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Sustainable Lake Water Conservation in Mining Areas: A Systematic Review of Influencing Factors and Strategic Frameworks

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Abstract: Lakes in mining areas face serious ecological degradation due to complex interactions between human activities, land use change, and industrial pressures. Globally, approximately 46.7% of lakes have lost their ecosystem resilience, with impacts such as declining water quality, sedimentation, heavy metal pollution, and biodiversity loss. While previous studies have mostly focused on post-mining pit lakes, limited attention has been given to conservation in active mining areas, leaving a critical research gap. This study aims to identify the factors influencing lake water resource conservation in mining regions, analyze the interrelationships among these factors, develop a conceptual model, and propose contextual strategies for sustainable conservation. A systematic literature review was conducted following the PRISMA 2020 protocol, using searches on Scopus and Web of Science for English-language publications from 2015 to 2025. Inclusion criteria emphasized empirical studies addressing lake conservation in mining areas. Study quality was assessed using the Mixed Methods Appraisal Tool (MMAT) version 2018, and data synthesis employed thematic analysis with NVivo 14 to identify key themes, factor relationships, and model design. From an initial 642 articles, 114 studies met the criteria. The analysis identified 13 key factors, with three dominant determinants: human–environment interaction, eco-friendly technology and innovation, and socio-economic pressures. Factor relationships included direct pathways such as institutional capacity and social capital, mediating roles such as environmental education and leadership, and negative moderation through economic pressures. The resulting conceptual model emphasizes integrating technological interventions, social capacity building, and environmental value internalization. Priority strategies include environmental education, institutional strengthening, community participation, and adoption of mitigation technologies. Overall, lake conservation in mining contexts requires an integrative social–ecological systems approach that balances technical innovation, social interventions, and mitigation of economic drivers.

Keywords: Lake conservation; Mining areas; Human–environment interactions; Environmentally friendly technology; Systematic literature review

1 Introduction

Lakes are one of the freshwater ecosystems that play a vital role in maintaining environmental balance, both as a source of clean water, a supporter of biodiversity, and a buffer against climate change [1]. However, in recent decades, anthropogenic pressures on lakes have shown a concerning trend. Approximately 46.7% of global lakes have experienced a decline in ecosystem resilience due to human activities, particularly land-use changes and industrial activities such as mining [2]. This phenomenon indicates that lakes that were once in a stable ecological condition are now under serious threat due to uncontrolled human activities. This situation is exacerbated by the increasing exploitation of natural resources around lake areas, which directly impacts water quality and quantity, as well as the degradation of riparian ecosystems that support the overall function of lakes [3].

The negative impact of mining activities on lakes is not limited to physical changes to the landscape, but also has implications for the chemical and biological quality of the water. Land use activities around lakes contribute to increased concentrations of heavy metals, sedimentation, and eutrophication, which ultimately damage aquatic community structures and reduce biodiversity [4]. In addition, morphological changes to lakes due to sedimentation and reduced riparian vegetation cause damage to habitats that are important for endemic species [5]. These conditions severely disrupt the lake ecosystem's function as a regulator of water and carbon cycles. In the Indonesian context, this challenge is further complicated by the presence of numerous lakes in mining-rich regions, increasing the potential for conflicts between conservation and exploitation and necessitating science-based interventions and integrated policies.

The existing body of research examining lake degradation in mining contexts exhibits considerable fragmentation, with scholarly attention disproportionately directed toward post-mining pit lakes rather than the more complex socio-ecological realities characterizing lakes situated within active extraction zones. While technical investigations have contributed valuable insights into hydrological engineering, catchment management, and experimental water treatment approaches [6, 7]. These works demonstrated uneven methodological standards and frequently presuppose stable environmental conditions typical of post-closure scenarios—conditions that differ substantially from the dynamic circumstances surrounding ongoing mining operations. Similarly, studies addressing geochemical contamination, sediment accumulation, and heavy-metal transport in mining-affected lake systems [8–10] have tended to foreground physicochemical indicators while neglecting critical dimensions such as community-based governance, institutional effectiveness, and the pressures arising from socio-economic dependencies. Furthermore, the literature reveals inconsistent conclusions regarding remediation efficacy; some technologies demonstrate promising short-term results, whereas others prove inadequate when confronted with the fluctuating hydrological regimes of active mining environments [11, 12]. These discrepancies reflect a persistent tendency within the field to operate within disciplinary boundaries, thereby constraining efforts to develop integrated understandings of lake conservation amid sustained industrial activity.

Concurrently, large-scale global analyses have established linkages between anthropogenic activities and the erosion of lake ecosystem resilience [2], yet such assessments typically fall short of delineating the specific causal mechanisms operating within mining-dominated landscapes or clarifying the differential role that socio-institutional arrangements play in shaping conservation outcomes across varied regional contexts. Although comparative investigations have illuminated how ecological vulnerabilities, fragmented governance structures, and asymmetrical stakeholder power relations influence conservation effectiveness in distinct settings [13, 14], These valuable insights have seldom been synthesized into analytical frameworks applicable to lakes experiencing active mining pressures. As a result, notwithstanding the substantial contributions of prior scholarship, a significant knowledge gap remains: the field lacks systematic efforts to integrate findings across disciplinary boundaries, identify principal determinants of conservation success, elucidate patterns of interaction among influencing factors, and construct comprehensive conservation models suited to the particular challenges posed by ongoing extractive activities. The present study responds to this gap by weaving together ecological, technological, and socio-institutional perspectives into a more unified conceptual framework for understanding lake conservation in active mining regions.

This study aims to identify factors that influence the conservation of lake water resources in mining areas, analyze the relationships between these factors, design a sustainable conservation model, and formulate contextual conservation strategies that can be implemented by stakeholders. The implications of this research include providing a strong scientific basis for policymakers in formulating regulations for lake management in mining areas, as well as contributing to evidence-based conservation practices. Furthermore, these findings are expected to enrich the conceptual framework in the field of ecology and water resource conservation, particularly in addressing environmental conservation challenges amid the growing pressure of extractive industry development.

Addressing these research gaps, this study developed four research questions, each serving a distinct analytical purpose. The first question asks: what factors have been identified in the literature as influencing lake water conservation in mining regions? Here, this study focuses on systematically mapping and categorizing the determinants reported across various empirical studies. Moving beyond simple identification, the second question explores how these factors interact with one another across different socio-ecological and governance settings. Rather than treating these factors as isolated variables, this study examines the structural connections and causal dynamics described in existing research. The third question shifts toward synthesis: what conceptual or operational models of lake conservation emerge from the reviewed evidence? This involves integrating findings into coherent frameworks that can guide both theory and practice. Finally, the fourth question addresses practical application: what strategies have proven effective for stakeholders managing mining-affected lake ecosystems? Through this structured inquiry, we progressively identify key determinants, interpret their relationships, construct an integrative conservation model, and translate findings into actionable strategies.

2 Methodology

This study employs a systematic literature review approach designed to be systematic, transparent, and replicable for identifying, evaluating, and synthesizing evidence related to lake conservation in mining areas. The study design follows evidence-based research principles [15], emphasizing methodological transparency and systematic structure in literature collection and analysis.

The literature search scope was formulated using the Population, Intervention, Comparison, Outcome (PICO) framework as detailed in Table 1. Articles were searched through two leading scientific databases, Scopus and Web of Science, ensuring broad source coverage and academic quality. The search strategy utilized Boolean logic with keyword combinations (Table 2).

