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The politics of knowledge use in wastewater management – A systematic literature review

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Previous research demonstrates that stakeholders possess diverse knowledge concerning wastewater impacts and appropriate management strategies. Importantly, these different kinds of knowledge are situated in a political context that influences whose knowledge is used to shape local management. While a better understanding of drivers behind the use of knowledge may enable decision-makers to include more stakeholders, a comprehensive review of the state of the literature is still lacking. To address this, this paper systematically reviews gray and peer-reviewed literature published between 1990 and 2023 that explores the politics of knowledge use in wastewater management. The findings show that decision-makers adopt a wide range of management strategies and that various factors influence knowledge use across these strategies. Although there appears to be recognition of the value of more localized and alternative forms of decision-making, local "non-experts" knowledge is still commonly excluded, and decision-making remains strongly driven by legal, scientific, and engineering perspectives. This poses the risk of rendering management initiatives and outcomes less effective due to an ill-fit to local needs or lack of support. It is argued that improving transparency around knowledge use in decision-making, bridging different knowledge systems, and facilitating local decision-making are needed steps forward. Future research should determine how these recommendations can best be adapted to specific contexts.

KEYWORDS

wastewater management, knowledge use, decision-making, knowledge politics, power

1 Introduction

Inadequate management of wastewater is a widespread issue with various ecological and social impacts. In the oceans, for instance, wastewater can be transported by currents over large areas or accumulate in nearshore zones (e.g., lagoons). This can lead to human health risks (water-borne diseases) and environmental degradation (e.g., threatening the health of coral reefs) (e.g., Hall, 2001; Shuval, 2003; Kocasoy et al., 2008; Reopanichkul et al., 2010). To better understand potential impacts, prior research looked at different wastewater sources and potential technologies to manage wastewater, ranging from black and gray water from domestic activities to wastewater generated by industrial operations (e.g., from mining or agricultural runoff). However, even though wastewater is often perceived as solvable through science and preventive policies (e.g., Mehta et al., 2007; Randhawa and

Marshall, 2014; Duncan, 2016; Sibanda et al., 2022; Hahn et al., 2023; Wessels, 2023), wastewater is a persistent and complex issue.

To understand the complexity of wastewater management issues, political ecology can provide further insights. Fundamentally, political ecology studies analyze environmental issues by studying stakeholder relations and associated power structures, with the aim to understand how society-nature relationships within socio-economic contexts are shaped (Mosedale, 2015; Nepal and Saarinen, 2016). In relation to water, previous political ecology studies have sought to understand water management through case studies, using the perspective of the waterscape to acknowledge the role of the local political context in shaping water-society relationships (i.e., the place-based nature of management as emphasized in political ecology; Swyngedouw, 1999; Johnston, 2003; Swyngedouw, 2009; Cole, 2012; Karpouzoglou and Vij, 2017). Where these studies focused specifically on the management of fresh water in terms of access and distribution given social disparities and considerable environmental challenges (e.g., local droughts), wastewater has often been represented as politically-neutral (Alley, 2002; Karpouzoglou, 2012; Karpouzoglou and Zimmer, 2016; Karpouzoglou et al., 2018). However, Zimmer (2012), Karpouzoglou (2012) and Karpouzoglou and Zimmer (2016) demonstrate in studies around Delhi (India) how wastewater can be a topic of contestation by considering the politics of knowledge (or: knowledge politics) and how this shapes management locally, using the perspective of the "wastewaterscape." Knowledge politics is an important concept in political ecology and considers how knowledge is created, contested and/or hybridized and gets included or excluded for decision-making. An important component of knowledge inclusion/exclusion is knowledge legitimacy, which is concerned with whose knowledge counts or who can claim to be in the know (Swyngedouw et al., 2002; Birkenholtz, 2008; Robbins, 2011; Boelens et al., 2016; Karpouzoglou and Zimmer, 2016). Using this approach, Karpouzoglou and Zimmer (2016) shed light on the role of power relationships in legitimizing or de-legitimizing different ways of knowing about wastewater held by stakeholders who work and live in the wastewaterscape, which leads to particular problematization of wastewater. Importantly, it was demonstrated how the traditional focus of national and state governments on expert knowledge for the implementation of wastewater management, design of infrastructure and monitoring of health and environmental risks made it harder for local residents with lay knowledge to inform decision-making. This was particularly true for poorer societal groups, and meant that their day-to-day experiences with wastewater issues such as overflows, pollution of freshwater sources and disease outbreaks were overlooked or poorly understood by decision-makers. Given the issues highlighted by these important works, a comprehensive literature review on the politics of knowledge and knowledge use in wastewater management would fill a gap to understand broadly how knowledge shapes the wastewaterscape, and consequences for sanitation.

The literature review conducted in this article aims to address the question: what different kinds of knowledge inform different management strategies, what factors determine knowledge inclusion or exclusion, and what consequences does this have for management? To illustrate the overall state of the literature, the review considers the development of studies over the years including their geographical scope, kind(s) of wastewater studied, methods used for data collection and whose knowledge was studied (knowledge holders). In order to understand the foundations shaping our current understanding, the review sheds light on the theoretical or analytical frameworks and concepts used in previous studies. For more insights in potential trends, the kinds of knowledge considered by decision-makers and the ways these manifest will be discussed. This will be further elaborated on by looking at different strategies adopted by decision-makers to manage wastewater issues and the factors that determine knowledge use. Finally, the review will discuss the recommendations made by previous studies to improve the inclusiveness of decision-making processes in terms of knowledge use.

2 Methods

For the design of this review, the ROSES guidelines (RepOrting standards for Systematic Evidence Syntheses) for systematic literature reviews in environmental research were used.

Both academic databases and gray literature sources have been searched covering the period 1990 to 2023. Academic databases included Web of Science, Scopus and Google Scholar. For gray literature, the databases OpenGrey.eu, Google Scholar, Base-Search, OATD (Open-Access Theses and Dissertations) and Search ProQuest were consulted. Other gray literature sources included the policy repositories UN Digital Library and Uropa. eu, and the websites of different NGO's and international donors working on wastewater management in different geographical regions. For searching the databases, the same search string was used with only minor changes (e.g., wildcards) to accommodate for the particular search engine. The only exception was the organizational websites, which were hand searched (e.g., by consulting the "documents" section of the website). The language used for all searches was English. Importantly, the majority of literature is available in this language, or at least includes an English abstract which makes them retrievable using English queries. Language proficiency of the first author includes English, French, German and Dutch and for this reason documents in these languages were considered. The search string can be found in Supplementary Appendix S1.

Some particular publications were used as "benchmark articles" (Haddaway et al., 2018). These publications were crucial for initiating the review and formulating the search query, as well as for assessing the comprehensiveness of the searches. For Web of Science, Scopus and Google Scholar, the article by Karpouzoglou and Zimmer (2016) was the benchmark reference; for thesis databases, the doctoral dissertations of Zimmer (2012) and Karpouzoglou (2012) and the master's thesis of Deelder (2013) were determined as benchmark documents.

In order to select relevant documents for further screening, inclusion and exclusion criteria were formulated (Table 1). These selection criteria were formulated based on the established understanding on the politics of knowledge and a close reading of selected benchmark studies.

TABLE 1 Inclusion and exclusion criteria for screening.

Inclusion criteria	Exclusion criteria
Document falls within one of the following categories: • Academic literature: peer-reviewed scientific articles and books • Gray literature: bachelor's and master's theses, doctoral dissertations, governmental documents and NGO reports	
Document incorporates issues around wastewater as part of its scope. For the purpose of this study, wastewater is understood as black[a] and/or gray water[b] or wastewater from industrial activities[c].	
Document reports on different stakeholders and their knowledge about wastewater and inquires on the inclusion or exclusion of knowledge in decision-making processes. Per document type, this aspect should minimally be covered in the following manner: • Books, theses and dissertations: one or more chapters • Scientific articles: overall scope and exceeds the conclusion and discussion sections • Governmental documents/NGO reports: overall scope, or individual chapters are found to be relevant	Document reports on knowledge from one specific stakeholder (e.g., report with expert observations submitted to a government authority) without contrasting this with knowledge held by others Studies that only mention different stakeholders and their knowledge about wastewater, as well as knowledge use as side-issue but focus on other aspects, or only incorporate this as part of the recommendations, conclusions or discussion, will be excluded for final full-text analysis in the literature review.
Document is written in English language	
Document contains an English abstract but a non-English full-text written in Dutch, French or German language	

[a]Discharges from toilets and sanitary services.
[b]Discharges from personal hygiene systems (showers/sinks), from kitchen and kitchenette areas, from washing walls and floors, washing clothes and industrial laundry services.
[c]From industrial, commercial or service activities other than those included under gray and black water (e.g., Singh et al., 2020; Chand et al., 2022).

Different screening stages were conducted and all decisions were recorded in a coding book in Excel. First screening was done at title-abstract-keywords level, enabling for a first identification of potentially relevant documents. A slightly different procedure was followed for books. Apart from reading the book synopsis, for potentially relevant books the table of contents was consulted to check for relevant chapters. Similarly, for retrieved book chapters found relevant during the first screening, the entire book was reviewed for other potentially relevant chapters by checking the table of contents and, when available, individual chapter abstracts. Selected chapters were then included for second screening and incorporated in the coding book. A second screening of selected documents was conducted by retrieving the full-text of studies and by reading introduction, conclusion and discussion of scientific literature, and introduction, executive summary, conclusion and recommendations of gray literature. Rejections were explained by means of a concise written justification in the coding book.

