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MORALITY BEFORE KNOWLEDGE

A narrative review of local ecological knowledge in urban water supply governance

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ABSTRACT

Background: According to the UN World Urban Prospect data, by 2050, 72.2% of the world's population will live in cities, especially in Asia and Africa. Meanwhile, in Indonesia, the urban population is estimated to reach 70% of the total population by 2045. This indicates the presence of population pressures due to rapid urbanization and environmental stress in the form of increasing demand for clean water supply to sustain urban population growth. This study is a narrative review examining the implementation of Local Ecological Knowledge (LEK) as a grassroots approach in urban water management in Indonesia and other countries. **Methods:** Through analysis of 24 case studies using a narrative review approach from both developing and developed countries, this research aims to identify key factors enabling the application of LEK within an integrated bottom-up water resource management framework. **Findings:** Analysis reveals three critical patterns: successful LEK integration occurs when traditional systems operate within strong social structures with institutional recognition; failures emerge from power imbalances and technocratic-centralistic approaches; and urbanization threatens LEK continuity. Indonesian cases reveal LEK manifesting in spiritual-ecological relationships with water sources, collective cultural practices as social control mechanisms, and autonomous community-based management systems. Self-supply practices by approximately 90% of Indonesian urban households represent adaptive resilience rooted in LEK. **Conclusion:** This study demonstrates that LEK is a culturally embedded knowledge system essential for sustainable urban water governance. The primary challenge is misalignment between community logic and institutional logic, perpetuated by power imbalances and dominance of scientific-instrumental knowledge. Achieving sustainability requires collaborative platforms bridging formal and local knowledge systems, and capacity-building support for existing community practices. **Novelty:** This study recommends a paradigm shift in water management from a predominantly technocratic-centralistic approach toward a hybrid planning model that recognizes LEK as a knowledge system that can be integrated into public policy frameworks.

KEYWORDS: Indonesia; local ecological knowledge; urban ethnoecology; urban water management.

1. Introduction

One of the global trends that is widely discussed around the world today is the rapid acceleration of urbanization. According to the World Urbanization Prospects from the UN, in 1950, only 30% of the world's population lived in cities, and by 2020, this percentage surged to 55%. By 2050, it is projected to reach 72.2%, mainly in Asia and Africa (Ameen & Mourshed, 2017). Meanwhile, in Indonesia, by the year 2020, there is a larger population

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living in the city, and this figure is projected to increase to 70% by the year 2045 (Setiawan & Sunarharum, 2020). This means that living space in urban areas will become more limited than ever, especially in major cities. On the other hand, one of the key challenges in facing rapid urbanization is ensuring access to clean water.

Urbanization and climate change are exacerbating water scarcity for the world's cities, with the global population facing water scarcity is projected to increase dramatically from 933 million people in 2016 to between 1,693 and 2,373 billion people in 2050 (He et al., 2021). However, this technical understanding of water scarcity must be complemented by recognizing that fresh water resources have historically been managed as shared commons by communities, where social responsibilities are expressed and codified in relationships and structures grounded in biocultural stewardship principles (Johnston, 2013).

In this context, clean water should not be understood merely as a physical resource managed through technical means, but rather as a biocultural space where biological, social, and cultural dimensions come together and shape the living experiences of urban communities (Rosinger, 2025). In this regard, water crises in urban areas around the world show that water issues are not only about quantity, but also about quality, access, stability, and equity. This also means that water insecurity is also manifests in various forms of psychological pressure, chronic stress, metabolic diseases, and socioeconomic gaps that are experienced differently across vulnerable groups (Rosinger, 2025).

In Indonesia, the paradox of clean water management in urban areas is particularly noticeable. Although the country has vast clean water resources, uneven distribution, environmental degradation, and weak governance often lead to localized water crises (Pawitan & Haryani, 2011). The urban water problems in Indonesia also arise from governance fragmentation, where surface water, groundwater, drinking water, and wastewater are managed by different actors and institutions at various government levels with overlapping responsibilities (Mulyana & Prasojo, 2020). Meanwhile, data show that 68.91% of households in Jakarta rely on self-supplied water sources such as groundwater and bottled water, rather than formal piped water (Cahyadi et al., 2022; Purba et al., 2021).

Similar pattern, also noticed in many cities of Indonesia, where about 90% households rely on community-based water resources like communal wells, refillable water, and other informal water resources (Cahyadi et al., 2022). Interestingly, the preference for relying on informal water sources indicates that this issue is not solely due to the absence of formal infrastructure, but is also influenced by economic factors, accessibility, and local perceptions of the quality of government-provided piped water (Gartin et al., 2010). This phenomenon suggests an underlying misalignment between the technocratic logic that underpins formal systems and the community's lived experiences and local ecological knowledge. Therefore, this condition demands a more holistic and deeper understanding of how urban communities perceive, experience, and manage clean water resources in their daily lives. Thus, this also raises the important question of how local ecological knowledge can contribute to water management practices that are more inclusive and sustainable.

