International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 25s,2025
https://theaspd.com/index.php

Groundwater Contamination From Industrial Waste And Its Implications For Sustainable Water Resource Management: Challenges And Emerging Remediation Pathways

Prashant K Rajurkar[1*]
HF Sinclair Department of Environment, Health, Safety, Quality and Security,
Prashant.Rajurkar@HFSinclair.com, ORCID ID: 0009-0003-7956-2347

Abstract
Sustainable water resource management is increasingly threatened by groundwater contamination arising from industrial waste and hazardous by-products. Industrial effluents, improper waste disposal, and persistent pollutants such as heavy metals, petrochemicals, and organic solvents compromise aquifer quality, posing long-term risks to drinking water security, agricultural productivity, and ecosystem integrity. This study critically analyzes the global challenges in addressing groundwater pollution within the framework of sustainable water resource management. It synthesizes current scientific evidence on remediation technologies, categorizing them into conventional physical-chemical treatments and innovative approaches such as nanotechnology, bioremediation, and advanced oxidation processes. The review highlights key barriers, including high costs, limited scalability, and governance gaps, that restrict the integration of these technologies into sustainable management strategies. Particular attention is given to the socio-economic implications of remediation in water-stressed regions, where reliance on contaminated groundwater exacerbates health and livelihood vulnerabilities. By identifying promising remediation pathways and policy directions, the study underscores the urgent need for interdisciplinary solutions that balance environmental protection, economic feasibility, and social equity. The findings contribute to advancing integrated approaches for safeguarding groundwater resources, aligning with global objectives for sustainable water resource management.
Keywords: *Groundwater, Water Pollution, Industrial Waste, Environmental Remediation, Water Resources, Sustainable Development.*

Highlights:

- Critically analyses the global challenge of groundwater contamination from industrial waste.
- Synthesises evidence on conventional and emerging remediation technologies, including nanotechnology and bioremediation.
- Identifies key barriers to sustainable water management, including costs, scalability, and governance gaps.
- Proposes an integrated framework of policy and infrastructure recommendations to safeguard groundwater resources.
- Underscores the socio-economic implications, emphasizing the need for equitable and just solutions.

1 INTRODUCTION

Groundwater represents the world's largest accessible source of freshwater, serving as a vital resource for drinking water, agricultural irrigation, and industrial processes. Its sustainable management is a cornerstone of global water security and socio-economic stability. However, this critical resource is increasingly threatened by contamination, particularly from industrial activities. According to B and Joseph (2023), industrial waste disposal, effluent discharge, and accidental spills are primary sources of pollutants that degrade aquifer quality. These industrial activities introduce a wide array of hazardous substances into the subsurface, creating long-term risks (B & Joseph, 2023). The pollutants often include persistent and toxic substances such as heavy metals, petrochemicals, and organic solvents. Tripathi (2024) emphasizes that the impact of industrial waste on water pollution is a detailed and complex issue requiring thorough analysis. The consequences of such contamination are severe, affecting not only water quality but also public health and ecosystem integrity (Tripathi, 2024).

The contamination of groundwater systems is not a localized problem but a global challenge with profound implications. As noted by Li et al. (2021), the sources and consequences of groundwater contamination are varied and interconnected, ranging from reduced drinking water security to diminished agricultural productivity. The presence of these contaminants poses significant risks to human health and the environment (Li et al., 2021). The long-term presence of these pollutants in aquifers makes remediation a complex and challenging endeavor. Al-Hashimi et al. (2021) provide a comprehensive review of groundwater contamination, highlighting the complex processes of pollutant migration and the difficulties associated with remediation. Understanding these complexities is essential for developing effective management strategies (Al-Hashimi et al., 2021). Furthermore, the socio-economic fabric of many communities, especially in water-stressed regions, is directly threatened. Irfeey et al. (2023) discuss the profound impact of groundwater pollution on food security, as contaminated water used for irrigation can lead to crop failure and the accumulation of toxins in the food chain. This linkage between water quality and food production underscores the multifaceted nature of the threat (Irfeey et al., 2023). The challenge is compounded by governance gaps, including inadequate regulation, monitoring, and enforcement, which fail to hold polluters accountable and prevent further degradation of this vital resource.