The screening process has been recorded in a flow diagram (Figure 1) as prescribed by the ROSES guidelines. It provides an adapted version of the standard flow diagram to accommodate for the specific character of this review. Searches for all databases were conducted in November 2020 and March 2021. This initially resulted in a set of 773 studies, with 137 retained after first screening. To this set were added 20 documents retrieved from websites of NGOs and donor organizations as well as 10 book chapters selected from books retrieved in search. For second screening, 161 studies could be retrieved at full text and six studies were not accessible. From this dataset, 46 studies were included for the review after second screening. An additional search of academic databases was conducted in January 2024 to identify and include studies (when relevant) that had been published over the last years. This resulted in a number of 105 additional studies and a number of 10 remaining after first and second screening. The final dataset used for this review consisted of 56 studies.

To ensure the appropriateness and clarity of screening criteria and to reduce the risk for bias, screening criteria and subsets of articles have been checked by two scientists not directly involved in the screening and coding. For the first consistency check, which was conducted during first screening, the subset consisted of 50 articles. For the second consistency check, which took place at second screening, the subset consisted of 10 articles. These repeated checks have stimulated critical reflection on the set of screening criteria and facilitated their improvement and clarification.

During analysis of the final dataset, two main ways for recording data were used. The coding book was used to record bibliographic data of selected documents (title, authors, journal of publication, author affiliations, study location, study aim and study methods). Qualitative coding was then conducted in MAXQDA (VERBI Software, 2020), a software that is used for qualitative and mixed data analysis. To guide coding, initial coding categories were formulated, and are enumerated in Table 2. These coding categories were constructed inductively, informed by the research question, political ecology background and selected benchmark studies.

Once all articles were analyzed, "summary tables" of coded segments from analyzed documents were generated in MAXQDA. These summary tables were instrumental to help identify sub-codes under the initial coding categories. A master file (Excel sheet) was gradually developed from the resulting code system in MAXQDA. This process allowed for the careful consideration of definitions for identified sub-codes and ways to distinguish them from each other. Moreover, filling in the master file based on the results from MAXQDA ensured the consistent reconsideration of the different dimensions across studies in terms of which sub-code(s) to attribute. Moreover, the master file helped to facilitate the last consistency checks as well as the generation of various figures. For the final consistency checks, two scientists were provided with five articles and asked to fill in the master file based on their reading of the articles and the provided definitions for the different codes. These checks helped to ensure coding categories

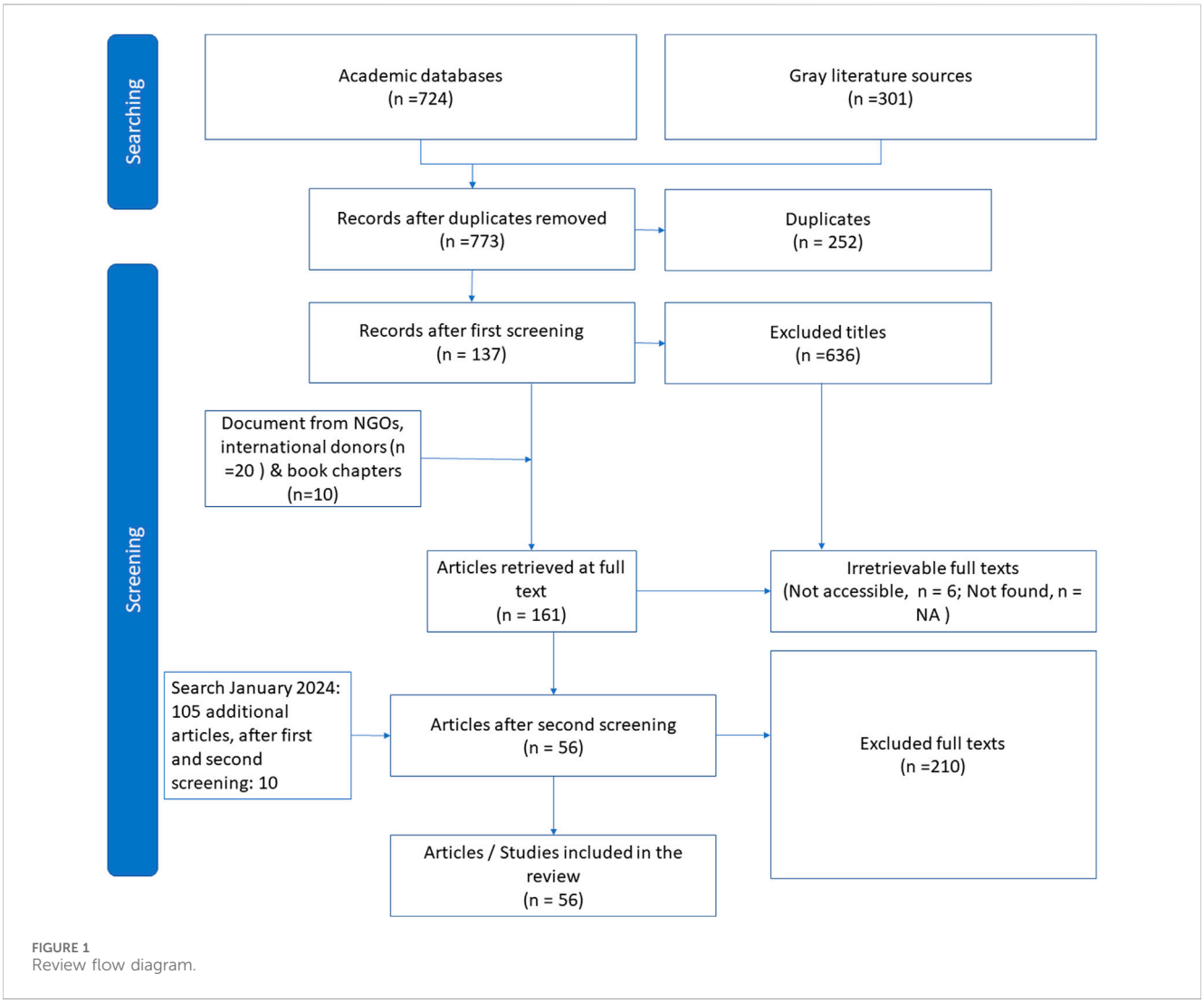

FIGURE 1
Review flow diagram.

TABLE 2 Initial coding categories for full-text analysis.

Coding category	Description
Knowledge holders	The stakeholders that were considered by the authors. Whose knowledge was studied by the authors?
Kinds of wastewater	The kind(s) of wastewater studied by the authors (thematic focus).
Kind(s) of knowledge considered for decision-making	The kind(s) of knowledge considered by decision-makers in the case(s) studied by the authors in the publication.
Factors for knowledge inclusion/exclusion	Factors that were described by the authors to play a role in knowledge inclusion or exclusion in the case(s) studied.
Strategies by decision-makers to try and tackle wastewater issues	Strategies used by decision-makers in the case(s) studied by the authors. Decision-makers can refer to governmental and non-governmental actors (e.g., NGOs or donors leading projects in the absence of the government).
Potential ways to improve knowledge inclusion	The recommendations or possibilities authors suggest to improve knowledge inclusion in decision-making processes for wastewater management.
Concepts	The concepts used to study political interactions in wastewater management
Theoretical perspectives	The theoretical framework(s) used by the authors to study the case(s).

were clear and coding yielded similar results. The first round of consistency check was crucial in the final revision of the sub-categories, ensuring clarity and clear distinctions. These revisions were then tested in a second round sharing four articles with two other scientists, leading to the final set of coding categories and results. The master file, which includes a list of definitions for all sub-codes, can be found in Appendix 2 of the Supplementary Material.

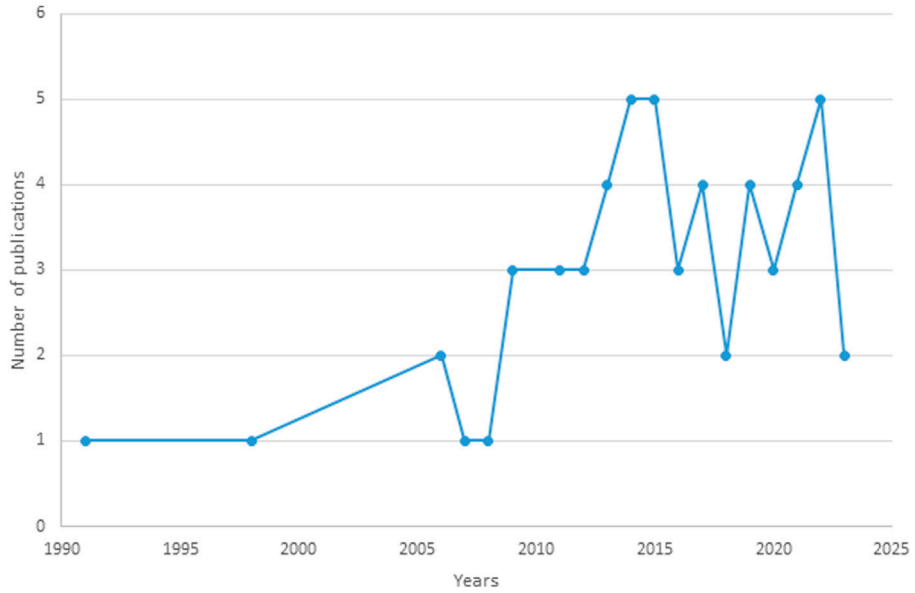

FIGURE 2
Number of publications over the years.