This misalignment is largely rooted in the dominance of technocratic and centralistic approaches to urban clean water access, which often ignore local contexts and community knowledge. For example, in Delhi city of India, the paradigm shift from community-based water management to a centralistic and technocratic approach at the time of British colonialization led to severe inequality in clean water access, even after the independence era in India (Ghosh & Kansal, 2019). On the other hand, a study in Bandung shows that community-built and collectively governed water distribution systems that are managed democratically have proven to be more sustainable and equitable (Purba & Wahyu, 2022). This comparison shows that the gap between theory and implementation in managing clean water is not merely caused by technical or financial limitations, but also by a paradigm that is heavily inclined toward a technocratic-centralistic approach and fails to adequately recognize local knowledge and practices that are more sustainable.

On the other hand, urban ethnoecology offers an alternative lens to understand the relationship between urban communities and water resources. This perspective views the

city not as a space separate from nature or traditional knowledge, but as a "biocultural refugia" that is a place where local and traditional knowledge survives and adapts to sustain the sustainability and diversity of urban culture (Emery & Hurley, 2016).

In this context, Local Ecological Knowledge (LEK) can be defined as "a cumulative body of knowledge, practices, and beliefs, which is adaptive, with intergenerational transmission, about the relationships between living beings and environment" (Alves & Sauto, 2024). This also applies in urban settings where there are more nuanced understandings and practices regarding the preservation of water resources.

Empirical studies show that community understandings of water quality are not only based on scientific standards, but also emerge from embodied experiences of consuming the water, social relations, and long-term practices. In this regard, communities perceive water through multisensory means such as its color, taste, clarity, and its impact on the body or on other living beings such as fish (Lasco & Hardon, 2024; West et al., 2016).

For example, Javanese communities have their own taxonomy for identifying whether water is safe to consume when boiling it. When a pot of water is boiled for a certain amount of time until it begins to boil, a bubbling sound can be heard, which the Javanese people recognize as *kemrengseng*. This indicates that the water has just started to boil but is not yet fully boiled, thus not yet safe to consume. If the water is boiled a little longer, the sound becomes louder and more steam is released, indicating that the water has reached the *mulak-mulak* phase and is now safe to drink. This knowledge still exists and remains relevant both in rural areas and urban settings.

Another example is that when collecting water from surface sources such as rivers or lakes, or from groundwater sources like wells, urban communities often use alum or stones to settle impurities in the water, and then filter it to make it safe for consumption. This shows that using alum to purify the water has become common practice for urban communities in regard to treating the water to make it safe to consume.

Furthermore, the local community is not passive when dealing with unsafe water sources. They actively process the water through various household practices like boiling, filtering, settling, or buying from trusted vendors. This reflects adaptation of their ecological and socio-economic context (Lasco & Hardon, 2024).

Furthermore, various study shows that integration of LEK into water management practices can foster ecological and social sustainability. Barthel (2008) discovered that social-ecological memory in the form of knowledge, practice, artefact, and social relations that is passed down from generation to generation is the key to adaptation of the urban ecosystem. Another finding also suggests the same in the context of river restoration, where LEK has been proven to be more effective than other interventions that rely solely on a technocratic-centralistic approach (Szałkiewicz et al., 2020).

Another study in Australia found that more than 90% of urban communities want to participate in decision-making regarding water security and have been shown to understand technical issues when they are explained clearly. This shows that there is alignment of interest and goal between the community and the water service provider (Allan et al., 2022). Meanwhile, another study in Indonesia discovered that the implementation of water resource management that engages with the local community and traditional governance has proven to enhance vegetation cover and to improve the quality of water (Pawitan & Haryani, 2011).

However, the study of ethnoecology in clean water management in urban areas is still very limited. Emery and Hurley (2016) argue that ethnoecology and ethnobiology research tend to focus on indigenous communities and rural communities, while, on the other hand, urban areas are often used only as a background, not as an active subject that has its own biocultural dynamic.

Therefore, it is important to examine the integration of Local Ecological Knowledge (LEK) into urban clean water management. In this context, LEK in various water management practices serves as the community's knowledge base, shaping the way they understand and manage water resources in urban spaces. Various case studies in Indonesia and other countries have shown successful water resource management when LEK is

integrated into management models. However, there are also cases where communities struggle to incorporate LEK into their management approaches.

This raises the question of which factors influence the successful application of LEK in urban water resource management. Most studies tend to focus on institutional aspects and social capital, but have not fully explored how water management practices actually emerge from the accumulation of the community's ecological knowledge of their local environment (Bajrami et al., 2023). As a result, a knowledge gap exists between local community knowledge and institutional logic, where nuanced understanding of water related issues such as drought mitigation, seasonal water patterns, and everyday water consumption behavior that remain unintegrated into formal planning frameworks. (Lasco & Hardon, 2024; West et al., 2016)

Therefore, this study aims to review the application of Local Ecological Knowledge (LEK) as a grassroots approach in urban clean water management in Indonesia and other countries. This research contributes to the literature by highlighting the features of the LEK approach that enable optimal bottom-up integration in urban water management, based on the analysis of successful case studies.