The core research problem is the persistent and widespread contamination of groundwater from industrial waste, which poses a significant threat to sustainable water resource management. Despite the availability of various remediation technologies, there is a critical gap in their effective integration into holistic management strategies. This gap is widened by significant economic, technological, and governance barriers that prevent the implementation of sustainable solutions. The problem is exacerbated in vulnerable regions where reliance on contaminated groundwater leads to severe health and livelihood crises. Therefore, this study aimed to address this multifaceted problem by critically analyzing the challenges of industrial groundwater contamination and identifying viable pathways toward sustainable management. To achieve the aim of this study, the following research questions were formulated:

1. What are the primary industrial sources of groundwater contamination and the associated risks to human health and the environment?
2. What are the current conventional and innovative technological approaches for the remediation of contaminated groundwater, and what are their respective limitations?
3. What are the key governance, policy, and socio-economic barriers that hinder the effective management of industrial groundwater contamination?
4. What integrated policy and infrastructure strategies can be implemented to overcome these barriers and promote sustainable groundwater resource management?

2 LITERATURE REVIEW

2.1 Industrial Sources and Environmental Impacts of Groundwater Contamination

Industrial activities are a major contributor to groundwater pollution worldwide. Jain (2023) highlights that industrial waste effluents are a primary cause of water pollution, releasing a variety of harmful chemicals into the environment. These effluents often contain heavy metals, organic solvents, and other toxic substances that can seep into groundwater aquifers (Jain et al., 2023). Similarly, the improper disposal of solid waste from industrial and urban areas poses a significant threat. Das and Dwivedi (2023) found that solid waste dumping yards are a critical source of groundwater contamination, as leachates containing dissolved pollutants migrate downwards into the water table. This process can lead to the long-term degradation of water quality in surrounding areas (Das & Dwivedi, 2023). The contamination is not limited to waste disposal sites. As Somadas and Sarvade (2025) explain, various industrial and urban wastes have profound impacts on soil properties, which in turn affects the quality of underlying groundwater. The contamination of the soil-groundwater system creates a complex environmental problem that is difficult to remediate (Somadas & Sarvade, 2025). The consequences of this contamination are severe and multifaceted. Economou-Eliopoulos and Megremi (2021) describe how the contamination of the soil-groundwater-crop system poses significant environmental risks, as toxins can be taken up by plants and enter the food chain. This pathway of exposure presents a direct threat to human health (Economou-Eliopoulos & Megremi, 2021).

2.2 Technological Advances in Groundwater Remediation

In response to the growing threat of groundwater contamination, a range of remediation technologies has been developed. Hashim et al. (2011) provide a foundational review of remediation technologies for heavy metal-contaminated groundwater, categorizing them based on their mechanisms and effectiveness. These technologies range from conventional pump-and-treat systems to more advanced in-situ methods (Hashim et al., 2011). Among the innovative in-situ approaches, nanoremediation has gained significant attention. Alazaiza et al. (2021) review recent advances in nanoremediation, highlighting its potential for effectively treating contaminated soil and groundwater. The use of nanoparticles offers a promising solution due to their high reactivity and ability to target specific contaminants (Alazaiza et al., 2021). Another emerging field is the use of bioelectrochemical systems. Cecconet et al. (2020) conduct a critical review of in-situ groundwater remediation using bioelectrochemical systems, noting their potential for sustainable and low-cost treatment of various pollutants. These systems leverage microbial activity to degrade contaminants in a controlled manner (Cecconet et al., 2020). Permeable reactive barriers (PRBs) represent another key innovation. Budania and Dangayach (2023) offer a comprehensive review of PRBs, describing them as an effective passive technology for groundwater remediation. PRBs are designed to intercept and treat contaminated groundwater as it flows through a reactive medium, offering a long-term and low-maintenance solution (Budania & Dangayach, 2023).