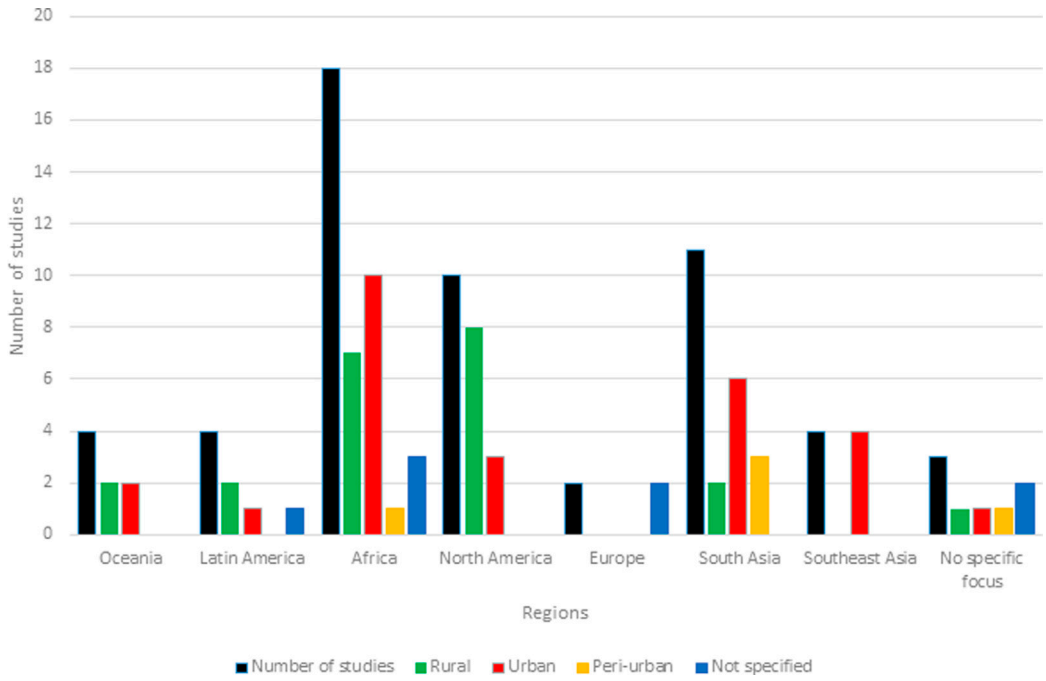

FIGURE 3
Geographical setting of studies.

3 Results

3.1 General research patterns

The number of studies in the politics of knowledge in wastewater management has remained limited over the years, from 1991 to November 2023 (Figure 2.). In fact, interest has grown only in the last 15 years, but not consistently.

Figure 3 shows an overview of studies based on regions and specific local settings. Most studies were conducted in Africa, South Asia and North America. Studies have been conducted in both urban and rural settings, but in Africa and South Asia there is a stronger

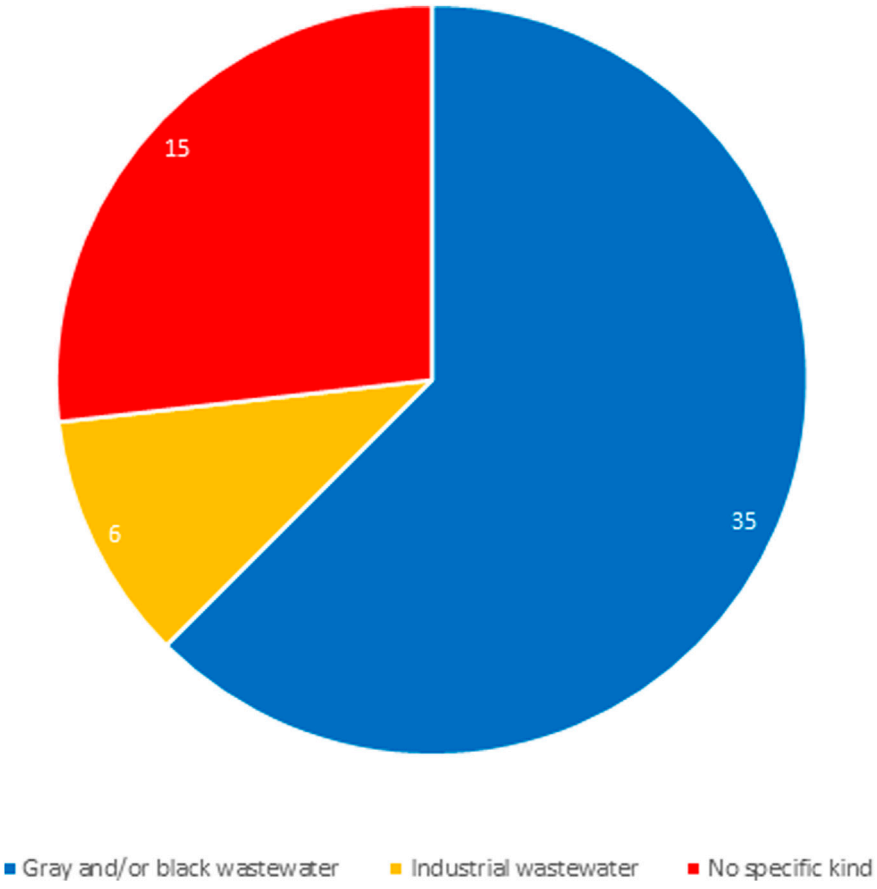

FIGURE 4
Kinds of wastewater considered in studies.

urban focus while in North America the rural is covered more. For all regions, peri-urban areas (PUAs) are still scarcely studied, but are expected to become areas with great risks for environmental issues and social conflicts given their quick growth worldwide (Karpouzoglou, 2012; Randhawa and Marshall, 2014; Kennedy-Walker et al., 2015; Karpouzoglou et al., 2018).

Different sources of wastewater are considered in the studies (Figure 4). These sources are defined as.

- Gray and/or black water - from households as well as facilities where industrial, commercial or service activities take place, corresponding to: 1) discharges from toilets and sanitary services, representing "black water," and 2) discharges from personal hygiene systems (e.g., showers and sinks), kitchen and kitchenette areas, washing walls and floors, washing clothes and industrial laundry services, representing "gray water."
- Industrial wastewater - from industrial, commercial or service activities other than those included under "Gray and/or black water" (e.g., mining tailings, agricultural run-off and chemicals).

Gray and/or black water are most commonly studied in the sample, with a smaller number of studies considering industrial sources of wastewater. Other studies either do not specify a source of wastewater, or consider wastewater flows from different sources together.

People as knowledge holders in different roles or organizations are considered in studies around the politics of knowledge in wastewater management. The bar chart (Figure 5) provides an overview of the different knowledge holders encountered in the reviewed works. These different knowledge holders are put into context throughout the review. Definitions of the different categories of knowledge holders can be found in Supplementary Appendix S2.

Recurrent categories include government authorities, residents, NGOs and community associations. This illustrates the authors' common focus on interactions between governmental and non-governmental stakeholders.

Different methods are used in studies on the politics of knowledge in wastewater management (Figure 6). Commonly used methods include interviews (mostly semi-structured), document analysis and field observations (including participant observation). The common use of (in-person) interviews and field observations illustrates the aim of researchers to understand local perspectives and experiences as well as socio-cultural particularities by direct immersion in the study site. Document analysis is often used in a complementary way with aforementioned

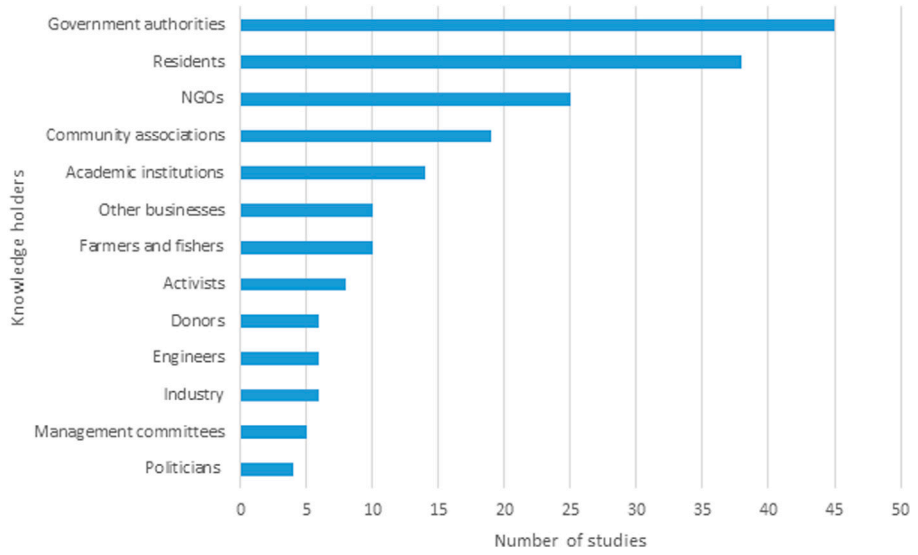

FIGURE 5
Knowledge holders in reviewed studies. The category of "other businesses" refers to businesses not otherwise mentioned in the figure.