Table 1. Scope of literature search

Components	Description
Population	Lakes around mining areas.
Intervention	Conservation strategies, conservation policies, and management models.
Comparison	Cross-location studies or approaches that do not use conservation strategies.
Outcome	Identification of factors, relationships between factors, conservation models, and conservation strategies.

Table 2. Database and keyword strings

Database	Keyword String
Scopus	TITLE-ABS-KEY ((“water” OR “hydrology”) AND (“resource” OR “supply”) AND (“conservation” OR “management” OR “sustainability”) AND (“mining” OR “extraction”) AND (“area” OR “region” OR “site” OR “location”) AND (“lake”)).
WoS	((“water” OR “hydrology”) AND (“resource” OR “supply”) AND (“conservation” OR “management” OR “sustainability”) AND (“mining” OR “extraction”) AND (“area” OR “region” OR “site” OR “location”) AND (“lake”)) (Title).

The development of the search strategy involved an iterative three-stage refinement process to achieve an optimal balance between comprehensiveness and precision. During the initial stage, broad keyword combinations related to water, conservation, and mining were employed, yielding over 2,000 preliminary records. The second stage incorporated more specific terminology associated with mining contexts, such as pit lake and extraction area, which helped narrow the scope of results. In the final stage, Boolean operators were further refined, and keyword searches were limited to title and abstract fields, producing the finalized search strings presented in Table 2. This systematic refinement approach ensured that the search captured studies with direct relevance to lake conservation in mining contexts while reducing the inclusion of unrelated literature.

The search period was limited to publications from the past 10 years (2015–2025) in English only. Inclusion and exclusion criteria were strictly defined to maintain study relevance and focus (Table 3).

Table 3. Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
Empirical study focusing on lake conservation in mining areas	Theoretical studies or conceptual reviews without empirical data.
Published in peer-reviewed scientific journals in the last 10 years	Non-peer-reviewed articles, such as organizational reports or opinions.
Available in full text and in English	Articles in languages other than English or available only in abstract form.

The identification and selection process followed the PRISMA 2020 protocol [16], providing a framework for transparent and traceable reporting through four main stages: identification, screening, eligibility, and final inclusion. Methodological quality assessment employed the Mixed Methods Appraisal Tool (MMAT) version 2018 [17], chosen for its ability to uniformly evaluate various research designs (qualitative, quantitative, and mixed).

Methodological quality appraisal was conducted for all included studies using the MMAT 2018 to uphold the rigor and transparency of this systematic review. This assessment enabled the evaluation of consistency, validity, and overall methodological soundness across qualitative, quantitative, and mixed-methods research designs within the dataset. The findings indicated that most studies achieved moderate to high quality scores, with qualitative and mixed-methods studies generally demonstrating stronger methodological performance than certain non-randomized quantitative studies. Table 4 provides a summary of the quality assessment outcomes based on the MMAT criteria.

Table 4. Summary of study quality assessment using Mixed Methods Appraisal Tool (MMAT) version 2018

Study Type (MMAT Category)	Number of Studies (n = 114)	MMAT Criteria Met (%)	Quality Category
Qualitative Studies	38 studies	80%–100%	High Quality
Quantitative–Descriptive	21 studies	60%–80%	Moderate to High Quality
Quantitative–Non-randomized	27 studies	60%–75%	Moderate Quality
Quantitative–Randomized	4 studies	100%	High Quality
Mixed Methods Studies	24 studies	75%–100%	High Quality
Total	114 studies	–	–

Evaluation using the MMAT 2018, as presented in Table 4, revealed that the majority of included studies achieved moderate to high methodological quality scores. Notably, qualitative and mixed-methods research designs exhibited the most robust methodological standards, scoring between 75% and 100% on quality criteria. In contrast, several non-randomized quantitative studies demonstrated weaknesses, particularly concerning measurement validity and the adequate control of confounding variables. These quality variations underscore the importance of interpreting findings with appropriate caution, especially when synthesizing evidence from studies with differing methodological strengths. Nevertheless, the predominance of moderate-to-high quality studies provides a sufficiently reliable foundation for drawing meaningful conclusions regarding lake conservation factors in mining contexts.

Following the compilation of eligible studies, data extraction encompassed study location, lake type, conservation strategies, identified factors, and key results. Data analysis was conducted qualitatively using thematic analysis assisted by NVivo 14 software, enabling systematic identification of patterns and relationships between concepts for constructing a contextual theoretical model of lake conservation.

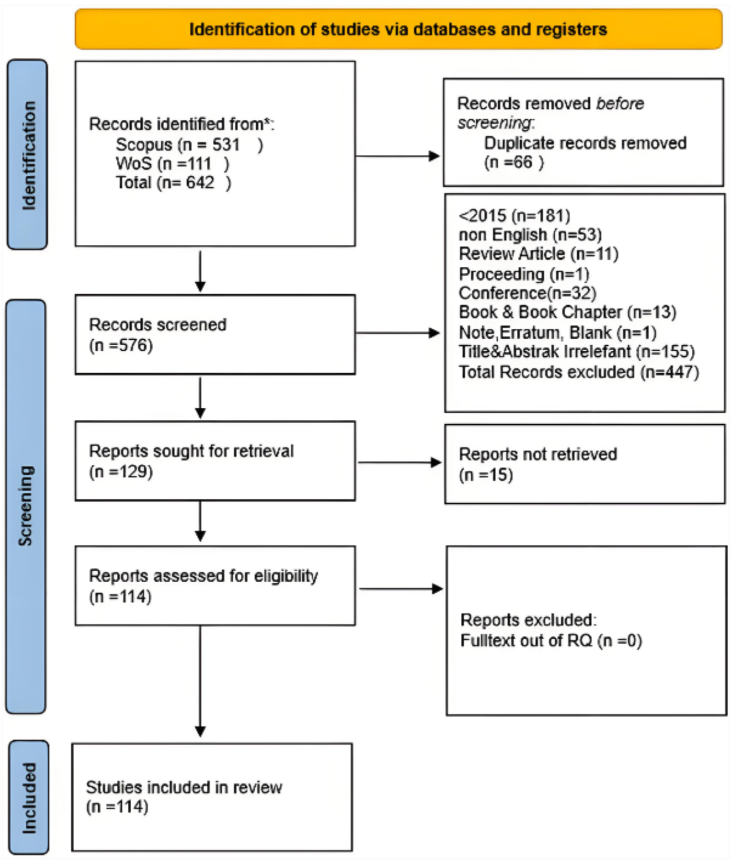

Figure 1. Prisma 2020 flow diagram

Based on the PRISMA 2020 flow diagram (Figure 1), the identification process began with searches in Scopus (531 articles) and Web of Science (111 articles), yielding 642 total records. After removing 66 duplicates, 576 records remained for screening. During this stage, 447 articles were excluded due to: publications before 2015 (181), non-English articles (53), review articles (11), proceedings (1), conference papers (32), books or book chapters (13), notes or errata (1), and irrelevant titles and abstracts (155). Of 129 reports sought, 15 were unobtainable, leaving 114 successfully accessed and assessed for eligibility. No reports were eliminated at the full-text stage as all aligned with the research question, resulting in 114 studies included in this systematic review.

