raised water tables; expanded irrigated area; reduced pumping energy	Demonstrated success of community participation and local hydrogeology-based planning
Watershed-Level Management	Rajasthan & Gujarat (MARVI Project)	Village-scale integrated recharge combined with livelihood interventions	Improved groundwater levels and community well- being	Scaling across diverse geological conditions remains a challenge
Manufacturing / Chemical / Energy / Pharmaceutical	Multiple industrial zones (India-wide)	Decision Support Systems (DSS) and Zero Liquid Discharge (ZLD) integration	Reduced groundwater dependency by 15–30% in well-managed facilities	Model-based evidence promising, but more empirical validation required

VII. DISCUSSION.

- Managing groundwater sustainably must combine technology (science), policy, and community engagement.
- Investment in ZLD and MAR systems can reduce long-term costs by 12 to 20 percent of total project cost (FAO, n.d.).
- Recharge through community approach increases compliance and knowledge.

- **Key challenges:**
- Expensive sophisticated systems of treatment.
- Lack of skilled technical manpower.

Uneven enforcement of regulations.

- Industrial planning for the future must integrate concerns about hydrogeology and resistance to climate change.

VIII. CONCLUSION.

- Industries need to move from depleting groundwater to sustainable management.
- Effective strategies include.
- Managed Aquifer Recharge (MAR).
- Zero Liquid Discharge (ZLD) • Wolf trap recycling and industrial ecology.
- AI-based monitoring and prediction tools.
- We must learn from and engage industry, government and communities.
- Sustainable water management of groundwater guarantees productive, environmental and a national security for water over time (Sposito in Water Resour 9:23–49, 2021).

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