2. Methods

2.1 Research design and approach

This study employs a narrative literature review method to examine the application of Local Ecological Knowledge (LEK) in urban clean water management. A narrative literature review was selected because of its capacity to provide an interpretative synthesis of broad and complex research topics, while also enabling deeper and more nuanced descriptions and interpretations (Green et al., 2006; Sukhera, 2022). This method offers the flexibility needed to explore under-researched and multidisciplinary issues, integrate diverse perspectives, and identify research gaps that may not be captured through more rigid review methods. The approach is particularly suitable for synthesizing findings from case studies across different geographical contexts and for identifying patterns, opportunities, and challenges in integrating LEK into urban water management systems. Furthermore, this review adopts an urban ethnoecology lens combined with an environmental anthropology perspective to understand water not merely as a physical resource, but also as a biocultural space that shapes community identity, social relations, and systems of value. This interpretative framework enables a more comprehensive analysis of the socio-cultural dimensions of water management beyond the dominant technocratic and centralized perspectives commonly found in conventional literature.

2.2 Data collection and analysis procedures

The literature search was conducted through academic databases, including Google Scholar, Elsevier, ScienceDirect, and institutional repositories, using combinations of keywords such as local ecological knowledge, traditional ecological knowledge, indigenous knowledge, urban water management, water supply, community-based water management, self-supply, and urban resilience. To broaden the scope of the review, literature in Indonesian was also included using keywords such as *pengetahuan ekologi lokal, manajemen air perkotaan, and pengelolaan air berbasis komunitas* (local ecological knowledge, urban water management, and community-based water management). The selected literature was evaluated based on thematic relevance to the research focus and its capacity to provide in-depth insights into the dynamics of LEK within urban contexts.

Studies were selected according to their relevance to the implementation of LEK or traditional knowledge in clean water management within urban or semi-urban settings. Priority was given to studies published within the last fifteen years to ensure contemporary relevance, although several foundational studies were also included due to their theoretical significance. From the screening and selection process, a total of 24 studies were reviewed.

These studies originated from various developing countries, including India, Iran, Bangladesh, Pakistan, Tanzania, South Africa, Mexico, Peru, and Indonesia, as well as developed countries such as the United States, Australia, Romania, and Albania.

The analysis was conducted thematically by identifying recurring patterns of success and failure in the application of LEK, contextual factors influencing the effectiveness of integration, and the various dimensions through which LEK manifests in urban water management practices. Findings from the selected studies were then synthesized narratively to construct a comprehensive understanding of how LEK operates within urban environments and the key characteristics that support effective bottom-up integration in water governance systems.

3. Results and Discussion

This study aims to review the implementation of Local Ecological Knowledge (LEK) as a grassroots approach to managing water resources in urban areas by examining case studies from Indonesia and other countries around the world. Of the 24 selected case studies, most are from developing countries such as India, Iran, Bangladesh, Pakistan, Tanzania, South Africa, Mexico, Peru, and Indonesia. Additionally, some case studies are from developed countries, including the United States, Australia, Romania, and Albania. This geographical diversity enables the identification of universal patterns in LEK application while also revealing context-specific manifestations and challenges.

Analysis of these case studies reveals three critical patterns. First, successful LEK integration occurs when traditional water management systems are built within strong social structures and receive institutional recognition. Second, implementation failures consistently emerge from power imbalances, where technocratic-centralistic approaches marginalize community knowledge and participation. Third, rapid urbanization threatens LEK continuity across all contexts, though the manifestation and intensity of this threat vary by region.

Of the 24 case studies analyzed, 13 demonstrate successful LEK integration, 7 show partial success where practices persist despite constraints, and 4 represent implementation failures. Geographical distribution reveals important patterns: all 9 Indonesian cases achieved either success or partial success, with no complete failures, suggesting strong grassroots LEK resilience despite limited formal recognition. In contrast, all 4 failure cases occurred where external actors (governments, donors, or NGOs) initiated interventions without meaningful community participation (South Africa, Tanzania, Mexico, Bangladesh).

The following sections present detailed findings organized by geographical context, followed by thematic analysis of LEK dimensions in Indonesian cases and practical implications for sustainable urban water governance.

3.1 Successes and failures of LEK implementation outside Indonesia

Case studies from outside of Indonesia reveal distinct patterns of success and failure in LEK application, shaped by institutional recognition, community empowerment, and integration mechanisms between local and formal knowledge systems. Analysis across four thematic categories consist of traditional systems integration, community-based initiatives, participatory governance models, and implementation failures, illuminates the conditions enabling or constraining effective LEK application in urban water management. The first thematic category is the traditional water management systems that successfully integrate social structure, cultural practices, and ecological knowledge, demonstrating resilience across diverse geographical contexts.

The *qanat* traditional water management system in the urban area of Jiroft, Iran, shows significant effectiveness in integrating LEK with social structures. The study shows that the *qanat* practice, which integrates social hierarchy, water-sharing cycles (*demn*), and collective participation, creates resilience against drought and climate change (Ghorbani et al., 2021). The success of this system lies in the balance between land ownership rights and

collective responsibility through cooperation and cultural rituals, thus creating efficiency without relying on large infrastructure and reducing potential inequalities in access to clean water.

Similar patterns also emerge in traditional water management systems, such as those in Aflaj, Oman, Acequias in the southwestern United States, and Qochas in Peru, showing that community-based water management practices passed down through generations can maintain ecological and social resilience (Almasri et al., 2025). The success of these traditional systems heavily depends on legal recognition, community involvement, and integration with modern scientific knowledge.