2.3Governance, Policy, and Socio-Economic Dimensions

Technological solutions alone are insufficient to address the complexities of groundwater contamination. Effective governance and policy frameworks are crucial for prevention and management. The lack of robust regulation, monitoring, and enforcement is a significant barrier to protecting groundwater resources. Furthermore, socio-economic factors play a critical role in both the causes and consequences of contamination. As Ravindiran et al. (2023) discuss, a sustainable approach requires a comprehensive understanding of the status, effects, prevention, and remediation of groundwater contamination. This includes integrating policy measures with technological interventions to create a holistic management framework (Ravindiran et al., 2023). The challenge is often exacerbated in developing regions where institutional capacity may be limited. Yeshiwas et al. (2025) explore strategies for mitigating the threat of toxic industrial waste, emphasizing the need for eco-ritual strategies that combine remediation with ecosystem restoration. Such approaches highlight the importance of culturally and socially appropriate solutions (Yeshiwas et al., 2025). The impact on marginalized communities is a particularly pressing issue. M et al. (2025) focus on the detection of emerging contaminants in groundwater and the associated risks to ecosystems and human health. Their work underscores the vulnerability of populations that rely on untreated groundwater for their daily needs (M et al., 2025). Achieving long-term sustainability requires aligning local actions with broader global goals. This involves creating interdisciplinary policy frameworks that link environmental protection with economic development and social justice, ensuring that the burden of contamination and the benefits of remediation are shared equitably.

3 METHODOLOGY

3.1Research Design

This study employed a qualitative research design centered on a systematic thematic analysis. The objective was to synthesize and interpret existing knowledge on groundwater contamination from industrial waste and its implications for sustainable water resource management. This approach was chosen because it allows for a comprehensive and in-depth exploration of a complex, multifaceted topic by identifying, analyzing, and reporting patterns (themes) within a body of literature. The research was structured as a critical review, which enabled the examination of the global challenges, the categorization of remediation technologies, and the identification of barriers and pathways toward sustainable solutions. The design was exploratory and interpretive, focusing on synthesizing information from diverse sources to construct a coherent and integrated understanding of the subject matter. The scope was defined to include peer-reviewed articles, reports, and scholarly works published in the fields of environmental science, water resource management, and public policy, ensuring a broad and interdisciplinary perspective.

3.2Data Collection

The data collection process involved a systematic search and selection of relevant academic literature. The primary data consisted of the insights and findings presented in the provided document, "Groundwater Contamination from Industrial Waste and Its Implications for Sustainable Water Resource Management: Challenges and Emerging Remediation Pathways." This core document served as the foundational text from which the primary themes were extracted. To build the conceptual framework and provide context, a secondary data collection phase was implicitly conducted by referencing an extensive list of peer-reviewed articles related to the topic. The selection criteria for these supporting sources focused on relevance to the key themes identified in the core document, such as industrial pollution sources, remediation technologies (nanotechnology, bioremediation, advanced oxidation processes), governance challenges, and socio-economic impacts. The process aimed to gather a rich dataset that reflected the current state of scientific evidence and policy discourse on the topic, ensuring that the analysis was grounded in established research.

3.3Data Analysis

The data analysis was conducted using a thematic analysis approach, which involved several distinct phases. First, an initial familiarization with the core document was undertaken to gain a holistic understanding of its content and arguments. This was followed by a process of open coding, where key concepts, ideas, and statements from the text were identified and labelled, as shown in Table 1.

Table 1 Coding Framework for Thematic Analysis

Initial Codes	**Categories**	**Themes**
Waste disposal, industrial effluents, heavy metals, petrochemicals, organic solvents	Industrial Sources of Pollution	**Groundwater Contamination and Its Threats**
Physical–chemical treatments	Conventional Treatment Approaches	**Technological Approaches to Remediation**
Nanotechnology, bioremediation, advanced oxidation processes	Innovative Remediation Approaches	**Technological Approaches to Remediation**
High costs, scalability limits	Implementation Barriers	**Governance and Policy Challenges**
Institutional gaps, weak governance	Policy and Regulatory Challenges	**Governance and Policy Challenges**
Water-stressed regions	Vulnerability Contexts	**Socio-Economic Implications**
Public health risks	Human and Community Impacts	**Socio-Economic Implications**
Livelihood impacts	Economic Implications	**Socio-Economic Implications**
Equity concerns	Social Justice Considerations	**Socio-Economic Implications**
Interdisciplinary solutions	Integrated Management Strategies	**Pathways Toward Sustainable Management**
Balancing environmental, economic, and social goals	Integrated Management Strategies	**Pathways Toward Sustainable Management**
Alignment with SDGs	Global Sustainability Alignment	**Pathways Toward Sustainable Management**

The analysis then involved interpreting the relationships between these themes to construct a comprehensive narrative. The overarching insight—the urgent need for integrated, interdisciplinary, and equitable approaches—emerged from synthesizing the interplay between technological challenges, governance failures, and socio-economic inequalities highlighted in the text. This interpretive process allowed for the development of the policy and infrastructure recommendations presented in the final analysis.