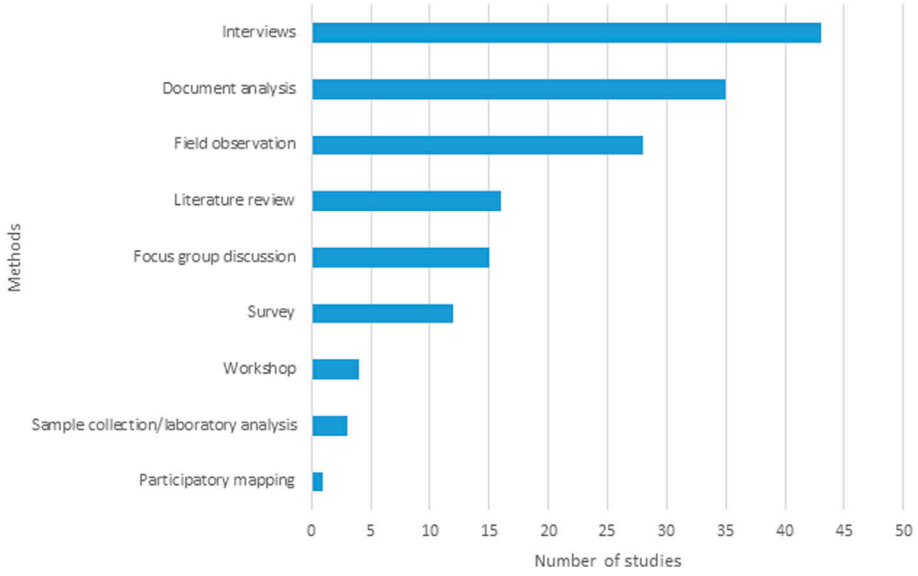

FIGURE 6
Overview of methods used in the reviewed studies.

methods, and aims to, for example, study legal requirements for stakeholder engagement.

3.2 Overview of the reviewed literature

A review of the literature identified three research foci in the politics of knowledge in wastewater management: 1) examination of governance frameworks and decision-making processes, 2) examination of place-based characteristics through the study of knowledge systems, socio-cultural dynamics and environmental discourses, and 3) participatory and community-based approaches. A research focus is understood as a topical focus, through which authors study the politics of knowledge using different concepts and theoretical or analytical frameworks. An overview is provided in Table 3.

The first research focus - "Governance Dynamics and Decision-Making Processes" - examines the specific characteristics and structures of governance frameworks and decision-making processes and the way these determine whose knowledge is used and how. While the majority of studies have a contemporary focus, some provide a historical perspective of laws and governmental

TABLE 3 Research foci and theoretical or analytical frameworks used.

Research foci → / Theoretical or analytical framework ↓	Governance dynamics and decision-making processes	Knowledge systems, socio-cultural dynamics and environmental discourses	Participatory and community-based approaches
Political Ecology (as sole theoretical framework)	Juric (2018); Baijius and Patrick (2019)	Deelder (2013); Karpouzoglou et al. (2018); Sibanda et al. (2022); Wessels (2023)	
Other theoretical framework (studies drawing upon another theoretical framework than Political Ecology)	Beder (1991); Jordan (1998); Yinusa and Wehn (2016); Fam and Sofoulis (2017); Al'Afghani et al. (2019)	May (2022); Naidoo (2022)	
Political Ecology (with other theoretical frameworks)	Zimmer (2012); Sutherland et al. (2015); Biza et al. (2022)	Kedzior (2011); Perreault et al. (2012); Zimmer (2012); Freitag (2013); Cairns (2014); Sutherland et al. (2015); Karpouzoglou and Zimmer (2016); Mueller et al. (2020); Rusca et al. (2022)	Putri and Moulaert (2017)
Analytical framework (studies drawing upon multiple theoretical frameworks, excluding political ecology)	Lippi et al. (2008); Mahoney (2011); Randhawa and Marshall (2014); Bardosh (2015); Kennedy-Walker et al. (2015); Annamalai et al. (2016); Singh (2017); Mosello et al. (2018); Abeysuriya et al. (2019); Amokwandoh et al. (2020); Turley and Caretta (2020); Randle (2021)	Saarilehto (2006); Mehta et al. (2007); Kroon et al. (2009); Macaraig and Sandberg (2009); Karpouzoglou (2012); Getachew (2013); Randhawa and Marshall (2014); Duncan (2016); Harriden (2022); Mayaux et al. (2022)	Armitage et al. (2009); Zakiya (2014); Power and Wanner (2017); Hendriksen (2019); Pillai and Narayanan (2022); Hahn et al. (2023)
Theoretical framework or analytical framework not explicitly stated		Freitag (2014)	Nare and Odiyo (2013); Himley (2014)

structures reflecting on the implications for contemporary decision-making processes (Mahoney, 2011; Biza et al., 2022). In contrast, Jordan (1998) and Beder (1991) describe a series of gradual, incremental, and larger changes over time. A specific strand of studies considers the access of stakeholders to decision-making processes (e.g., Mosello et al., 2018; Baijius and Patrick, 2019; Randle, 2021). While the majority of these studies examine factors that contribute to exclusion, Randle (2021) explores the ways in which citizens have successfully lobbied to gain access to decision-making processes.

The second research focus - "Knowledge Systems, Socio-Cultural Dynamics and Environmental Discourses" - comprises a series of studies that examine the place-based characteristics of wastewater management. These studies demonstrate how the management of wastewater is shaped by a complex interplay of highly localized socio-political, socio-cultural and socio-ecological processes. These processes exert a significant influence on how people perceive and conceptualize wastewater and associated management solutions. Crucially, these studies emphasize how these processes occur within contexts characterized by power asymmetries which inform whose knowledge is deemed suitable to shape management initiatives. This is considered using a variety of perspectives, including the hydrosocial cycle (Freitag, 2013; Naidoo, 2022), liquid dynamics (Mehta et al., 2007), urban metabolism (Rusca et al., 2022), obduracy (Harriden, 2022), and the wastewaterscape (e.g., Perreault et al., 2012; Zimmer, 2012; Karpouzoglou and Zimmer, 2016). Some studies seek to gain a deeper understanding of the processes of management through discourse and narrative analysis by examining the ways in which different stakeholders discuss and define wastewater pollution (Karpouzoglou, 2012; Deelder, 2013; Karpouzoglou et al., 2018). Others examine the discourses around stakeholder involvement in management processes (Saarilehto, 2006; Getachew, 2013) or concentrate on discourses and narratives on infrastructure development (Macaraig and Sandberg, 2009; May, 2022). Lastly, the studies in this category examine diverse epistemologies or systems of knowledge (e.g., what is knowable, how knowledge is created). Some of these studies investigate individual stakeholder knowledge and how this differs between groups and shapes management (e.g., Kedzior, 2011; Mayaux et al., 2022; Wessels, 2023), while others focus more specifically on potential "knowledge incompatibilities," which refers to the exclusion of knowledge that conflicts or does not align with traditional knowledge used, and challenges knowledge integration (Kroon et al., 2009; Duncan, 2016).

The third research focus - "Participatory and Community-Based Approaches" - encompasses alternative, more participatory approaches to wastewater management which aim to accommodate to a broader range of different kinds of knowledge for decision-making. A number of studies investigate novel participatory approaches for use by government authorities, NGOs or donors to ensure management interventions will be better aligned with local particularities and needs (Armitage et al., 2009; Zakiya, 2014; Power and Wanner, 2017; Putri and Moulaert, 2017; Hendriksen, 2019). Other studies report on the application of participatory environmental monitoring as a means to complement government-led monitoring schemes or to increase transparency of previously closed processes (Nare and Odiyo, 2013; Himley, 2014). Transdisciplinary projects and their required design to facilitate the advancement of sanitation development is another area of inquiry for this research focus (Pillai and Narayanan, 2022; Hahn et al., 2023).