Wirata (2025) summarized the effects of community participation based on LEK in clean water supply projects from six studies in the Amazon, India, Southeast Asia, and several communities in Africa. They found that community participation, integrating local knowledge, contributes to successful water management. In this context, the interventions examined included the recognition and application of customary practices in national or regional policies, particularly in land management and sustainable water storage systems. The results showed increased biodiversity conservation, more efficient resource management, and strengthened social resilience and community cohesion.

The second thematic category is the community-based initiatives in resource-constrained urban settings that reveal LEK's capacity to address infrastructure challenges through adapted solutions. Case studies in Delwara, Rajasthan, Odisha, and Cuttack, India, demonstrated the effectiveness and efficiency of community-based water management in urban poor areas. The study discovers that in Delwara, the revitalization of community ponds and traditional wells successfully increased water availability and drought resilience through grassroots initiatives supported by cooperation among NGOs, local governments, and community groups (Poricha & Dasgupta, 2011; Wirata, 2025). Meanwhile, in Cuttack, communal toilets and the use of simple filtration technology for wells improved clean water quality (Poricha & Dasgupta, 2011).

Another study in the eastern part of Romania discovered that traditional water distribution that covers up to a 100 km range is proven effective in providing water needs for the local community, although rapid urbanization and industrial expansion also caused concerning water pollution (Gheorghe et al., 2012). In this context, water is no longer seen only as a physical resource but as a socio-political element that shapes relationships, values, and daily practices, ultimately forming a collective identity.

The third thematic category is the participatory governance model that shows success in transforming ecological awareness and redefining water governance relationships. These cases demonstrate that LEK relevance extends beyond technical water provision to encompass identity formation, environmental consciousness, and democratic participation in resource management.

A study in Phoenix, about the ethnohydrology study, revealed a culturally shared model among urban communities regarding water quality risks due to low investment in water management and dry desert conditions. At the same time, communities believed that government monitoring and household filtration could provide safer drinking water (Gartin et al., 2010). This means that the community has its own perceptions and interests in taking part in water management practices.

Another study in the United States revealed environmental awareness through rainwater harvesting practices. In this regard, a group of communities in Tucson, Arizona, shows that although rainwater harvesting practice did not result in a significant reduction in drinking water consumption, daily interactions with rainwater helped shape ecological awareness and an identity as "ethical desert dwellers" (Radonic, 2019). Interestingly, this study shows that water becomes not only a physical resource but also a socio-political element that shapes relationships, values, and daily practices, resulting in collective identity.

Another study in Queensland, Australia, also shows that the majority of residents, over 90 percent, wanted to be involved in setting urban water security goals, particularly regarding water restrictions and service quality (Allan, 2022). The study found that

communities could understand technical terms such as level-of-service when explained clearly. The results highlight the importance of collaboration between communities and water service providers in sustainable water security planning, as there is alignment of interests and goals between them.

These findings highlight the importance of collaboration between communities and water service providers in sustainable water security planning, revealing that perceived gaps between community and institutional interests often result from inadequate communication rather than fundamental incompatibility. This case strongly supports participatory governance models that genuinely engage community knowledge and preferences.

The fourth thematic category is the implementation failures that reveal persistent structural challenges that must be addressed for broader LEK integration. Analysis of failure cases identifies three primary barriers: power imbalances in decision-making processes, inadequate community capacity building, and institutional frameworks that exclude local knowledge systems.

A systematic review of 16 case studies on community participation in urban water management revealed that failures often occur due to limited interaction between representatives and communities, power imbalances, and the dominance of elites and experts in decision-making processes (Purba & Wahyu, 2022). The study highlighted that traditional systems in Latin America and regions such as Aflaj and Qochas now face serious challenges from urbanization and the loss of intergenerational knowledge transfer. Furthermore, a systematic literature review of 66 research articles from 2002 to 2022 found that urbanization generally negatively impacts LEK, particularly knowledge about biodiversity and natural resource use (Rangel et al., 2024).

In this regard, Boakye and Akpor (2012) studied communities along the Msunduzi River, South Africa, where communities could not meaningfully participate in projects due to unmet expectations, lack of interaction between "community representatives" and the community itself, and limited knowledge about water management. Similarly, the lack of community capacity and knowledge contributed to the failure of water conservation projects in Iringa District, Tanzania (Chumbula & Massawe, 2018). This study also highlights that the donors initiated water projects in Iringa, but communities were not involved in all project phases. This results in a lack of communication and knowledge to participate in project maintenance, resulting in suboptimal outcomes.

Furthermore, outside of Africa, Garciadiego (2022) studied the Magdalena River restoration project in Mexico City and found that power imbalances determined project success. In this context, academics and the government initiated the restoration, involving some urban settlements with little or no connection to the river, while people most affected by the project, mostly disadvantaged groups in informal settlements, were ignored. Similarly, a case study in Bangladesh showed that while traditional knowledge of water management offers valuable insights into water ecology and flood resilience, its implementation in Khulna City remains constrained by weak governance, limited institutional capacity, and globalization pressures that reduce the cultural value of water (Asad et al., 2023).