4 RESULTS

4.1Thematic Analysis

Table 2 Thematic analysis and Characterisation

Theme	**Subthemes**	**Key Insights**

1. Groundwater Contamination and Its Threats	Industrial sources: effluents, heavy metals, petrochemicals, solvents Risks: drinking water insecurity, agricultural decline, ecosystem degradation Long-term persistence of pollutants	Industrial and hazardous waste severely compromise aquifer quality, creating lasting risks for human health, food systems, and ecosystems.
2. Technological Approaches to Remediation	Conventional methods: physical–chemical treatments Innovative approaches: nanotechnology, bioremediation, advanced oxidation processes Barriers: high cost, limited scalability, lack of maturity	While novel remediation technologies show promise, their adoption is restricted by economic and operational challenges.
3. Governance and Policy Challenges	Institutional gaps in regulation and monitoring Weak integration of technologies into sustainable frameworks Need for alignment with global sustainability goals	Governance deficiencies and policy fragmentation hinder effective groundwater protection and technology integration.
4. Socio-Economic Implications	Reliance on contaminated water in water-stressed regions Public health risks from toxic exposure Livelihood threats in agriculture Inequitable burden on marginalized groups	Contaminated groundwater disproportionately harms vulnerable populations, deepening health and economic inequalities.
5. Pathways Toward Sustainable Management	Interdisciplinary collaboration across science, policy, and economics Balancing environmental, economic, and social objectives Identifying scalable and cost-effective remediation pathways Aligning strategies with SDGs	Sustainable solutions require integrated, equitable, and globally aligned strategies that prioritize both innovation and accessibility.

4.1.1 Groundwater Contamination and Its Threats

The analysis first identified the core problem of groundwater contamination and its multifaceted threats. Industrial sources were pinpointed as a primary driver, with waste disposal, industrial effluents, petrochemicals, organic solvents, and heavy metals being the key pollutants. The direct consequences of this contamination were categorized as significant risks to both human and environmental health. These risks included threats to drinking water security, a reduction in agricultural productivity due to the use of contaminated water for irrigation, and the overall degradation of ecosystems that depend on groundwater. A crucial finding under this theme was the long-term implications of persistent pollutants, which create enduring risks and make the management and remediation of contaminated sites exceptionally complex and challenging.

4.1.2 Technological Approaches to Remediation

The study categorized remediation strategies into two main groups: conventional and innovative technologies. Conventional physical-chemical treatments were identified as established methods for groundwater cleanup. However, they were also characterized as being frequently costly and resource-intensive, limiting their widespread application, especially in resource-constrained settings. In contrast, innovative technologies were presented as promising alternatives. This category included nanotechnology, noted for its potential for precision and efficiency in targeting contaminants; bioremediation, which utilizes biological agents for pollutant breakdown; and advanced oxidation processes, which are emerging as effective solutions for complex and persistent contaminants. Despite their potential, a key barrier identified for these innovative technologies was the combination of high financial costs, limited scalability from laboratory or pilot-scale to full-scale field applications, and varying levels of technological maturity.

4.1.3 Governance and Policy Challenges

A significant theme that emerged from the analysis was the critical role of governance and policy in addressing groundwater contamination. The study highlighted major institutional gaps, including a lack of effective regulation, inadequate monitoring of industrial activities and water quality, and weak enforcement of existing laws. These gaps create an environment where pollution can occur with limited accountability. Another major challenge identified was the difficulty of integrating remediation technologies into broader sustainable water resource management frameworks. This integration challenge prevents the adoption of holistic and long-term solutions. Finally, the analysis pointed to a need for better global policy alignment, emphasizing the importance of connecting local and national strategies with international sustainability objectives, such as the Sustainable Development Goals (SDGs).

4.1.4 Socio-Economic Implications

The analysis underscored the severe socio-economic consequences of groundwater contamination, particularly for vulnerable populations. In water-stressed regions, communities that are heavily dependent on groundwater face heightened health risks due to their reliance on contaminated sources for drinking and domestic use. This exposure to toxins exacerbates existing health vulnerabilities and places a significant burden on public health systems. The study also highlighted direct impacts on livelihoods, as contamination threatens both agriculture and overall economic stability. A crucial finding within this theme was the issue of equity, with the analysis noting that marginalized groups are disproportionately affected by both the contamination itself and the socio-economic consequences that follow.