Thematic analysis was performed with NVivo 14 software, following a systematic three-stage coding approach comprising open, axial, and selective coding in an iterative manner. The open coding phase initially yielded 176 distinct codes, which were subsequently refined and grouped into the twelve determinant categories reported in the Results section. To strengthen coding reliability, the research team engaged in multiple rounds of cross-verification throughout the analytical process. For the sake of methodological transparency, illustrative examples of the initial codes are presented below.

Sample Codes:

• "mine runoff increases sediment load" > Human–Environment Interaction > Hydrological disturbance.

• "community-led monitoring helps detect pollution early" > Community Participation > Monitoring activities.

• "use of remote sensing improved water level tracking" > Eco-friendly Technology & Innovation > Monitoring technologies.

• "economic dependence on mining reduces willingness to comply with conservation rules" > Economic & Social Pressures > Livelihood dependency.

• "local leaders mobilized collective clean-up activities" > Environmental Leadership > Collective action mobilization.

• "communities safeguard lakes due to ancestral identity ties" > History & Cultural Identity > Place attachment.

• "misaligned economic policies weaken conservation enforcement" > Social Structure & Institutions > Enforcement gaps.

• "low awareness of pollution risks hampers preventive action" > Environmental Risk Awareness > Risk perception.

Following the thematic coding process, the identification of relationship types among factors was conducted through a systematic analytical procedure grounded in established methodological conventions from social-ecological systems research and mediation-moderation analysis frameworks [18, 19]. Three categories of relationships were distinguished based on the following operational criteria:

(1) Direct relationships were identified when the literature explicitly described a factor as having an immediate, unmediated influence on conservation outcomes. Indicators included causal language such as "directly affects," "contributes to," or "determines," and empirical evidence demonstrating a primary effect without requiring intermediate variables.

(2) Mediating relationships were identified when a factor was described as transmitting or channeling the effect of another variable onto conservation outcomes. Key indicators included phrases such as "through," "via," "facilitates the effect of," or sequential causal chains where Factor A influences Factor B, which in turn influences conservation.

(3) Moderating relationships were identified when the literature indicated that a factor altered the strength or direction of relationships between other variables and conservation outcomes. Indicators included conditional language such as "depends on," "strengthens/weakens the effect," or "under conditions of," suggesting interaction effects rather than sequential mediation.

The classification process involved two researchers independently coding relationship types from each included study, followed by consensus discussions to resolve discrepancies. Inter-rater agreement reached 87% before consensus resolution. The conceptual model was constructed through an integrative synthesis process. First, all identified factors were mapped based on their citation frequency and thematic clustering. Second, relationship types were overlaid to create a network of connections. Third, factors were spatially arranged according to their predominant relationship type: direct factors positioned proximally to the conservation outcome, mediating factors positioned as intermediary nodes, and moderating factors positioned as contextual influences intersecting relationship pathways. This visual arrangement was iteratively refined through team discussions to ensure theoretical coherence with social-ecological systems frameworks.

3 Results

3.1 Description of Literature Obtained

This section provides an overview of the literature analyzed in this study, including the temporal distribution of publications, research topic trends, and the interrelationships between key themes in lake conservation in mining areas. Data visualization using bar charts and VOSviewer overlays is used to identify patterns in the growth of publications and the dynamics of keyword evolution.

Figure 2 shows the distribution of the number of articles published per year from 2015 to 2025. It can be seen that in the early period (2015–2017), the number of articles was relatively low and tended to decline from 8 articles in

2015 to 5 in 2017, then reached its lowest point in 2019 with only 1 article. Following this, there was a consistent and significant upward trend, beginning in 2020 with 6 articles, continuing to rise each year until reaching its peak in 2025 with 29 articles. This pattern indicates a growing interest or increased research productivity, particularly after 2019, which may be influenced by external factors such as funding policies, technological advancements, or increased research focus on specific topics. The sharpest increase occurred between 2024 and 2025, showing a very significant surge in publications in the final year.

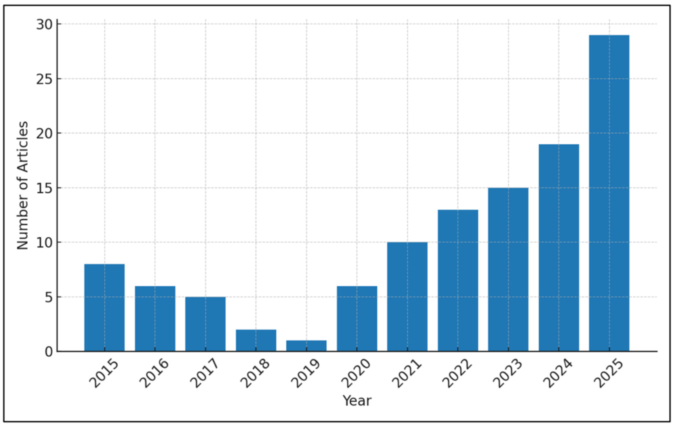

Figure 2. Temporal distribution of publications

The bibliometric analysis was conducted using VOSviewer software (version 1.6.19) with specific analytical parameters: a minimum keyword co-occurrence threshold of five, full counting method for keyword attribution, and overlay visualization mode to capture temporal dynamics. These parameters were selected to balance analytical comprehensiveness with interpretive clarity, ensuring that only keywords with sufficient recurrence across the corpus were retained while excluding peripheral terms that might obscure dominant thematic patterns.

The resulting visualization (Figure 3) illustrates keyword interrelationships in water resource management research through temporal color gradients (dark blue representing 2018 publications progressing to yellow for 2026) and node sizes proportional to occurrence frequency. Two distinct thematic clusters emerge from this analysis. The left cluster, dominated by earlier publications (2018–2021), features keywords such as remote sensing, Google Earth Engine, climate change, and environmental monitoring, reflecting an initial research emphasis on spatial analysis technologies and detection methodologies. The right cluster contains more recent topics (2022–2025), including water resources management, geochemistry, and heavy metals, indicating a scholarly pivot toward water quality assessment and pollution dynamics. Keywords such as Ebinur Lake function as bridging nodes connecting both clusters, suggesting that certain case studies have served as empirical platforms for integrating technological monitoring approaches with geochemical analyses. This temporal evolution—from technology-centered environmental monitoring toward integrated water quality management—reveals a disciplinary trajectory that the present review addresses by synthesizing both technical-ecological and socio-institutional dimensions into a unified conceptual framework, thereby responding to the fragmentation evident in the existing literature.

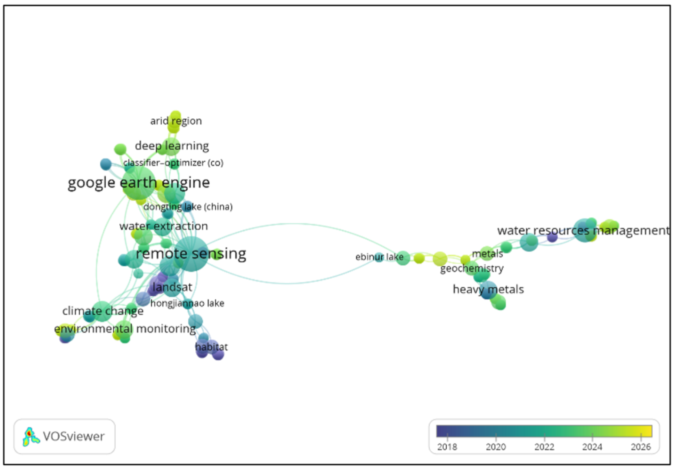

Figure 3. Interrelationships between main themes

3.2 Factors Affecting the Preservation of Lake Water Resources in Mining Areas

The conservation of lake water resources in mining areas involves complex interrelated factors spanning ecological, social, economic, technological, and institutional dimensions. Understanding these factors' distribution and roles is crucial for developing effective, adaptive, and sustainable management strategies, as illustrated in Figure 4.