Across these international case studies, several cross-cutting insights emerge. First, LEK effectiveness depends not on knowledge existence alone but on institutional recognition and integration mechanisms that bridge local and formal knowledge systems. Second, successful implementation requires genuine power-sharing and meaningful participation in decision-making. Third, traditional systems face common threats from urbanization and modernization, yet communities demonstrate strong adaptive capacity when provided institutional support rather than replacement. Fourth, water quality and access issues intersect with power, identity, and social justice, requiring approaches that address these dimensions alongside technical considerations.

3.2 Indonesia cases: LEK manifestation and adaptations

LEK implementation in Indonesian urban water management demonstrates both similarities and distinctions from international patterns. Indonesian cases reveal strong grassroots resilience and culturally embededed water knowledge, but also face similar challenges of institutional non-recognition and urbanization pressures. This section examines Indonesian cases using the same four thematic categories applied to international contexts, thus enabling direct comparison while highlighting Indonesian-specific manifestations.

In Indonesia, LEK as an approach to urban water management is commonly found, especially in urban areas that are vulnerable and not reached by piped water systems. In this context, there are various applications of LEK, including connections to spiritually-ecological water sources, community-based traditional management systems, and self-supply practices rooted in local knowledge.

A study in the riverside area of Palangka Raya revealed that for the Dayak Ngaju community, rivers are not merely a resource, but living entities shaping identity, economy, and social systems (Priono & Ellisa, 2025). Traditional ecological knowledge passed down through generations includes a deep understanding of hydrological cycles and river biodiversity. However, the currents of modernization and top-down policies have shifted this harmonious relationship toward more utilitarian exploitation, creating tension between preserving tradition and urban development. This research found that hybrid planning models integrating local knowledge, community participation, and scientific innovation can reduce these tensions (Priono & Ellisa, 2025).

Similar to this, in the Gunungsewu karst region, Gunungkidul Regency, Yogyakarta Province, another study showed that ponds do not just function as water containers, but as cosmological landscapes where water, trees, spirits, and humans interact in ecological and spiritual networks. In this context, rituals such as *merti telaga* and *memule* play important roles in maintaining material and spiritual balance and strengthening collective identity (Martias, 2024). Environmental degradation due to infrastructure projects and invasion by non-native species has triggered the phenomenon of "*telaga mati"* or "pond death" which not only means the loss of water sources but also the breakdown of spiritual and ecological connections. Interestingly, there is a social response in the form of grassroots movements applying slow activism, meaning patient conservation efforts rooted in local knowledge and respecting reciprocal relations between humans and non-humans. In this case study, what is notable is the understanding that water sources can act as both material and spiritual entities, opening space for integrating local cosmology into more inclusive and sustainable environmental governance (Martias, 2024).

At a more practical level, traditional ecological knowledge is also visible in community-based landscape management systems. A study in the Kali Bekasi River Basin by Utami et al. (2018) revealed how local communities maintain the *talun* agroforestry system, combining bamboo with various other plants. This system supports biodiversity and ecosystem functions while serving as economic and cultural resource. Bamboos planted along riverbanks maintain soil stability and prevent erosion through practices transmitted across generations. Despite strong urbanization pressure, the *talun* system survives because it provides tangible ecological and economic benefits that communities directly experience, demonstrating LEK's adaptive capacity when economic viability combines with ecological effectiveness.

Indonesian community-based water initiatives reveals organizational capacity and aoutonomous management systems operating largely separated from formal governance structure. A study in Bandung city also showed higher sustainability levels in community-managed water distribution systems compared to government-built communal wells (Maryati et al., 2022). The study emphasized that communal distribution systems have formal institutional elements such as water committees, strong community participation from the early stages, and tariff implementation supporting financial sustainability.

In contrast, communal wells built top-down without community involvement and relying only on voluntary contributions were weak institutionally and financially. Nevertheless, both systems face serious environmental challenges, especially water source degradation, over-extraction of groundwater, and insufficient water filtration efforts to make it safe to consume (Suryani et al., 2019). Therefore, it is important for the government to support bottom-up management systems, particularly in clean water education and simple water filter technology assistance, so that the quality of water from existing communal practices remains within safe consumption limits.

Indonesian LEK includes collective cultural practices that function as participatory governance mechanisms, creating a legitimate spaces for community engagement in environmental monitoring and decision-making. Regarding this, a study in Kampung Code, Yogyakarta, by Seftyono (2012) showed how the Merti Code ritual, in the form of *sedekah sungai* or "charity for the river", is not just an expression of spirituality or gratitude to the river, but also serves as a social control mechanism for river conservation. In this context, the Code River has become a philosophical symbol of the Yogyakarta palace, representing balance between Mount Merapi in the north, the Keraton Palace in the center, and the Southern Sea or "*Segara Kidul*". In this ritual, Residents collect representatives of water from seven springs in seven villages along the Code River from north to south and gather it in the central part of the river, located in Kampung Cokrodiningratan. After the collection, residents perform wayang and gamelan as part of the Merti Kali ritual.