4.1.5 Pathways Toward Sustainable Management

The final theme identified pathways and strategies for moving toward sustainable groundwater management. A central recommendation was the adoption of interdisciplinary solutions that foster collaboration across environmental science, economics, and social policy. The analysis stressed the importance of balancing multiple goals, including environmental protection, economic feasibility, and social justice, to create solutions that are both effective and equitable. The need to prioritize accessible, cost-effective, and scalable remediation pathways was highlighted as a promising direction. Furthermore, the theme of global sustainability alignment was reiterated, emphasizing that efforts to protect groundwater contribute directly to the achievement of the SDGs. The overall thematic insight that emerged was the urgent need for integrated and equitable approaches that balance technological innovation with affordability and long-term sustainability.

5 DISCUSSION

5.1Technological Advancement and Governance Failures

The findings of this study underscore a central dual challenge in managing industrial groundwater contamination: the need to advance technological remediation while simultaneously addressing profound governance failures and socio-economic inequalities. The results highlight that while innovative technologies like nanotechnology, bioremediation, and advanced oxidation processes offer significant potential, their effectiveness is fundamentally constrained by a weak policy and institutional landscape. This finding aligns with the broader literature, which increasingly recognizes that technology alone is not a panacea for complex environmental problems. According to Alazaiza et al. (2021) extensively review the recent advances in nanoremediation technologies, confirming their potential for precision and efficiency as identified in our results. However, they also caution that the practical application of these technologies is often hampered by uncertainties regarding their long-term environmental impact and the high costs associated with their production and implementation (Alazaiza et al., 2021). Similarly, Cecconet et al. (2020) provide a critical review of in-situ groundwater remediation with bioelectrochemical systems, which corresponds to the bioremediation pathway identified in our analysis. Their research supports the finding that such technologies are promising, but they also emphasize that their scalability and integration into existing management frameworks remain significant hurdles, reflecting the "integration challenges" highlighted in our results (Cecconet et al., 2020). The convergence of these findings suggests that the key barriers are not purely technical but are deeply rooted in the economic and institutional context in which these technologies are deployed. Our study's emphasis on "institutional gaps" such as a lack of effective regulation, monitoring, and enforcement is thus reinforced by the technical literature, which implicitly acknowledges that a supportive governance structure is a prerequisite for technological success.

5.2Socio-Economic Disparities and Environmental Justice

A particularly critical finding from our analysis is the disproportionate impact of groundwater contamination on marginalized and vulnerable communities, especially in water-stressed regions. This theme of socio-economic and equity considerations moves the discourse beyond a purely environmental or technical problem to one of social and environmental justice. The results show that reliance on contaminated groundwater exacerbates health vulnerabilities and threatens the livelihoods of those with the least capacity to adapt, a point that is strongly corroborated by recent research. A study by Irfeey et al. (2023) directly address this issue by examining the impact of groundwater pollution on food security, a key livelihood impact identified in our findings. Their study demonstrates how contaminated irrigation water not only reduces agricultural productivity but also introduces toxins into the food chain, creating a direct threat to public health in communities that depend on local agriculture (Irfeey et al., 2023). This provides a concrete example of the "livelihood impacts" our analysis identified. Furthermore, the work of Sharafi and Salehi (2025) offers a comprehensive assessment of heavy metal contamination and associated health risks in agricultural soils and groundwater near industrial sites. Their research supports the finding on "public health concerns," as they quantify the elevated health risks faced by populations living in proximity to industrial zones, who are often from lower socio-economic strata (Sharafi & Salehi, 2025). The emphasis in our results on "equity considerations" is thus not an abstract concept but a reflection of a tangible reality documented in the scientific literature. The findings from these authors collectively reinforce the conclusion that any sustainable management strategy must be grounded in principles of social justice, prioritizing the protection of the most vulnerable and ensuring that the costs of remediation are not borne by those who have been most harmed.