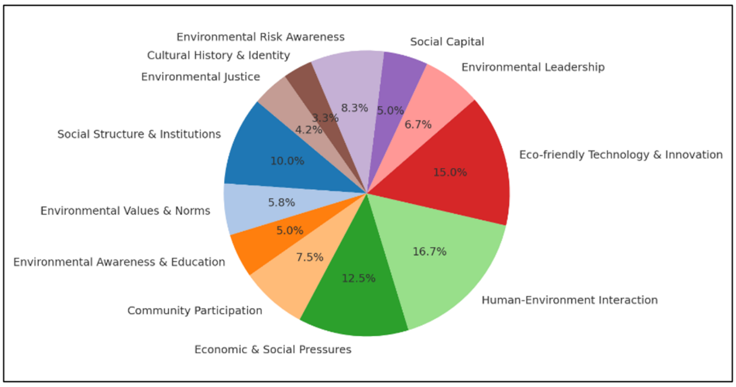

Figure 4. Summary of factors affecting lake water resource conservation

Analysis reveals that human-environment interaction (20 citations) dominates as the most influential factor in lake water conservation. This predominance indicates that reciprocal relationships between human activities—mining, irrigation, infrastructure development—and lake ecosystem responses determine degradation or sustainability outcomes. These interactions affect water quality, sediment dynamics, habitat loss, and systemic ecosystem function changes [10, 20]. For instance, a study documenting the cascading effects of coal mining on the groundwater-soil-vegetation system in the Bojianghaizi watershed, Inner Mongolia, revealed that mining-induced groundwater level changes significantly reduced soil water content by at least 49.73%, soil organic matter by 47.56%, and soil available nitrogen by 59.90% compared to non-mining areas. Furthermore, as the groundwater table increased from less than 0.5 m to more than 7 m depth, vegetation communities progressively transitioned from hydrophilic and halophytic species to xerophilous species, demonstrating the direct pathway through which extraction activities fundamentally alter lake-adjacent ecosystems [10].

Eco-friendly technology & innovation (18 citations) ranks second, emphasizing technology's critical role in mitigating mining's negative impacts. These technologies encompass satellite-based monitoring, wastewater treatment systems, and ecosystem rehabilitation techniques that restore water quality [12, 21]. The practical application of such technologies has been demonstrated at Poyang Lake, China's largest freshwater lake. By implementing the Otsu Method for histogram-based image segmentation combined with Sentinel-1 synthetic aperture radar (SAR) imagery on Google Earth Engine, this approach achieved 92% accuracy in detecting surface water extent after rectification. The cloud-based monitoring system enabled automated threshold selection for temporal and spatial variation analysis, revealing that Poyang Lake's surface water area fluctuated annually and tended to shrink both at its center and boundaries from 2017 to 2020 [12]. Similarly, an evaluation of phytoremediation capabilities using Ipomoea aquatica Forsk. (water spinach) was conducted across seven abandoned coal mine pit lakes in the Raniganj Coalfields, West Bengal, India. Over a 90-day period, the results indicated notable improvements in water quality post-phytoremediation, including substantial increases in dissolved oxygen (DO) levels, demonstrating that biological treatment technologies offer viable, cost-effective solutions for rehabilitating mining-affected water bodies [8].

Economic and social pressures (15 citations) follow, highlighting conflicts between mining, industrial, and agricultural economic needs versus conservation goals. These pressures drive excessive water exploitation, causing quality and quantity decline, while socio-economic demands compromise environmental standards [13, 22]. Compelling evidence of this tension emerged from a study at Lake Koronia, a Ramsar Convention wetland in Greece. Research documented a 30-year decline in environmental quality primarily driven by continuous groundwater extraction for agricultural irrigation, resulting in water scarcity, environmental degradation, and biodiversity loss. Critically, while most surveyed farmers acknowledged Lake Koronia's international protection status, many did not readily accept responsibility for its deterioration stemming from excessive water extraction and nitrogen pollution. However, the study also revealed notable willingness among farmers to transition to alternative fertilization methods, cultivate less water-intensive crops, adopt improved agricultural practices, and explore ecotourism opportunities—indicating that economic pressures, while powerful, can potentially be redirected through appropriate incentive structures [13].

Social structure & institutions (12 citations) significantly shape policy frameworks, law enforcement, and inter-agency coordination. Institutional strength determines conservation implementation success, exemplified through policies restricting mining in lake buffer zones [23]. A comprehensive analysis of the Baiyangdian Lake Watershed in the North China Plain illustrated the critical role of institutional water management strategies in addressing groundwater depletion. The findings demonstrated that groundwater storage decreased by 494 × 10^8 m^3 from 1965 to 2019, with human factors—including groundwater extraction and water transfer projects—contributing 54.23% to groundwater balance changes compared to 45.77% from climate change. To restore sustainable groundwater development, the study proposed a combination of institutional strategies, including restricted groundwater exploitation, increased water use efficiency, managed aquifer recharge, and water diversion implemented over a 20-year period [23]. This evidence underscores how institutional coordination and long-term policy planning are essential for reversing human-induced hydrological degradation.

Environmental risk awareness (10 citations) and community participation (9 citations) represent important drivers, though less influential than direct human-environment interactions. The significance of community participation is particularly evident in findings demonstrating that effective water management plans rely heavily on the acceptance and active engagement of individuals dependent on water resources [13]. Without community buy-in, even well-designed conservation policies may face implementation barriers.

Environmental leadership (8 citations) mobilizes conservation agendas and resources, though its impact remains below technological factors or economic pressures. Environmental values & norms (7 citations) and relatively low scores for environmental awareness & education (6 citations) and social capital (6 citations) indicate potential weakness areas, despite their capacity to strengthen regulatory compliance and enhance multi-stakeholder collaboration effectiveness [24, 25]. The assessment of Bhojtal Lake in Bhopal, India, demonstrated the importance of social capital and local knowledge in lake conservation efforts. The study highlighted that rural communities in the catchment are highly dependent on underlying aquifers, while the Bhopal population exhibits high dependency on Bhojtal for water supply and socio-economic and cultural wellbeing. Crucially, localized knowledge of catchment hydrogeology can optimize the targeting and efficiency of management interventions, suggesting that social capital embedded in local communities represents an underutilized resource for conservation. The study also warned that over-reliance on appropriation of water from increasingly remote sources is currently compensating for the lack of attention to protecting or regenerating local resources [24].

Environmental justice (5 citations) and cultural history & identity (4 citations) remain relatively overlooked, despite their relevance to equitable distribution of environmental benefits and burdens in mining areas with clean water access disparities [8, 26]. Environmental justice considerations have been directly addressed in the context of mining-affected communities, particularly in West Bengal's Raniganj Coalfields. Research in this region revealed that while coal mine pit lakes collectively store approximately 0.4 billion m^3 of water—representing significant potential as alternative water sources—both river water and pit lakes are currently heavily polluted by mining and industrial effluents, rendering them unsuitable for anthropogenic use. This disparity, where communities bear the environmental burdens of mining while being denied access to usable water resources, exemplifies environmental justice concerns. Successful implementation and long-term scalability of rehabilitation efforts require addressing several interlinked challenges spanning technological, economic, social, policy-related, ecological, and data-driven dimensions, reflecting the need for integrated approaches that address equity concerns alongside technical solutions [8].