In regard to the theoretical frameworks utilized in the study of the politics of knowledge in wastewater management, political ecology was identified as the most prevalent framework across the three research foci. Nevertheless, it was discovered that a considerable number of studies that use political ecology as central framework draw upon

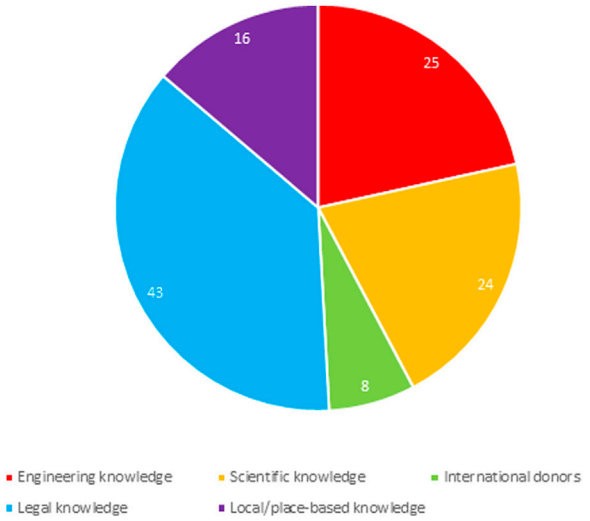

FIGURE 7
Kinds of knowledge considered in decision-making.

additional insights from other theoretical frameworks (n = 11) (e.g., Perreault et al., 2012; Zimmer, 2012; Cairns, 2014; Sutherland et al., 2015). There are also studies that use another specific theoretical framework than political ecology to guide research (see "other theoretical framework" in Table 3). This includes social construction of technology (Beder, 1991), Peter Hall's model of social learning (Jordan, 1998), rational institutional theory (Yinusa and Wehn, 2016), knowledge ecology (Fam and Sofoulis, 2017), political economy (Al'Afghani et al., 2019), political ontology (May, 2022), and social constructionism (Naidoo, 2022). Moreover, half of the studies (n = 28) develop an analytical framework that draw upon multiple theoretical frameworks, excluding political ecology (see "analytical framework" in Table 3). The common occurrence of studies in this category shows the variation in approaches to inquire on the politics of knowledge in wastewater management. Some studies (n = 3) do not further specify a theoretical framework or analytical framework. Freitag (2014) uses grounded theory (a methodology for generating theories) to identify themes and facilitate comparisons of stakeholder definitions of water quality and management implications. Nare and Odiyo (2013) and Himley (2014) focus on specific implemented participatory environmental monitoring schemes and inquire on the degree of community empowerment by reviewing these schemes.

3.3 Kinds of knowledge considered for decision-making

Figure 7 shows the kinds of knowledge that were considered in decision-making processes in different studies.

The dominant type of knowledge considered in the reviewed studies was legal knowledge, which is primarily fixed and prescriptive in nature, typically derived from regulatory frameworks. It can be argued that the implementation of policy represents the most straightforward application of legal knowledge (e.g., Lippi et al., 2008; Kroon et al., 2009; Sutherland et al., 2015; Al'Afghani et al., 2019; Randle, 2021). Another manifestation is the prescription of stakeholder roles (in and outside of government). In some instances, this may result in a certain degree of empowerment for non-governmental stakeholders. Examples of this include the conferral of formal status upon slum quarters (Power and Wanner, 2017), or the establishment of a public right to request information or actions from authorities (Jordan, 1998; Mahoney, 2011; Zimmer, 2012). The use of legal knowledge also occurs in cases where government authorities make decisions without direct input from other stakeholders by exercising their legal authority. This can occur in the context of granting permits or the drafting of new policies, such as those pertaining to pollution guidelines or spatial plans (e.g., Kedzior, 2011; Annamalai et al., 2016; Biza et al., 2022; Naidoo, 2022).

Legal knowledge, through its prescriptive nature, also determines how other kinds of knowledge such as engineering and scientific knowledge should be used. To illustrate, policies may prescribe particular technologies (e.g., types of toilets, sewer or treatment systems, evacuation channels) (e.g., Macaraig and Sandberg, 2009; Singh, 2017; Amokwandoh et al., 2020; Rusca et al., 2022; Wessels, 2023) or specify the kinds of scientific information required by stipulating water quality criteria (e.g., monitoring protocols and permissible concentrations; Freitag, 2013; Himley, 2014; Karpouzoglou and Zimmer, 2016; Turley and Caretta, 2020), and impact assessment procedures (e.g., Mahoney, 2011; Karpouzoglou et al., 2018).

Another common kind of knowledge is engineering knowledge which is employed at various stages of the decision-making process for wastewater management. Engineering knowledge is used for the conceptualization of projects, most commonly in the development, construction and operation of infrastructural works (e.g., Perreault et al., 2012; Randle, 2021; Biza et al., 2022; Harriden, 2022; May, 2022). Infrastructure construction can assume a variety of forms, including the implementation of sludge management systems or injection wells for managing wastewater from mining operations (Juric, 2018; Turley and Caretta, 2020; Naidoo, 2022), the construction or extension of sewerage networks and treatment systems or plants (e.g., Macaraig and Sandberg, 2009; Perreault et al., 2012; Freitag, 2013; Cairns, 2014; Baijius and Patrick, 2019; Mueller et al., 2020), the construction of toilets (Bardosh, 2015; Power and Wanner, 2017), and the construction or extension of marine outfalls (Beder, 1991; Jordan, 1998). It is often the case that wastewater issues are considered solely from an engineering perspective, which is presumed to be apolitical and value-neutral but poses the risks of excluding alternative perspectives (Barry, 2001; Mehta et al., 2007; Karpouzoglou, 2012). Zimmer (2012), Macaraig and Sandberg (2009) and Mueller et al. (2020) posit that the dominance of engineering expertise in project conceptualization may be closely related to specific visions of development and modernity that inherently require highly specialized technical expertise. Harriden (2022) offers another intriguing perspective, arguing that certain solutions can become so deeply entrenched in engineers' minds that exploring alternative solutions becomes challenging.

Scientific knowledge also informs wastewater management in different ways. The first way is through the adoption of published scientific material in the design of management projects or strategies. Used with engineering knowledge, it can help to

identify potential management technologies or make improvements. Examples of this include the choice of marine outfalls based on studies that indicate low risks (Beder, 1991; Jordan, 1998) and partnerships with local or international universities to pilot new technologies (Deelder, 2013; Sutherland et al., 2015; May, 2022; Pillai and Narayanan, 2022).

Another common avenue through which scientific knowledge informs wastewater management is in the context of water pollution assessments. This responsibility is either legally stipulated or delegated to specialized laboratories (Nare and Odiyo, 2013; Himley, 2014), academic institutions or contracted experts (e.g., Kroon et al., 2009; Turley and Caretta, 2020; Pillai and Narayanan, 2022). This expert-led process is critiqued for the potential to yield narrow interpretations of wastewater pollution that fail to consider alternative perspectives. For example, daily experiences and sensory perceptions of local residents for wastewater and pollution were found to be disregarded when scientific measurements were available (Freitag, 2013; Himley, 2014; Duncan, 2016; Karpouzoglou and Zimmer, 2016; Juric, 2018; Turley and Caretta, 2020).

Given that the development of wastewater management in developing countries frequently involves international donor organizations, such as the World Bank and USAID, their knowledge also plays a role in decision-making. These organizations engage in a variety of activities, including the direct initiation of project design and implementation as well as financial contributions to local authorities and/or NGOs (Cairns, 2014; Bardosh, 2015; Abeysuriya et al., 2019; Hahn et al., 2023). It is notable that different studies have identified a potential risk associated with the dominance of donor-driven knowledge over local stakeholders' perspectives. Donor knowledge is generally Western-influenced and built on specific scientific and engineering expertise. It generally involves the implementation of pre-defined or pre-tailored solutions (e.g., specific toilets) with limited possibilities for local adaptation (e.g., Mehta et al., 2007). This rigidity can be attributed to a combination of factors, including a lack of financial and human resources of aid recipients, and pressure on donor organizations to demonstrate immediate results to the public. This can lead to an emphasis on short-term and/or ill-suited interventions, which may not necessarily result in long-term sustainable outcomes (Saarilehto, 2006; Mehta et al., 2007; Kennedy-Walker et al., 2015; Mosello et al., 2018).

Another kind of knowledge that can inform decision-making processes is local/place-based "non-expert" knowledge, generally held by local residents, community associations or community leaders. The objectives for including this type of knowledge vary. One motivation is the limitations that local authorities may face in carrying out monitoring activities or impact assessments. In such cases, local residents are consulted or actively trained to support authorities in data collection (Mahoney, 2011; Amokwandoh et al., 2020; Pillai and Narayanan, 2022). Another reason for the inclusion of local knowledge is to increase the chances of selecting and implementing management solutions that fit local needs and will be accepted by the end users (e.g., graywater techniques, treatment facilities) (e.g., Sutherland et al., 2015; Hendriksen, 2019; Harriden, 2022; Hahn et al., 2023). Occasionally, the inclusion of local knowledge can also be a result of effective advocacy (Beder, 1991; Randle, 2021), while Perreault et al. (2012) and Mayaux et al. (2022) also describe the situation where politicians identify with local stakeholders which may facilitate inclusion. The inclusion of this knowledge type is generally a reflection of changes in management strategies, which will be described further in the next section.

3.4 Management strategies

This section will look at the management strategies implemented to address wastewater issues. Management strategies are receptive in different ways to specific kinds of knowledge (e.g., place-based knowledge) depending on the roles and responsibilities attributed to stakeholders in their implementation and the priorities established by decision-makers. While management strategies are generally implemented by government authorities, this may also be done by non-governmental actors, such as NGOs or donors. Three broader categories of management strategies can be seen in Figure 8, characterized by their focus on long-term or short-term planning, or achieving behavioral change. These can be further distinguished by different sub-categories. It should be noted that infrastructure development was most commonly found to be coupled with different strategies. As a stand-alone strategy, it was found in 10 studies. More details and examples on infrastructure development are presented in section 3.3 above, specifically in the paragraph on engineering knowledge. In the subsequent three sections, the different strategies and their relation to the different kinds of knowledge are described in more detail. Section 3.4.4 will then look at the different factors for the use of knowledge in these management strategies.