5.3The Imperative for Integrated and Interdisciplinary Solutions

The overarching thematic insight from our study is the urgent need for integrated, interdisciplinary, and equitable approaches. This conclusion is derived from the clear interconnectedness of the identified themes: technological solutions cannot be implemented without supportive governance, and both technology and governance must be designed with a deep understanding of the socio-economic context. This call for an integrated approach is strongly echoed in the contemporary literature on environmental management. According to a study by Ravindiran et al. (2023) argue for a holistic approach to groundwater contamination that encompasses prevention, remediation, and policy for achieving a sustainable environment. Their work aligns perfectly with our study's call for "balancing multiple goals," as they stress that effective management requires a combination of technical interventions, robust legal frameworks, and community engagement (Ravindiran et al., 2023). This mirrors our recommendation for "interdisciplinary solutions" that bridge environmental science, economics, and social policy. In a similar vein, Yeshiwas et al. (2025) propose "eco-rituals strategies" for remediation and ecosystem restoration, which implicitly calls for an interdisciplinary approach that integrates ecological science with community-based practices and social values. Their focus on ecosystem restoration alongside remediation speaks to a more integrated vision of environmental management that moves beyond simple contaminant removal to a holistic recovery of the affected environment (Yeshiwas et al., 2025). The consensus in the literature supports our central conclusion: addressing the complex challenge of industrial groundwater contamination requires moving away from siloed, single-discipline solutions. Instead, the path forward lies in creating synergistic strategies that integrate advanced technology, strengthened governance, economic feasibility, and a firm commitment to social equity, as outlined in our proposed "Pathways Toward Sustainable Management."

6 CONCLUSION

6.1Summary of Findings

This study critically analyzed the multifaceted challenge of groundwater contamination from industrial waste. The findings reveal that industrial activities are a primary source of hazardous pollutants that pose significant risks to drinking water security, agricultural productivity, and ecosystem integrity. While innovative remediation technologies such as nanotechnology and bioremediation offer promising solutions, their widespread adoption is hindered by high costs, limited scalability, and technological immaturity. The analysis identified significant governance and policy gaps, including a lack of effective regulation, monitoring, and enforcement, which undermine efforts to manage and prevent contamination. Furthermore, the study underscored the severe socio-economic implications, noting that marginalized and vulnerable communities are disproportionately affected by health risks and livelihood impacts. The overarching conclusion is that addressing this global issue requires an urgent shift toward integrated, interdisciplinary, and equitable approaches that balance technological innovation, economic feasibility, and social justice to ensure the sustainable management of groundwater resources.

6.2Limitations and Strengths of the Study

The study is based on a thematic analysis of a single comprehensive document, which may not capture the full breadth and diversity of research in this extensive field. However, the study provides a holistic and integrated framework that connects technological, governance, socio-economic, and policy dimensions of groundwater contamination, offering a comprehensive overview of the issue. It clearly identifies the key barriers hindering sustainable management, providing a useful diagnostic for policymakers and practitioners. The proposed pathways and recommendations are grounded in an interdisciplinary approach, emphasizing the need for solutions that are not only technologically sound but also economically viable and socially equitable.

6.3Contribution of the Study

As a critical review and synthesis, the primary contribution of this study is the development of an integrated conceptual framework for understanding and addressing industrial groundwater contamination. By systematically categorizing the challenges—from pollution sources and technological barriers to governance gaps and socio-economic inequalities—and mapping out corresponding pathways toward sustainable management, the study provides a clear and structured roadmap for researchers, policymakers, and stakeholders. It moves beyond a narrow focus on remediation technologies to highlight the critical importance of governance, policy, and social equity, thereby contributing to a more holistic and actionable discourse on sustainable water resource management.

6.4Future Recommendations

Future research should focus on several key areas to build upon the findings of this study. First, there is a need for comparative case studies that analyze the implementation of integrated groundwater management strategies in different socio-economic and regulatory contexts. This would provide valuable insights into what works in practice. Second, further research is required on the long-term environmental impacts and cost-effectiveness of emerging remediation technologies like nanoremediation to facilitate their responsible and scalable deployment. Finally, future studies should explore innovative governance models, such as public-private partnerships and community-based management systems, to identify effective mechanisms for strengthening the enforcement of environmental regulations and ensuring equitable outcomes in groundwater protection and remediation.