The citation distribution reveals an academic attention hierarchy regarding conservation factors. High-citation factors directly relate to tangible mining impacts on ecosystems, while low-citation factors connect to indirect socio-cultural dimensions. This pattern reflects technical-ecological perspectives' dominance over sociological-cultural viewpoints in the literature, though both prove equally crucial for long-term conservation success. Nearly half of all citations concentrate on three main factors—human-environment interaction, eco-friendly technology & innovation, and economic & social pressures—collectively representing over 50% of research attention.

These findings confirm that successful lake water conservation in mining areas demands holistic approaches combining technological interventions, human activity control, and economic pressure mitigation. While technological innovations effectively enable monitoring and rehabilitation, social factors, including environmental awareness, cultural values, and social capital, require strengthening for sustainable solutions [13, 24]. Institutional strengthening and environmental leadership play strategic roles in integrating economic interests with ecosystem conservation. The empirical evidence from diverse geographical contexts—ranging from Inner Mongolia's arid coal mining regions to Greece's Mediterranean wetlands and India's densely populated mining districts—consistently demonstrates that conservation outcomes depend not merely on the availability of technical solutions, but fundamentally on the social, economic, and institutional contexts within which these solutions are implemented.

The primary challenge involves managing trade-offs between mining-driven economic growth and lake ecosystem sustainability, necessitating adaptive, participatory policy mechanisms [22]. Future conservation strategies must balance technological solutions with social-institutional approaches, ensuring comprehensive addressing of both direct environmental impacts and underlying socio-cultural dynamics that influence conservation behavior and outcomes in mining-affected lake regions. Achieving greater resilience and regional self-sufficiency requires measures that protect and regenerate local water resources rather than perpetuating dependence on remote sources—a principle applicable across the diverse mining-affected lake systems examined in this review [24].

3.3 Relationships Between Factors Affecting Lake Water Resource Conservation in Mining Areas

The conservation of lake water resources in mining areas is the result of complex interactions between social, cultural, technological, and economic factors that influence each other through direct, mediated, or moderated relationships. A comprehensive understanding of the interrelationships between these factors is important for designing adaptive and sustainable management strategies, as explained in Table 5.

Table 5. Summary of the relationship between influencing factors

Concept of Cause	Concept of Consequence	Types of Relationships	Description	Ref.
Social and institutional structure	Preservation of lake water resources	Directly	A well-organized social structure and strong institutions are capable of regulating the distribution of roles, establishing rules, and enforcing conservation policies. In the context of mining areas, this structure facilitates coordination among stakeholders.	[27]
Environmental values and norms	Preservation of lake water resources	Directly	Values and norms that emphasize environmental concern encourage pro-sustainability collective behavior, reducing excessive exploitation practices around the lake.	[28]
Environmental awareness and education	Preservation of lake water resources	Mediation	Education improves understanding of the ecological functions of lakes, which mediates the relationship between knowledge and conservation behavior.	[29]
Community participation	Preservation of lake water resources	Directly	Active community involvement in water quality monitoring and environmental rehabilitation improves the effectiveness of conservation in mining areas.	[14]
Economic and social pressure	Preservation of lake water resources	Moderation (negative)	Economic pressures can undermine conservation priorities if pressing economic needs take precedence over preservation.	[30]
Human-environment interaction	Preservation of lake water resources	Directly	Interaction patterns determine the extent to which human activities have a positive or negative impact on lake quality.	[31]
Environmentally friendly technology and innovation	Preservation of lake water resources	Directly	Environmentally friendly technology minimizes mining waste and improves the quality of lake ecosystem restoration.	[32]
Environmental leadership	Preservation of lake water resources	Mediation	Effective community leaders mediate the influence of values, norms, and participation into tangible collective action.	[33]
Social capital	Preservation of lake water resources	Directly	Networks of trust and cooperation strengthen communities' capacity to manage lakes sustainably.	[34]
Environmental risk awareness	Preservation of lake water resources	Directly	Risk awareness encourages preventive measures against water and lake ecosystem damage.	[35]
History and cultural identity	Preservation of lake water resources	Mediation	Cultural identity tied to the lake helps the community stay committed to conservation.	[36]
Environmental justice	Preservation of lake water resources	Directly	The principle of fairness ensures the equitable distribution of the benefits and burdens of lake management, enhancing community legitimacy and compliance.	[37]

Analysis of relationships between causal factors and lake water conservation in mining areas (Table 5) reveals a complex socio-ecological system operating through direct, mediating, and moderating influences. Social and institutional structures exert significant direct influence on conservation success by providing governance frameworks, regulating role distribution, and ensuring policy implementation. Franken and Schütte [27] emphasizes that shared resource management success depends heavily on institutional effectiveness, including participation mechanisms, sanctions, and transparency. In mining contexts, adaptive institutions facilitate cross-sector coordination among local governments, mining companies, and communities.

Environmental values and norms directly shape pro-conservation collective behavior. Values emphasizing nature, harmony, and prohibiting destructive practices create social legitimacy for conservation actions [28]. Strong social norms drive compliance without strict law enforcement, particularly in highly cohesive societies. Environmental awareness and education function as mediators, increasing understanding of lake ecological functions and encouraging conservation behavior. Internalized environmental knowledge increases ecosystem ownership, strengthening protective commitment [29]. In mining contexts, environmental education bridges knowledge gaps between companies and communities, steering interactions toward collaboration.

Community participation contributes directly and substantially to conservation success. Participation improves decision quality by combining local and technical knowledge while creating ownership [14]. In mining areas, participation includes water quality monitoring, habitat restoration, and pollution control. Conversely, economic and social pressures act as negative moderators, shifting community priorities from conservation toward potentially destructive economic activities when economic needs are pressing. Sustainability requires aligning economic growth with ecosystem capacity [30]. In mining lake areas, economic pressures trigger illegal mining or excessive water use.

Human-environment interactions directly affect lake ecosystem quality. Interactions based on traditional ecological knowledge maintain sustainability, while exploitative interactions accelerate degradation [31]. These interactions determine whether economic activities can coexist with conservation in mining areas. Environmentally friendly technology and innovation directly impact by reducing mining waste, improving water efficiency, and restoring damaged ecosystems. Technology plays a crucial role in supporting social capital, as environmentally friendly technology adoption requires trust networks between developers, government, and communities [32].

Environmental leadership mediates by transforming values and participation into collective action. Leaders with social legitimacy and technical competence garner cross-group support and ensure program sustainability [33]. In mining contexts, leadership often comes from local figures or NGOs acting as community-company intermediaries. Social capital directly contributes to conservation effectiveness. Trust networks, reciprocity norms, and social cohesion strengthen communities' shared resource management capacity. In mining areas, social capital initiates cross-sector cooperation [34].

Environmental risk awareness directly relates to damage prevention behavior. Risk perception influences awareness and preventive action readiness [35]. Communities understanding mining pollution risks to lake water engage more actively in monitoring and reporting violations. History and cultural identity mediate connections between cultural values and conservation commitment. Emotional and historical landscape attachment encourages long-term protective behavior, often manifested through water-related rituals or customary prohibitions [36].