3.4.1 Long-term planning

The adaptation of governance structures to more effectively address wastewater issues represents a widely used strategy for long-term planning in wastewater management. One way is the establishment of new and specialized authorities that have responsibility for wastewater management. These authorities can be established at national level (e.g., Central Pollution Control Board - CPCB, India) (Karpouzoglou, 2012; Karpouzoglou and Zimmer, 2016), regional level (e.g., the Lake Koocanusa Working Group of Montana and British Columbia) (Juric, 2018) and even at city level as public entity (e.g., health service of Maputo, Mozambique) (Biza et al., 2022) or private entity (e.g., Lusaka Water and Sewer Company - LWSC, Zambia) (Kennedy-Walker et al., 2015). They typically bring together stakeholders with (specialized) legal, engineering and scientific knowledge which can make it challenging for alternative knowledge, especially place-based "non-expert" knowledge, to be considered.

Another adaptation of governance structures is the decentralization of management practices. Decentralization aims to acknowledge the capacity of local institutions to govern, to stimulate community-based management and to improve public accountability (Mehta et al., 2007; Deelder, 2013; Faguet, 2014; Abeysuriya et al., 2019). Duncan (2016), Kroon et al. (2009) and Nare et al. (2006) examine the implementation of local management bodies in Canterbury (New Zealand), the Great Barrier Reef region (Australia) and the Mzingwane Catchment (Zimbabwe), respectively, tasked with the development of management plans or monitoring and surveillance operations (in the case of

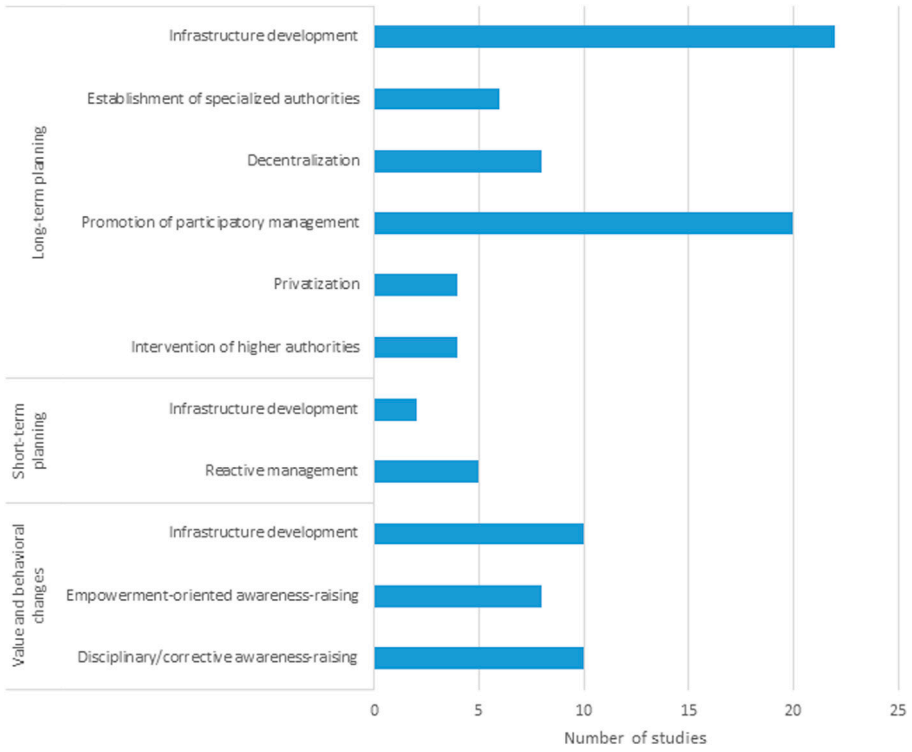

FIGURE 8
Strategies used in wastewater management.

Zimbabwe). Apart from rural settings focused on by the previous studies, decentralization can also be implemented in urban areas. For example, in Delhi, 12 sanitary zones were established, each comprising superintendents and chief sanitary inspectors and further subdivided into wards (Zimmer, 2012). Similar to the specialized authorities discussed before, such local management bodies often bring together government officials (legal knowledge) with scientists and/or engineers, demonstrating their focus on highly specialized kinds of knowledge.

However, in decentralized contexts or where this is being pursued the promotion of participatory management is common. This is thought to foster a sense of commitment and ownership among end users which would contribute to more successful long-term management results (Annamalai et al., 2016). Initiatives can be started by donors, as illustrated by Cairns (2014) in Sapecho (Bolivia), where a water committee was established by the NGO ACDI/VOCA (supported by USAID) to involve community members in the construction, implementation, and maintenance of a WatSan system. Commonly, the impetus for such initiatives originates from government authorities. One example is the revision of the Central Rural Sanitation Program and the implementation of the Clean India Campaign (SBA) by the Indian government, which has been instrumental in driving community-led and people-centered sanitation initiatives, including educational campaigns and cost-sharing for construction of sanitation facilities (Singh, 2017). Other examples are the involvement of local communities in transdisciplinary initiatives in the CANALPY project in Allepey, Kerala, India, which aimed to identify solutions for decentralized sanitation systems (DEWATS) (Pillai and Narayanan, 2022), and the Alaska Water and Sewer Challenge (AWSC), which sought to develop innovative water and sanitation solutions in collaboration with native communities (Fam and Sofoulis, 2017). Apart from system development and operation, participatory management may also serve to shape monitoring schemes with different degrees of actual empowerment. For example, it may aim to enhance the transparency and perceived legitimacy of water pollution assessments by allowing observation of sampling procedures (Himley, 2014). Showing a further degree of empowerment, Nare and Odiyo (2013) describe a case in South Africa (Luvuvhu Catchment) where the objective was to equip stakeholders with the knowledge and tools necessary for active participation in monitoring.

A further adjustment made to governance structures is the privatization of public services. In this context, private service providers are legally granted the responsibility for the implementation of public services. While motivations for privatization may vary, it is generally driven by the assumption that market forces can more effectively help increase service coverage (Pack, 1987; Radić et al., 2021; Rusca et al., 2022). Lippi et al. (2008) and Abeysuriya et al. (2019) describe cases in Italy and Malaysia respectively, where sanitation services were privatized at a nation-wide level through long-term concessions. However, in Malaysia services were privatized and centralized in one single entity, which raised questions on the actual (remaining) role for local and state governments. Focusing on Jakarta (Indonesia) and Maputo (Mozambique) respectively, Putri and Moulaert (2017) and Rusca et al. (2022) show that privatization can also be implemented at city-level where the private sector is expected to provide on-site

sanitation facilities. An inherent risk of privatization, further discussed in the next section, is that social disparities may be magnified, particularly affecting poorer and marginalized societal groups who commonly lack the required resources to pay for service coverage or are not considered worthy of the necessary investments.

A smaller number of studies describe yet another management strategy, which involves the intervention of higher government authorities in the jurisdiction of lower-level authorities, community-led projects or privatized management arrangements. Reasons for such interventions may vary and include perceived mismanagement by local authorities (Mayaux et al., 2022), an absence of local political representation (Saarilehto, 2006), or mismatches between formal and informal (community-led) management arrangements (Annamalai et al., 2016). Returning to the strategy of privatization, Abeysuriya et al. (2019) describe the assumption of ownership over the previously privatized Malaysian water consortium (IWK) by the state. This intervention has had positive outcomes in terms of an increased orientation to service and downward revision of tariffs for users.

3.4.2 Short-term planning

Management strategies do not always have a long-term outlook and decision-makers adopt reactive management to address problems only as they arise. It is important to note that this strategy may occur concurrently with other strategies when distinct decision-makers are involved or when strategies evolve over time. In a number of studies, it has been documented that government authorities have only taken action in the context of disease outbreaks, such as cholera, which tends to particularly affect poorer areas. Prior to actual outbreaks, reports of wastewater pollution are disregarded due to their low perceived urgency or the perception that people should change their own behavior first (Nare et al., 2006; Karpouzoglou, 2012; Karpouzoglou et al., 2018). Another example of reactive management is illustrated by Kedzior (2011), who describes how, for the sacred Ganges River, local authorities permitted the release of water upstream for the purpose of diluting pollution in direct response to mounting protests from worshippers. Serving as another example, Mosello et al. (2018) stress how international NGOs in crisis situations such as in the Central African Republic tend to prioritize short-term sanitation interventions over long-term development, monitoring and evaluation. This hinders careful gender-sensitive needs assessments and the consideration of cultural specificities.

3.4.3 Value and behavioral changes

Where the previously mentioned strategies considered long-term or short-term interventions in management arrangements, decision-makers may also aim to change values and practices of people in order to reach certain management objectives. This is usually done through awareness-raising activities, but these may serve different objectives. Empowerment-oriented awareness-raising initiatives can serve to equip local communities with the knowledge deemed necessary by decision-makers to understand wastewater issues, and to generate the motivation to address them. Examples include the training of students through summer and winter schools to build awareness in their respective communities (Pillai and Narayanan, 2022), the implementation of "triggering campaigns" to scale up Community-Led Total Sanitation (CLTS) (Bardosh, 2015) or the provision of facilitators and guidance documents to local government authorities for awareness-raising (Abeysuriya et al., 2019).