This ritual becomes a collective moment in which the community reaffirms shared responsibility for river conservation and provides space to identify pollution or degradation issues, then builds consensus on corrective actions needed. Similar practices are also found in the Gajah Wong River Basin, Mrican, Yogyakarta. The *merti kali* activities carried out routinely in this area not only strengthen spiritual and cultural dimensions but also encourage active community participation in river environmental management (Firdausi & Dewangga, 2024). This shows that traditional ecological knowledge plays a central role in shaping how communities understand, evaluate, and care for rivers as cultural, spiritual, and social spaces, forming community identity.

While Indonesian cases show no complete implementation failures comparable to those in South Africa, Tanzania, Mexico, or Bangladesh, they face significant challenges that constrain LEK effectiveness and sustainability. These challenges primarily involve water quality issues, environmental degradation, and tension between traditional practices and top-down development policies. Research on five community-based water supply projects in Cikarang found that none met safe water standards, yet communities proved resilient enough to sustain themselves (Roekmi et al., 2018). This represents a partial success where communities demonstrate organizational sustainability but face technical limitations in ensuring water safety. Similarly, the Bandung study revealed that both community-managed and government-built systems struggle with water quality issues, particularly inadequate filtration and treatment (Suryani et al., 2019; Maryati et al., 2022).

Environmental degradation poses another significant challenge as shown in "pond death" phenomenon in Gunungkidul due to infrastructure project and invasive species, threatening both material water sources and spiritual-ecological relationships (Martias, 2024). In Palangka Raya, top-down modernization policies shift the Dayak Ngaju's harmonious relationship with rivers toward utilitarian exploitation, creating tensions between tradition preservation and urban development (Priono & Ellisa, 2025). These findings shows that Indonesian challenges emerge not from community exclusion or lack of LEK, but from technical capacity gaps and external development pressures that threaten existing functional systems. Communities retain knowledge and organizational capacity but need support to address water quality issues and resist environmentally destructive development. This suggests that appropriate interventions should strengthen rather than replace existing systems, providing technical assistance while respecting community autonomy.

To provide a clearer comparative understanding of how LEK has applied in different contexts, both internationally and within Indonesia, the following table 1 summarizes key

factor across four thematic categories: traditional systems integration, community-based initiatives, participatory governance models, and implementation failures. This comparison highlights the recurring structural and institutional conditions that shape the outcomes in urban water management.

Table 1. Key success factors and main challenges in international and Indonesia case studies by thematic categories

Thematic Category	Cases	Key Success Factors	Main Challenges
Traditional Systems Integration	*Qanat* (Iran), Aflaj (Oman), Acequias (USA), Qochas (Peru), Kampung Code & Gajah Wong (Yogyakarta)	Legal recognition, community involvement, integration with modern science	Loss of intergenerational knowledge, urbanization pressure
Community-Based Initiatives	Delwara, Odisha, Cuttack (India), Romania, Bandung & Cikarang (Indonesia)	Grassroots mobilization, NGO-government cooperation, simple technology	Water pollution, limited technical capacity
Participatory Governance	Phoenix (USA), Tucson (USA), Queensland (Australia), Code & Gajah Wong River (Yogyakarta)	Clear communication, alignment of interests, community engagement	Bridging technical and local knowledge
Implementation Failures	Msunduzi River (South Africa), Iringa (Tanzania), Magdalena River (Mexico), Khulna (Bangladesh), Palang Karaya & Gunung Sewu (Indonesia)	N/A	Power imbalances, elite dominance, lack of community participation, weak governance

The table summarizes four thematic categories indetified in various local water management systems across different regions. Each category highlights different patterns of success and challenges. Traditional system integration emphasizes the blending of traditional knowledge with modern science, though it also faces threats from urbanization and declining traditional practices. Community-based initiatives demonstrate the ability of grassroot urban community and various actors collaboration but often struggle with technical and environmental limitations. Participatory governance focuses on transparent communication and shared decision-making, yet difficulties remain in connecting technical and local knowledge. Meanwhile, implementation failures reveal structural barriers such as power imbalances and weak governance that hinder effective community participation.

3.3 The dynamics of LEK in self-supply practices as a common pattern of informal water management in Indonesia

Interestingly, several studies consider self-supply or household-managed water as an important method rooted in local knowledge and a key survival strategy in urban areas of Indonesia. In this sense, self-supply is an alternative water management method that can function as the main or only source of clean water, or as a complement or substitute for piped water systems. In this context, practices of extracting groundwater through wells and boreholes are common in South and Southeast Asia, including Indonesia.

Furthermore, Cahyadi et al. (2022) stated that self-supply is an alternative approach for areas not covered by formal water systems in Indonesia. The study argued that self-supply is a form of water governance often excluded from discussions on water provision, yet it is widely practiced. It shows that almost 90% of households in Jakarta use self-supplied water, either enhanced or unenhanced. Therefore, ignoring self-supply methods

may create a knowledge gap about water care practices between the government and local communities.

In this context, the most common self-supply methods are the use of refill water and the construction of communal wells. Both sources are widely used by lower to middle-income communities because they are much more affordable than using piped water services from the local water company (PDAM). In Bandung city, for example, a survey by Suryani et al. (2018) showed that around 52% of residents in urban kampungs prefer informal water sources such as communal wells and packaged refill water over tap water. This preference is strongly influenced by economic considerations, as communal wells are considered more affordable than piped water services. Although there are contamination risks, user satisfaction with these informal water sources remains high, reflecting acceptance of community-based water management systems.