Environmental justice directly relates to conservation success. Perceived fairness in conservation benefit and burden distribution increases policy legitimacy and community compliance [37]. In mining areas, environmental justice ensures negative impacts aren't solely borne by vulnerable groups and restoration benefits are evenly distributed.

These factors form a complex cause-effect network. Structural factors (institutional, leadership, social capital) provide frameworks; cultural factors (values, norms, history) shape motivation; instrumental factors (technology, participation) facilitate action; while contextual factors (economic pressures, environmental risks) moderate relationship strength. Lake water conservation in mining areas results from multi-level interactions between social, cultural, technological, and economic factors, requiring integrative approaches combining institutional strengthening, environmental value prioritization, and technological innovation while considering risk dynamics and environmental justice.

3.4 Model for Preserving Lake Water Resources in Mining Areas

This conceptual model maps the interrelationships between various social, cultural, economic, and technological factors that influence the conservation of lake water resources in mining areas. The model distinguishes between direct, mediating, and moderating relationships to show the diverse pathways of influence on conservation goals. Direct factors contribute immediately to sustainability, mediating factors act as amplifiers or catalysts for the influence of other factors, while moderating factors alter the strength or direction of these relationships. This visualization helps identify strategic intervention points that can enhance the effectiveness of conservation policies. The relationships between factors and the types of interconnections are explained in Figure 5.

The conceptual model in Figure 5 illustrates multidimensional relationships between determining factors and lake water resource conservation in mining areas. The model positions the dependent variable (conservation) as a blue node representing the ultimate goal, while determining factors are distinguished by relationship types—direct, mediating, and moderating—with different colored arrows indicating influence pathways. Direct factors appear on the left, mediating factors in the upper center, and moderating factors in the lower center, reflecting their hierarchical roles in conservation outcomes.

Direct relationships, indicated by green arrows, signify immediate contributions to conservation. Social structure & institutions shape governance mechanisms and stakeholder coordination essential for effective water resource management [27]. Environmental values & norms provide foundations for collective behavior, internalizing environmental concern, and influencing community compliance with conservation rules [28]. Community participation enables social oversight and ecosystem improvement through rehabilitation activities, water quality monitoring, and policy advocacy [14]. Human-environment interaction, eco-friendly technology & innovation, social capital, environmental risk awareness, and environmental justice also demonstrate direct relationships, contributing through mining waste reduction and equitable benefit distribution [32, 35, 37]. In the figure, these direct factors are visually grouped on the left with arrows pointing straight toward the central conservation node, underscoring their role as immediate causal drivers. These factors collectively indicate that conservation success depends on institutional capacity, social norms, community engagement, and technological support.

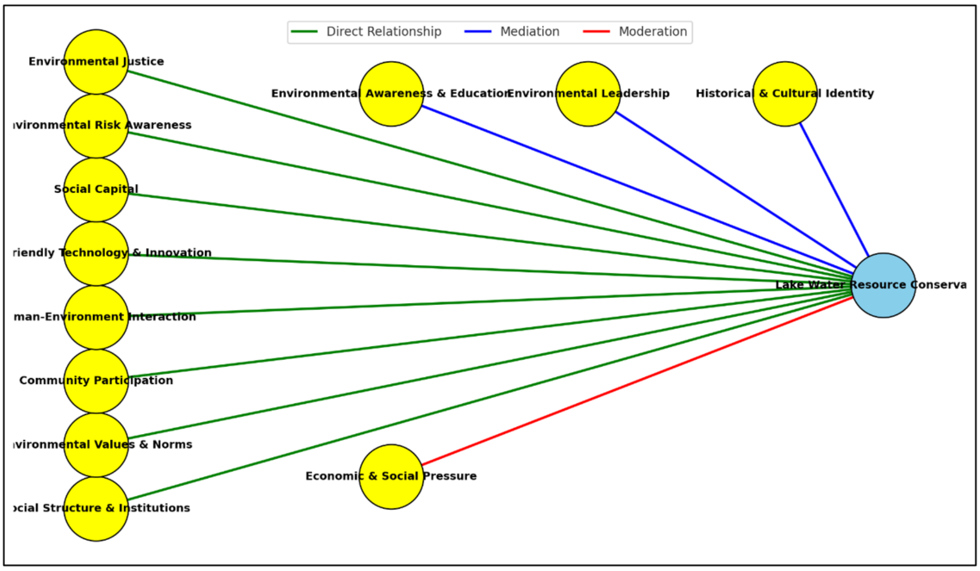

Figure 5. Model for preserving lake water resources in mining areas

Mediating factors, represented by blue arrows, bridge other determinants and conservation. Environmental awareness & education mediates relationships between ecological knowledge and pro-environmental behavior; educated communities internalize conservation urgency and apply it practically [29]. Environmental leadership mediates community values, norms, and participation impacts by consolidating collective action direction and strategy [33]. Historical & cultural identity mediates communities' emotional and social attachment to lakes, creating identity symbols, strengthening conservation commitment [36]. In the visual model, these mediating factors are positioned above the conservation node, with downward blue arrows showing how they channel or amplify the effects of other determinants before they reach the outcome. These mediating factors amplify other factors' influence while catalyzing motivation transformation into consistent conservation behavior.

Moderating factors, illustrated by red arrows, alter the strength or direction of other factors' relationships with conservation. Economic & social pressure exemplifies negative moderation, where economic pressures shift societal priorities from conservation to meeting urgent economic needs [30]. In mining contexts, high economic dependence on extractive activities can hinder strict environmental policy implementation. The visual placement of moderating factors below the central node, with red diagonal arrows intersecting other pathways, emphasizes their role in weakening, redirecting, or constraining otherwise positive influences. However, understanding moderation enables designing mitigation policies like economic incentives or compensation schemes aligned with conservation goals.

From a social-ecological systems theory perspective [19], this model reflects complex interactions between social and ecological subsystems. Direct factors operate as structural and functional inputs contributing immediately to conservation, while mediating factors reinforce or transform effects through behavioral, awareness, or social commitment changes. Moderating factors function as contextual controllers, weakening or strengthening specific influence pathways. This approach aligns with adaptive co-management concepts, where conservation success depends on social actors' ability to adapt strategies to changing conditions [31].

The model emphasizes social capital [34], and environmental justice [37], as long-term sustainability foundations. Social capital enables cross-sector coordination, while environmental justice ensures conservation policy legitimacy. Combined with strong environmental leadership, these aspects mitigate negative economic and social pressure effects. Eco-friendly technology leverages innovation for lake ecosystem restoration efficiency, reinforcing technological interventions as effective complements to community-based strategies.

Conceptually interpreted through path analysis or structural equation modeling, the model shows multiple direct and indirect influence paths. Direct paths indicate immediate effects, while indirect paths through mediation suggest interventions targeting mediating factors enhance overall impact. Moderating factors highlight interaction analysis needs, where independent variables' conservation effects depend on moderating variable levels.

The model represents resilience thinking principles, viewing conservation sustainability as dynamic interactions between social adaptive capacity and ecosystem capacity. When economic pressures are high, strong adaptive capacity from social capital and environmental leadership maintains conservation effectiveness. Internalized environmental values strengthen risk awareness and motivate environmentally friendly technology use despite socio-economic pressures.

This conceptual model serves as both a causal relationship representation and a diagnostic tool for evaluating socio-ecological readiness supporting conservation in mining areas, providing theoretical and practical foundations for developing adaptive, equitable, evidence-based policy interventions.