Awareness-raising can also aim to correct or problematize certain behavior perceived to impede the achievement of management objectives that have been determined by decision-makers. Examples of this include implementing awareness campaigns to end open defecation (Power and Wanner, 2017), promoting proper wastewater disposal practices for slum residents (Zimmer, 2012), and showcasing the benefits of scientific knowledge and modern technology compared to traditional knowledge and practices (Sibanda et al., 2022). However, several studies point to the political objectives that can be served by problematizing behavior and associated awareness-raising activities. These studies indicate the possibility of awareness-raising campaigns to shift responsibility for wastewater pollution from government authorities, service providers or industries to the community by implicating them as the main producers of wastewater which increases the chance for reactive management and a lack of response to community input (Kedzior, 2011; Deelder, 2013; Rusca et al., 2022; Wessels, 2023).

3.4.4 Factors for knowledge use

Various common factors that influence the use of knowledge across the different management strategies were identified. These factors, and the different ways in which they manifest, will be further described in this section. An overview of the factors and their occurrence across studies is provided in Figure 9.

The use of knowledge can be informed by the *governance structure* in different ways. First, a lack of clarity on roles and responsibilities can put into question whose knowledge should be used and how. This can hinder service provision by specialized authorities like the LWSC (Kennedy-Walker et al., 2015; Yinusa and Wehn, 2016), while in decentralized contexts it may lead to local authorities relinquishing responsibility for infrastructure maintenance and waste handling to local residents (Zimmer, 2012). Coupled with unclear responsibilities, fragmented bureaucracies along sectoral lines can make it challenging for authorities to engage in transdisciplinary initiatives (Pillai and Narayanan, 2022). However, Hahn et al. (2023) and Getachew (2013) also show how stakeholders' own understanding of their roles can limit their engagement, showing the need for clear communication about this early in decision-making.

Also of note concerning the governance structure is the composition of management boards which reflects whose knowledge is deemed conducive to inform decision-making. Karpouzoglou (2012) and Kedzior (2011), in their analysis of the Central and State Pollution Boards in India, note that the Regulatory Board members are appointed by the government, with scientists and engineers being selected but community members or representatives excluded. This has resulted in a narrow focus on technical interventions for industrial sources of pollution, largely neglecting domestic wastewater sources. Similarly, Juric (2018) illustrates how influential local actors in the Lake Koocanusa Working Group have particularly marginalized local tribes by establishing closed membership committees that restrict participation in the development of water quality objectives and mitigation strategies (e.g., the construction of treatment plants at

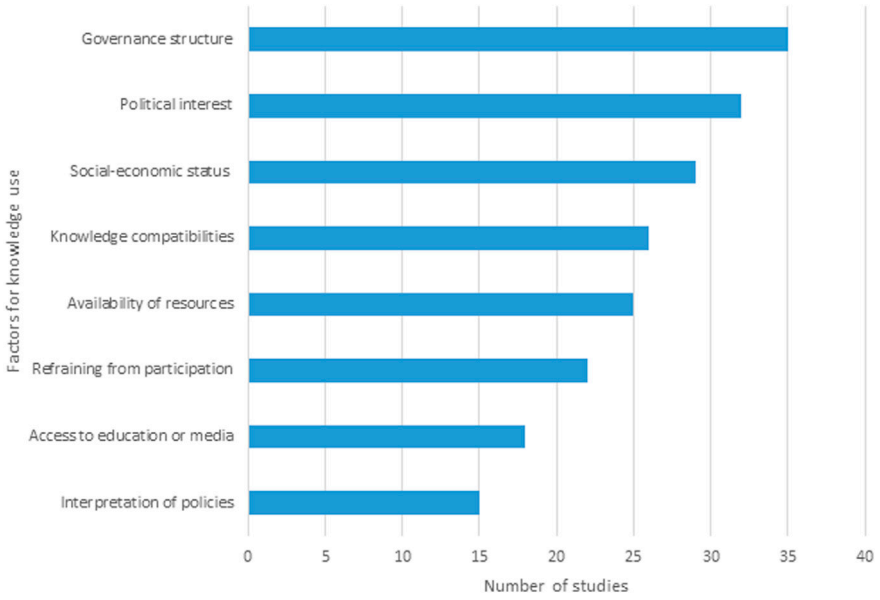

FIGURE 9
Factors for knowledge use.

mining sites). Additionally, the indirect representation of stakeholders in management boards can affect knowledge use. In a research on water quality monitoring and surveillance, Nare et al. (2006) note that many stakeholders are represented by local government authorities in stakeholder councils which may lead to misinterpretation or knowledge getting lost in bureaucratic procedures. Another issue of representation is elucidated by Baijius and Patrick (2019), who note that Canadian First Nations are represented by agents of the federal government rather than own members, centralizing decision-making processes in federal institutions.

A further structural aspect concerns the authority that is granted to lower government levels and which determines the possibilities to initiate local projects and the resources available for that. In the study by Deelder (2013) in Chiang Mai, Thailand, management of the Mae Kha Canal was transferred from the central government to the municipality. Notwithstanding the municipality's collaboration with the local university on a prospective management plan for the canal, its autonomy in terms of actual infrastructure development is limited because of a dependence on the central government for financial support. Similarly, Abeysuriya et al. (2019) found that in Indonesia, despite decentralization efforts, local governments lack actual control in terms of budgetary allocations and flexibility to adapt planning locally. Providing another perspective, Macaraig and Sandberg (2009) describe how centralization of control over the "Big Pipe" sewer expansion project in King City (Toronto, Canada) from the city to the region, as part of a broader effort to reduce responsibilities of municipal government, has directly reduced the ability of the city council to influence decision-making.

Another potential challenge in terms of governance structures is their inability to accommodate participatory management approaches and to open up to a broader range of knowledge types. The causes for this include 1) a lack of coordination between government levels which inhibits data exchange and ability to respond to stakeholder needs (Nare and Odiyo, 2013), 2) weak formal government bodies that lead to an over-reliance on informal management arrangements that risk to amplify local power asymmetries (Cairns, 2014), 3) rapidly changing administrations that hinder consistent planning and stakeholder engagement (Mahoney, 2011), and 4) a lack of communication between governing bodies and community members (Armitage et al., 2009; Nare and Odiyo, 2013; Sutherland et al., 2015).

As a last point on the governance structure, the extent to which stakeholders can and are willing to associate to lobby for their interests and speak with a unified voice can also influence the use of knowledge. Perreault et al. (2012) describe how the indigenous Onondaga Nation and the local Partnership of Onondaga Creek movement cooperated and were successful negotiating an alternative to a large regional treatment facility for combined sewer overflows in the form of underground storage and later treatment at a central facility. In another study on graywater management, Randle (2021) describes the formation of the "Greywater Guerillas," a collective of graywater advocates in Los Angeles (US) who united to challenge the domination of public service agencies who opposed decentralized small-scale graywater systems for fear of relinquishing control. Their advocacy efforts, combined with increased water stress due to prolonged droughts, eventually led to an overhaul of the Plumbing Code and increased opportunities to implement graywater systems.

Another relevant factor to consider for the use of knowledge is *political interest* to achieve particular economic, personal or political objectives. Such interests directly guide whose knowledge is considered to contribute to their fulfilment, and whose knowledge does not or is even opposed to them. Firstly, economic interests involved in politicized decisions can be manifested through the prioritization of business areas or

middle-class and elite neighborhoods for investments in sanitation infrastructure to make these even more attractive for investors. However, this neglects poorer neighborhoods and contributes to their portrayal as "dirty" and problematic areas (Deelder, 2013; Power and Wanner, 2017; Biza et al., 2022). Another way in which economic interests and political interests intersect, leading to reactive management, is the reduction of regulatory constraints, lax enforcement or downplaying of wastewater pollution in order to stimulate industrial development and economic growth which is often a high priority. In such cases, wastewater issues are instead ascribed to high rates of urbanization or lack of public awareness (Kedzior, 2011; Karpouzoglou, 2012; Karpouzoglou et al., 2018).

Apart from economic interests, personal political interests can also play a role in the use of knowledge. Kennedy-Walker et al. (2015) illustrate this by identifying peri-urban areas as "political playgrounds" for local politicians, due to their high population density providing major voter bases. In these areas, activities that advance the position of individuals and political parties are prioritized, complicating land allocation for sanitation service provision due to the emphasis on short-term and personal gratification. Similarly, Zimmer (2012) notes that in informal settlements in Delhi, politicians and local authorities become more interested in wastewater issues before elections, but that this interest wanes after the elections, resulting in unfinished projects and persisting issues.

Another way through which political interests can manifest is through the effort of decision-makers to "simplify" decision-making processes by only accommodating to very specific kinds of knowledge. Singh (2017) and Kedzior (2011) illustrate two distinct approaches by authorities. The first is to focus on sanitation coverage to achieve international goals in terms of increasing the total number of connections rather than ensuring an equitable use. Stakeholder engagement and awareness-raising campaigns are then seen as an additional burden, slowing overall progress. The second approach entails an engagement that is limited to stakeholders that align with the government's objectives on sanitation development. This allows for the claim of good governance while limiting broader engagement. This approach is accompanied by awareness-raising activities and disciplinary measures designed to equip currently excluded stakeholders with the required knowledge and to achieve the behavioral changes deemed necessary for meaningful participation in the future. This portrayal of stakeholders as not yet ready to participate and thus excluded is also discussed by Zimmer (2012) and Rusca et al. (2022). These authors describe how authorities choose to problematize individual practices and emphasize the community's responsibility for wastewater issues, thereby reducing their own accountability and deflecting demands for enhanced services.