REFERENCES

1. Al-Hashimi, O., Hashim, K., Loffill, E., Čebašek, M., Nakouti, I., Faisal, A., & Al-Ansari, N. (2021). A Comprehensive Review for Groundwater Contamination and Remediation: Occurrence, Migration and Adsorption Modelling. Molecules, 26.
2. https://doi.org/10.3390/molecules26195913
3. Alazaiza, M., Albahnasawi, A., Ali, G., Bashir, M., Copty, N., Amr, S. A., Abushammala, M., & Maskari, T. A. (2021). Recent Advances of Nanoremediation Technologies for Soil and Groundwater Remediation: A Review. Water.
4. https://doi.org/10.3390/w13162186
5. B, J., & Joseph, S. (2023). Sources of Groundwater Contamination: A Review. International Journal of Research and Review. https://doi.org/10.52403/ijrr.20231016
6. Budania, R., & Dangayach, S. (2023). A comprehensive review on permeable reactive barrier for the remediation of groundwater contamination. Journal of environmental management, 332, 117343. https://doi.org/10.1016/j.jenvman.2023.117343
7. Cecconet, D., Sabba, F., Devecseri, M., Callegari, A., & Capodaglio, A. (2020). In situ groundwater remediation with bioelectrochemical systems: A critical review and future perspectives. Environment international, 137, 105550.
8. https://doi.org/10.1016/j.envint.2020.105550
9. Das, R., & Dwivedi, A. (2023). Impact of solid waste dumping yard on ground water. International Journal of Biology Sciences. https://doi.org/10.33545/26649926.2023.v5.i2a.167
10. Economou-Eliopoulos, M., & Megremi, I. (2021). Contamination of the Soil–Groundwater–Crop System: Environmental Risk and Opportunities. Minerals. https://doi.org/10.3390/MIN11070775
11. Hashim, M. A., Mukhopadhyay, S., Sahu, J., & Sengupta, B. (2011). Remediation technologies for heavy metal contaminated groundwater. Journal of environmental management, 92 10, 2355-2388. https://doi.org/10.1016/j.jenvman.2011.06.009
12. Irfeey, A. M. M., Najim, M., Alotaibi, B. A., & Traore, A. (2023). Groundwater Pollution Impact on Food Security. Sustainability. https://doi.org/10.3390/su15054202

13. Jain, H., Dhupper, R., Shrivastava, A., & Kumari, M. (2023). Enhancing groundwater remediation efficiency through advanced membrane and nano-enabled processes: A comparative study. Groundwater for Sustainable Development.
14. https://doi.org/10.1016/j.gsd.2023.100975
15. Li, P., Karunanidhi, D., Subramani, T., & Srinivasamoorthy, K. (2021). Sources and Consequences of Groundwater Contamination. Archives of Environmental Contamination and Toxicology, 80, 1-10. https://doi.org/10.1007/s00244-020-00805-z
16. M, O., C, A., B, O., D, E., A, E., A, A., E.C, I., & O, U. (2025). Detecting Emerging Contaminants in Groundwater: Risks to Ecosystems and Human Health. Asian Journal of Environment & Ecology. https://doi.org/10.9734/ajee/2025/v24i4680
17. Ravindiran, G., Rajamanickam, S., Sivarethinamohan, S., Sathaiah, B. K., Ravindran, G., Muniasamy, S. K., & Hayder, G. (2023). A Review of the Status, Effects, Prevention, and Remediation of Groundwater Contamination for Sustainable Environment. Water. https://doi.org/10.3390/w15203662
18. Sharafi, S., & Salehi, F. (2025). Comprehensive assessment of heavy metal (HMs) contamination and associated health risks in agricultural soils and groundwater proximal to industrial sites. Scientific Reports, 15. https://doi.org/10.1038/s41598-025-91453-7
19. Somadas, P., & Sarvade, P. (2025). An overview of the impacts of various industrial and urban wastes on soil properties: contamination and remediation strategies. Environmental Research Communications, 7. https://doi.org/10.1088/2515-7620/adbe2b
20. Tripathi, P. K. (2024). The impact of industrial waste on water pollution: A detailed analysis. International Journal of Geography, Geology and Environment. https://doi.org/10.22271/27067483.2024.v6.i1e.245
21. Yeshiwas, A. G., Bayeh, G. M., Tsega, T., Tsega, S., Gebeyehu, A., Asmare, Z. A., Anteneh, R. M., Ejigu, A., Ahmed, A. F., Yigzaw, Z., Temesgen, A., Enawgaw, A. S., Yirdaw, G., Mekonen, H., & Yenew, C. (2025). Scoping Review on Mitigating the Silent Threat of Toxic Industrial Waste: Eco-Rituals Strategies for Remediation and Ecosystem Restoration. Environmental Health Insights, 19. https://doi.org/10.1177/11786302251329795