3.5 Strategies to Support the Preservation of Lake Water Resources in Mining Areas

The preservation of lake water resources in mining areas requires strategies that integrate social, technical, and cultural dimensions to address ecological and socio-economic challenges simultaneously. Based on the thematic analysis of 114 reviewed articles, seven distinct strategies were identified, which can be organized into three conceptual dimensions reflecting different intervention approaches. The first dimension encompasses social capacity-building strategies, which focus on developing human and collective resources through environmental education and awareness, community participation in monitoring, and environmental leadership. The second dimension comprises institutional strengthening strategies, centered on establishing effective governance frameworks and cross-scale coordination mechanisms. The third dimension includes technical-cultural integration strategies, which address the interplay between technological solutions, value-norm systems, and economic pressures that shape conservation outcomes. This tripartite framework reflects the literature's recognition that sustainable lake conservation cannot rely on single-sector interventions but must simultaneously address knowledge gaps, governance deficits, and structural constraints. The distribution of citations across these strategies, along with detailed explanations of each strategy's role, is presented in Figure 6.

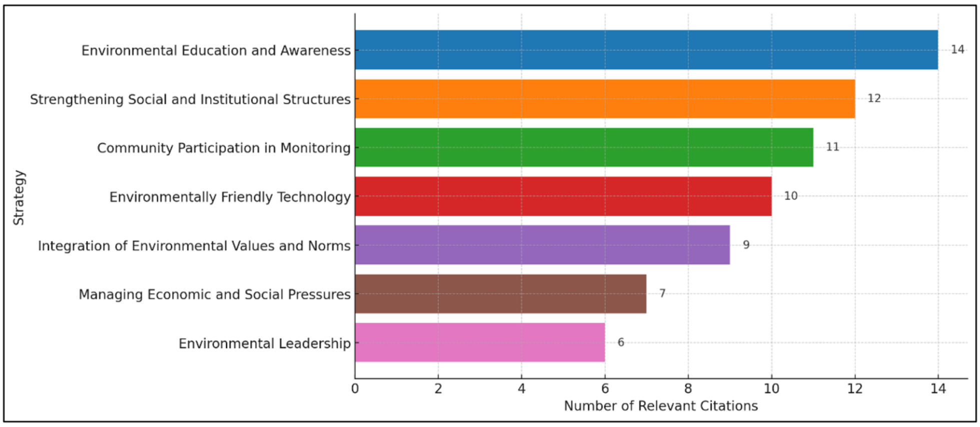

Figure 6. Summary of lake water resource conservation strategies

Figure 6 presents the distribution of citations for lake water resource conservation strategies in mining areas from an environmental sociology perspective. Environmental education and awareness leads with 14 citations, followed by strengthening social and institutional structures (12 citations), community participation in monitoring (11 citations), environmentally friendly technology (10 citations), integration of environmental values and norms (9 citations), managing economic and social pressures (7 citations), and environmental leadership (6 citations).

The dominance of environmental education and awareness reflects the literature's focus on individual and collective awareness factors [29]. Environmental education creates long-term effects on ecological behavior by shaping value orientations and strengthening sustainability-related social norms. In mining areas facing lake water quality degradation, sedimentation, and heavy metal contamination, this approach proves crucial [9]. The emphasis aligns with environmental literacy principles, linking knowledge to concrete actions in lake water resource management [38].

Strengthening social and institutional structures (12 citations) emphasizes effective institutional frameworks for regulating, monitoring, and enforcing conservation regulations [27, 31]. From a social-ecological systems perspective, local institutions link community actors with formal policies, enabling adaptive management responsive to ecosystem changes [39]. Studies indicate conservation success depends heavily on cross-scale coordination between communities, government, and private sectors [40].

Community participation in monitoring (11 citations) aligns with participatory environmental governance paradigms, positioning communities as active actors in water quality monitoring and decision-making [14]. Community involvement increases policy legitimacy while expanding local knowledge integration with scientific data. In mining contexts, this helps identify pollution sources quickly, strengthens transparency, and encourages industry accountability [29].

Environmentally friendly technologies (10 citations) highlights technical innovations' importance in mitigating mining impacts. Filtration systems, constructed wetlands, and tailings treatment methods reduce pollutants and improve water quality [11]. Environmental sociology literature emphasizes that technology adoption depends on social factors, including institutional capacity, community support, and policy incentives [41].

Environmental values and norms integration (9 citations) underscores internalizing ecological values into community social norms [28]. This value-based approach leverages local wisdom and customary rules regulating human-nature interactions, creating moral foundations for conservation behavior. Traditional practices in mining-area communities, such as waste disposal prohibitions and fishing season regulations, have long served as effective conservation mechanisms predating formal regulations [42].

Managing economic and social pressures (7 citations) recognizes that ecosystem sustainability requires addressing communities' economic dependence on mining [43]. Economic diversification, alternative livelihood development, and skills training reduce exploitation pressures on lake resources. Economic pressures often barrier community participation in conservation, as short-term survival needs override long-term ecological interests [44].

Environmental leadership (6 citations) remains significant despite fewer citations. Local leaders with social legitimacy catalyze change by mobilizing resources, building collaborative networks, and strengthening community commitment [33]. Within transformational leadership frameworks, community figures facilitate transitions toward sustainable practices while bridging scientific knowledge, policy, and local values [45, 46].

The citation distribution reveals priorities within environmental sociology literature. Socially-based strategies—education, institutional capacity, and participation—dominate counts, while technical measures and leadership rank lower. This indicates that lake water resource preservation in mining areas is viewed as a complex socio-political challenge rather than merely a technical issue.

Analysis demonstrates that environmental sociology literature positions socially-based strategies as key factors in preservation efforts. High citation counts underscore that conservation success depends on communities' capacity to understand, manage, and make collective decisions regarding lake water resources. Technical strategies remain relevant but prove more effective when integrated with social approaches. This pattern reflects shifts from top-down conservation models toward collaborative approaches based on social-ecological systems, where ecological sustainability requires social sustainability.

4 Discussion

This discussion synthesizes findings on determining factors, relationships, conceptual models, and strategies for lake water resource preservation in mining areas. The main findings reveal that human-environment interactions, environmentally friendly technological innovations, and economic-social pressures dominate as determinants influencing lake ecosystem quality and sustainability. The prominence of human-environment interactions reflects the inherently anthropogenic nature of mining activities, where extraction processes directly alter hydrological regimes, sediment dynamics, and water chemistry—making this factor unavoidable in any lake conservation discourse within mining contexts. Environmentally friendly technology ranks highly because the mining industry increasingly faces regulatory pressure and corporate social responsibility demands, prompting researchers to explore technological solutions that demonstrate measurable, quantifiable outcomes for stakeholders and policymakers. Meanwhile, economic-social pressures emerge as dominant due to the fundamental tension between resource extraction as an economic driver and ecosystem preservation—a conflict particularly acute in developing regions where mining often represents primary livelihoods. The relatively lower attention to socio-cultural factors such as environmental justice, cultural identity, and social capital may stem from the predominance of natural science and engineering perspectives in water resource research, which traditionally prioritize technical-ecological variables over sociological dimensions. The resulting conceptual model integrates these findings into a visual framework, facilitating strategic intervention point identification.