On the other hand, although self-supply practices still have limitations in water quality, they are maintained because they can meet water needs directly, even during water crises. In this regard, a study by Roekmi et al. (2018) on the sustainability of five community-based water supply projects in Cikarang found that none of the projects met safe water standards, yet the community was strong enough to support itself. In line with this, urban community water care practices reflect the presence of an ecological knowledge system that encourages people to prefer self-supply practices over piped water provided by the government. People are able to use their senses to assess whether the water is suitable for consumption (West et al., 2016). Moreover, this knowledge system is formed through shared memory and experience emerging from social networks within and around the community (Barthel, 2008). In this sense, the ecological knowledge system acts as a value framework influencing collective preferences and actions in managing and distributing the clean water supply.

This knowledge enables communities to develop autonomous water supply management systems that are considered more effective for local conditions than standardized piped systems, which often fail to respond to daily needs. Therefore, LEK serves as a foundation in shaping self-supply practices that are contextualized at the community level.

3.4 Recommendations for sustainable urban water management

Based on the literature review on the dynamics of LEK in urban water governance, both in Indonesia and globally, these recommendations are presented using an anthropological framework. This perspective positions water not only as a physical resource but also as a socio-cultural entity that shapes identity, social relations, knowledge, and collective values. Therefore, the sustainability of urban water management must be achieved through integration that respects cultural dimensions and the autonomy of local knowledge.

Based on case studies of the successes and challenges of LEK in urban water management across various geographic contexts, water management scholars have tried to develop more holistic and integrated methods that combine bottom-up approaches with top-down support. First, it is important to improve the water governance paradigm, which previously leaned towards a technocratic-utilitarian approach, toward recognizing the socio-cultural dimension of water. The old paradigm tends to view water as a commodity that must be engineered and distributed efficiently, focusing on large infrastructure development, with success measured by quantitative fulfillment of clean water supply. Improving this paradigm requires acknowledging that water is a living entity and a spiritual landscape, as exemplified by the Dayak Ngaju community in Palangka Raya, who see rivers as living entities, or communities in the Gunungkidul karst hills, who view lakes as cosmological landscapes where human and non-human interactions occur. In this context, sustainability no longer only means meeting physical needs but also encompasses social, ecological, and spiritual cohesion of the community.

Therefore, it is very important for the government and stakeholders from community groups, as well as private companies, to integrate rituals and cultural practices related to water, such as *Merti Kali* on the banks of Code River in Yogyakarta and *talun* agroforestry

planting in Bekasi, into formal water management frameworks. These rituals and inherited traditions are not merely cultural expressions or spiritual practices, but also effective social control mechanisms that reaffirm collective responsibility for the preservation of clean water resources, while providing legitimate participatory space for communities to identify pollution and degradation issues. Recognizing these socio-cultural dimensions will transform the relationship between the state and communities from a provider-receiver model into a partnership based on mutual respect for the most vital resources.

Second, the focus should be on building knowledge bridges through the integration of LEK and formal science. Case studies from around the world show significant challenges rooted in power imbalances and the dominance of formal knowledge by elites and technocrats, who systematically tend to overlook local insights. Some cases, like *qanat* practices in Iran and regions in Acequias, USA, are heavily dependent on legal recognition of the system and its integration with modern science. To address these challenges, hybrid planning models are needed that explicitly recognize LEK as a legitimate part of the prevailing knowledge system. This recognition can be realized through collaborative, non-hierarchical platforms allowing academics, local governments, communities, and private companies such as PDAM and PAMSIMAS to interact on equal footing.