These findings reinforce conclusions on human activities' dominant impact on lake ecosystem resilience decline while expanding socio-cultural and economic dimensions previously underexplored in active mining contexts [2]. The emphasis on environmentally friendly technology as a conservation pillar aligns with studies [12, 21], but crucially highlights technology's insufficiency without institutional strengthening and community participation. Unlike Lund et al. [6] or Panigrahi et al. [7], who focus on pit lake rehabilitation, this study emphasizes conservation in areas with active mining, making strategies more adaptive to economic-social dynamics. The novel contribution integrates environmental sociology perspectives into lake conservation models, combining technical-ecological factors with social norms, cultural identity, and environmental justice.

Theoretically, findings align with Political Ecology and Social-Ecological Systems (SES) Theory frameworks. Political Ecology explains how power distribution, economic interests, and social inequality determine resource management patterns, including how economic-institutional pressures shape exploitation or conservation [47].

SES Theory emphasizes social-ecological subsystem linkages, with human-environment interactions central to sustainability dynamics [19]. Factors like human-environment interaction, environmentally friendly technology, and community participation function as feedback mechanisms determining system resilience. The SES framework's relevance for understanding lake conservation complexity in mining areas emerges through key variables—social capital [34], environmental norms [28], and environmentally friendly technology [32]—interacting dynamically. environmental justice theory [37], enriches this framework by adding benefit-burden distribution dimensions, while the risk perception theory [35], explains individual preventive action motivations.

Theoretical implications significantly advance SES concepts [19], and adaptive co-management [48]. The conceptual model demonstrates how structural variables (institutions, social capital) interact with cultural variables (values, norms, identity) and instrumental variables (technology, participation), producing conservation outcomes. Practically, results guide local governments and mining companies in developing evidence-based policies through environmental education investment, local institutional capacity strengthening, and environmentally friendly technology adoption incentives. Policy-wise, integrating environmental justice considerations and mitigating economic pressures ensures conservation program legitimacy and sustainability.

Several unexpected findings emerged. Environmental justice factors receive minimal literature attention despite high relevance in inequality-prone mining areas, possibly explained by the dominance of a technical-ecological perspective, overlooking socio-political aspects. Weak emphasis on social capital and environmental education appears paradoxical given their potential as important catalysts for policy compliance and cross-sector collaboration, indicating research bias requiring broader socio-cultural dimension inclusion.

Critical appraisal of the reviewed literature reveals several methodological limitations and potential biases requiring acknowledgment. First, cross-sectional designs predominate across the 114 studies, constraining causal inference regarding factor-outcome relationships; longitudinal investigations tracking conservation outcomes over extended timeframes remain notably scarce. Second, as indicated by the MMAT assessment, non-randomized quantitative studies exhibited moderate quality scores (60%–75%), with particular weaknesses in measurement validity and inadequate control of confounding variables. Third, convenience sampling and geographic concentration characterize much of the literature, with studies disproportionately representing specific regions, potentially limiting generalizability across diverse mining contexts and socio-ecological settings. Fourth, operationalization of socio-cultural constructs—including social capital, environmental norms, and cultural identity—lacks standardization across studies, complicating cross-study comparisons and meta-analytic synthesis. Fifth, publication bias likely inflates positive intervention outcomes, as studies reporting null or negative conservation results encounter greater publication barriers. Finally, few studies explicitly address researcher positionality or reflexivity, a particularly salient omission given the politically sensitive nature of mining-community relations and the potential for researcher assumptions to influence data interpretation. These methodological constraints suggest that while the evidence base continues to expand, future research should prioritize longitudinal designs, standardized measurement protocols, and greater attention to contextual diversity and researcher reflexivity.

Methodologically, employing systematic literature review based on PRISMA 2020, MMAT 2018, and thematic analysis with NVivo 14 represents study strengths, enabling systematic, transparent, replicable synthesis. Article selection from reputable databases with strict inclusion-exclusion criteria ensures finding relevance and quality. Limitations include focusing solely on English-language articles (2015–2025), potentially overlooking relevant local or non-English publications. Qualitative thematic analysis interpretation depends on researcher's consistency, though minimized through three-researcher collaboration.

Identified knowledge gaps include insufficient studies linking environmental justice to conservation effectiveness, limited cultural identity role exploration in strengthening conservation commitment, and scarce long-term technology-based strategy evaluations. Future research should adopt mixed-methods designs combining quantitative conservation strategy effectiveness measurements with qualitative socio-cultural dynamics analyses. Cross-country comparative studies can provide conservation model adaptation insights across different legal, social, and ecological contexts. Community-based participatory monitoring approaches should integrate local knowledge into formal policy.

Overall, lake water resource preservation in mining areas represents a multidimensional challenge requiring integrative approaches. Long-term success depends on combining technical interventions, social capacity strengthening, environmental value-norm internalization, and economic pressure mitigation, supported by adaptive, equitable policies. These findings enrich theoretical frameworks while providing practical stakeholder guidance for designing effective, contextual, sustainable preservation strategies.

5 Conclusions

This systematic review demonstrates that lake water resource conservation in mining areas constitutes a fundamentally socio-ecological challenge characterized by multi-level factor interactions operating through direct, mediating, and moderating pathways. The synthesis of 114 empirical studies reveals a persistent tension within the literature between technical-ecological approaches emphasizing measurable environmental interventions and socio-cultural perspectives foregrounding governance, values, and community agency—a disciplinary divide that has constrained the development of integrated conservation frameworks.

The conceptual model emerging from this analysis offers a significant contribution by mapping these diverse factors into a unified relational structure, thereby enabling scholars and practitioners to identify leverage points where interventions may yield cascading benefits across multiple domains. Critically, the model reveals that conservation outcomes depend not merely on the presence of individual factors but on the configuration of relationships among them—particularly how mediating factors such as environmental leadership and cultural identity amplify or channel the effects of structural determinants, and how moderating forces such as economic pressures can attenuate otherwise positive influences.

From a theoretical standpoint, this study advances the integration of social-ecological systems theory with political ecology and environmental justice frameworks, demonstrating their complementary explanatory power for understanding conservation dynamics in extractive contexts. The findings challenge predominantly technocentric approaches by highlighting that institutional capacity, normative foundations, and equitable governance arrangements are equally determinative of long-term sustainability outcomes.

Several limitations warrant acknowledgment. The restriction to English-language publications from 2015–2025 may have excluded relevant regional scholarship, particularly from non-Anglophone mining contexts where substantial conservation experience exists. Additionally, the thematic synthesis approach, while enabling cross-study integration, necessarily abstracts from context-specific variations that may influence factor salience and relationship dynamics in particular settings.

Future research should prioritize three underexplored dimensions identified through this review: the mechanisms through which environmental justice considerations influence conservation legitimacy and compliance; the role of place-based cultural identity in sustaining long-term conservation commitment; and longitudinal assessments of how factor relationships evolve as mining operations transition through different phases. Methodologically, mixed-methods designs combining quantitative effectiveness evaluation with ethnographic investigation of socio-cultural dynamics would provide the comprehensive understanding necessary for developing truly adaptive conservation approaches across diverse mining-affected lake ecosystems.

Author Contributions

Conceptualization, R.S. and D.W.; methodology, R.S.; software, R.S.; validation, R.S., D.W., E.S., and I.N.; formal analysis, R.S.; investigation, R.S.; resources, R.S. and D.W.; data curation, R.S.; writing—original draft preparation, R.S.; writing—review and editing, R.S., D.W., E.S., and I.N.; visualization, R.S.; supervision, D.W. and E.S.; project administration, R.S.; funding acquisition, R.S. All authors have read and agreed to the published version of the manuscript.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

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