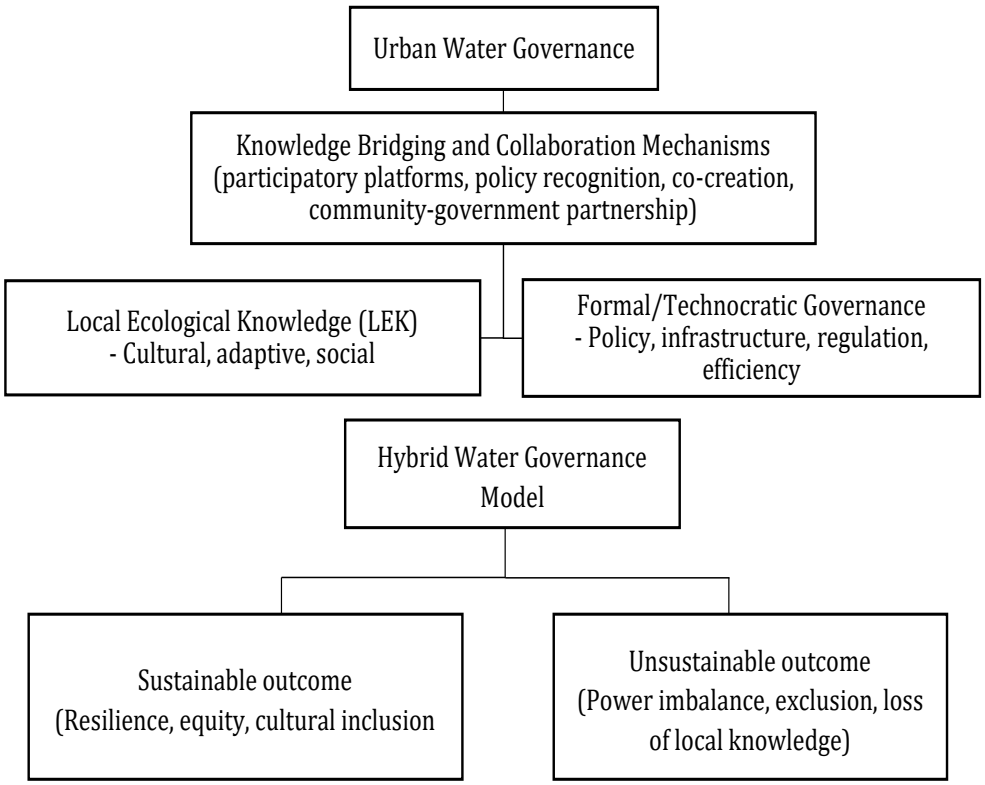

Fig. 1 Conceptual framework of hybrid urban water governance

This approach will ensure that any technical intervention is based on a shared understanding of water risks and quality held by the community. Furthermore, it is important for the government to support bottom-up capacity, focusing on community-based water management systems that are already operating autonomously. This support should be directed toward clean water education and provision of simple water filtration technologies to address water quality issues, which often remain a weakness in self-supply practices at the community level.

Third, it is essential to strengthen social resilience and intergenerational knowledge transfer. Massive and rapid urbanization can disrupt intergenerational knowledge transfer, posing an existential threat to the sustainability of LEK. In Indonesia, the self-supply practice, commonly undertaken by nearly 90% of households across the provinces, shows that communities possess strong knowledge autonomy and adaptive strategies to meet

water needs independently. Therefore, it is important to recognize self-supply as a legitimate local water resilience strategy, with a focus on improving water quality and safety.

To illustrate the relationship between LEK, formal governance systems, and sustainability outcomes, the following figure 1 consists of conceptual framework visualizes the hybrid model proposed in this study. It highlights how the integration of community-based knowledge and technocratic approaches can create more adaptive, and culturally grounded urban water governance. The figure above shows that sustainable water governance emerges when LEK and formal governance interact through collaboration, mutual recognition, and shared decision-making. In contrast, the absence of integration often leads to unsustainable outcomes characterized by power imbalances, social exclusion, and the erosion of local knowledge. This framework emphasizes that bridging knowledge systems is essential to achieve both ecological resilience and social equity in urban water management.

4. Conclusions

This narrative review of 24 case studies from Indonesia and other countries confirms the critical, yet often unrecognized, role of Local Ecological Knowledge (LEK) in achieving sustainable and equitable urban water supply governance. The analysis of successful and failed implementation cases reveals that LEK is not merely a supplementary technical fix but a fundamental, culturally embedded knowledge system that manifests in three core dimensions: spiritual-ecological relationships with water sources, collective cultural practices as social control mechanisms, and autonomous community-based water management systems. The preceding discussion of Indonesian cases highlights a crucial finding: the persistence of self-supply practices by the majority of urban households is a clear manifestation of local water resilience rooted in LEK, rather than simply a failure of formal infrastructure. This community-driven approach, which includes traditional water quality assessment and purification methods, demonstrates a practical and adaptive capacity that is often overlooked by technocratic, top-down governance models. The primary challenge to broader LEK integration is the misalignment between community logic and state institutional logic, which is perpetuated by power imbalances and the dominance of scientific-instrumental knowledge. Successful cases, both internationally and in Indonesia, consistently show that the effectiveness of LEK is contingent upon institutional recognition and integration mechanisms. Therefore, achieving sustainable urban water management requires a fundamental paradigm transformation toward a hybrid planning model.

This model must explicitly recognize and support the autonomy of local knowledge systems. To realize this transformation, key strategies must be implemented, directly addressing the gaps identified in the analysis. Formal public policy frameworks must recognize LEK as a legitimate and equal knowledge system alongside modern scientific knowledge, including legal recognition of traditional water rights and governance structures, moving beyond a purely utilitarian view of water to one that incorporates its cosmological and socio-cultural dimensions. Collaborative platforms must be established to bridge the knowledge gap between formal institutions and local communities, ensuring genuine power-sharing and meaningful participation, facilitating a two-way flow of information where formal science informs and is informed by local insights. Interventions should focus on strengthening the capacity of existing self-supply practices, such as improving water quality in communal wells, rather than attempting to replace them with standardized, centralized systems. This approach supports the adaptive resilience already demonstrated by urban communities. By implementing these strategies, water governance can shift from a predominantly technocratic-centralistic approach to a more inclusive, equitable, and ecologically sound hybrid model that leverages the full potential of Local Ecological Knowledge.

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G. P. S. W. performed the research, analyzed the data and literature, collected and interpreted the data, and wrote the manuscript.

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