A further relevant factor to understand the use of knowledge is *differences in social-economic status*. A number of studies report on middle-class or elite societal groups particularly benefiting from infrastructure development, such as sewerage extensions, the construction or improvement of drainage channels, or the installation of treatment plants, while poorer groups tend to be excluded. Similarly, these middle-class and elite groups are mostly empowered in cases of decentralization, privatization or participatory management initiatives (e.g., Nare et al., 2006; Zimmer, 2012; Singh, 2017; Rusca et al., 2022). In the case of privatized services, the fact that poorer social groups have fewer financial resources contributes to a divergence in service coverage (Putri and Moulaert, 2017; Rusca et al., 2022). Moreover, higher social classes generally have better political connections, enjoy higher education and are perceived to be more responsible and "clean," which further adds to the divide between higher and lower societal groups (e.g., Nare et al., 2006; Lippi et al., 2008; Zimmer, 2012; Karpouzoglou et al., 2018; Rusca et al., 2022; Wessels, 2023). It is observed that disparities in social status have affected the perceptions of decision-makers with regards to the capabilities of stakeholders to participate meaningfully. For example, Nare and Odiyo (2013) observe that water quality monitoring in South Africa remains fully controlled by experts despite government ambitions for more participatory management, while Mosello et al. (2018) note that women were excluded from WASH development by the international NGO Action Contre la Faim International in the Central African Republic due to high rates of illiteracy. Challenges faced by women, young people, the elderly, and individuals with physical disabilities are also relevant to mention. It is frequently observed that participatory management initiatives fail to adequately address the specific needs of such groups. This can make it difficult to join meetings, for example, due to speech or hearing impairments. Additionally, they can serve to perpetuate gender roles and age-related prejudices concerning capacity and physical ability (Cairns, 2014; Amokwandoh et al., 2020).

Yet another factor in the use of knowledge is *knowledge (in) compatibilities*. This refers to how well different kinds of knowledge align with the knowledge that currently informs management. First of all, the very knowledge used to assess wastewater pollution can cause incompatibilities (e.g., Deelder, 2013; Karpouzoglou and Zimmer, 2016). An example of this is the reliance on specific chemical indicators by the US Environmental Protection Agency for water quality assessments, which largely excludes consideration of impacts measured by other types of indicators (e.g., mercury or arsenic) (Freitag, 2013). Another illustrative example is provided by Kroon et al. (2009) who note that in the "Tully Murray Floodplain Program" the knowledge held by farmers proved to be incompatible with the scientific findings on the decline in water quality for the Great Barrier Reef. Although farmers identified erosion damage and sediment management as priorities, scientific studies indicated that nitrate and herbicides from agricultural run-off were the primary pollutants and the latter became the focus of the management strategy. Another cause for knowledge incompatibilities can be related to disparate visions on development. The study by Mueller et al. (2020) in Leh (Ladakh, India) provides an illustrative example. There, a community-managed system with dry toilets was replaced by a centralized water distribution and sewage system (including a treatment plant) with a national funding scheme. In essence, these technologies are tied to visions of modernity in the context of rapid urbanization, yet they fail to consider specificities such as the traditional use of dry toilets for manure in local agricultural practices.

In practice, once fixed criteria or preferences on knowledge required for decision-making are set, it is often challenging for stakeholders with different knowledge to contribute meaningfully. As May (2022), Himley (2014), Turley and Caretta (2020) and Kedzior (2011) discuss, the rejection of non-scientific and "non-expert" knowledge by authorities may make stakeholders dependent

on other knowledge holders in order for their own positions to be considered. In West Virginia, to prove water pollution residents were found to strongly depend on scientists employed by mining companies for groundwater quality testing near injection wells used to store wastewater from hydraulic fracturing (Turley and Caretta, 2020). Similarly, in the Ganges Basin (India), in order to be seriously considered by government authorities in plans for infrastructure development, local stakeholders had to rely on engagement with foreign activists or experts as knowledge from international experts was highly valued (Kedzior, 2011). Such dependencies were also noted by (May, 2022), who explains how an indigenous movement, opposed to the "megacollector" wastewater project in Lake Atitlán (Guatemala), sought out help from Western scientific experts to support a campaign for alternative solutions in the form of dry sanitation technologies. This Western knowledge was perceived as modern and advanced by decision-makers, thereby increasing its consideration.

Another relevant and practical factor for knowledge use is *availability of resources*. Kroon et al. (2009) and Nare and Odiyo (2013) emphasize the importance of allocating sufficient time for management formulation and stakeholder engagement. Lack of time was found to result in rushed stakeholder participation and insufficient consideration of different perspectives. Also relevant is the availability of financial resources. Shortages of money can result in the inability of local government authorities to implement management in decentralized contexts (Abeysuriya et al., 2019), the exclusion of stakeholders in the formulation of management due to insufficient resources to organize engagement (Yinusa and Wehn, 2016), or the exclusion of poorer groups in the development of sanitation infrastructure when they cannot contribute to the investments to be made (Saarilehto, 2006). Equally important is the availability of qualified staff or volunteers. In the study by Lippi et al. (2008), differences in technical expertise led to power disparities between service providers and governing bodies after privatization, resulting in suboptimal service delivery.

When speaking of factors for knowledge use, it is noteworthy that *stakeholders may refrain from participation*. This can lead to their exclusion in decision-making, but can also mean stakeholders do not want to contribute to the actual implementation of management initiatives. Firstly, Annamalai et al. (2016) and Sutherland et al. (2015) posit that there must be a genuine willingness and commitment to assume responsibility for wastewater management. Nevertheless, a reluctance to address the subject of sanitation and wastewater management may act as a deterrent to involvement (Karpouzoglou, 2012). For example, Mosello et al. (2018) describe the reluctance of women to voice concerns regarding personal hygiene to male NGO representatives conducting scoping surveys, while Cairns (2014) illustrates how negative perceptions of wastewater deterred individuals from contributing to the maintenance of the installed wastewater system in Sapecho (Bolivia). From a different perspective, communities receiving aid may experience uncertainty adopting novel and unfamiliar sanitation technologies, which may lead to unsuccessful management outcomes in the long-term when technologies are rejected and left unused (Singh, 2017; Hendriksen, 2019; Sibanda et al., 2022). Another reason to refrain from engaging in decision-making is a lack of trust in government authorities. A lack of trust may originate from repeated failures by government authorities to provide adequate sanitation services (Kennedy-Walker et al., 2015; Karpouzoglou and Zimmer, 2016). Distrust in government authorities can also affect the results of awareness-raising initiatives (Getachew, 2013; Bardosh, 2015). Getachew (2013) shows how this constituted a significant impediment to community engagement in health promotion (particularly sanitation) in Ethiopia. Health workers were regarded as political actors, and public health messages perceived as originating from the national government and scientists and being detached from community experiences. Interestingly, Kedzior (2011), Wessels (2023) and Zimmer (2012) describe how a lack of trust in government authorities, with particular groups in the community choosing not to engage in decision-making or to comply with governmental regulations, can lead to a shift on the part of the government authorities to perceive that community members are the cause of (persisting) wastewater issues. This shift in perspective is manifested through increased enforcement measures (e.g., fines, displacement) and a push for awareness-raising programs to force behavioral changes, further alienating communities from the government.

An additional factor to mention due to its empowering nature is the *access of community members, community leaders or NGOs to education or media* in order to raise their voice and promote their interests. Randle (2021), when reflecting on the work of the "Greywater Guerillas," discussed how interested citizens were empowered by the collective through installation training and workshops. This equipped the citizens with knowledge on graywater systems and regulations and made them active advocates for small-scale systems in negotiations with government authorities. Similarly, having or gaining access to media can allow for the promotion of interests of particular stakeholders, as shown by Beder (1991) and May (2022). In Australia, for example, a critical debate on the use of deep-water outfalls was effectively prevented through the government's concealment of data indicating waste accumulation in the marine environment. However, an increase in environmental awareness by 1989, coupled with higher media coverage, led to a broader dissemination of information regarding marine contamination and associated health risks. This proved advantageous for opposition groups, who were thus able to challenge the perceived benefits of deep-water outfalls (Beder, 1991).

A last factor that can influence the use of knowledge is the *interpretation of policies* and the certainty or uncertainty this gives in terms of stakeholder roles, permissible activities and knowledge that should guide decision-making. A direct way in which this manifests is through court rulings on whether the implementation of contested wastewater infrastructure projects may proceed or not (Mahoney, 2011; Perreault et al., 2012; May, 2022). Where court rulings lead to specific judgements with direct implications for knowledge use, unclear legal provisions can also affect knowledge use. For example, Juric (2018) considers that the lack of clarity regarding the roles of "other interested parties" in providing input, as outlined in the Lake Koocanusa Working Group's guiding document, undermined the position of stakeholders outside existing management committees. In the context of decentralization, Abeysuriya et al. (2019) observes that the lack of clarity in Indonesian national guidelines on the development of wastewater management contributes to confusion among local governments

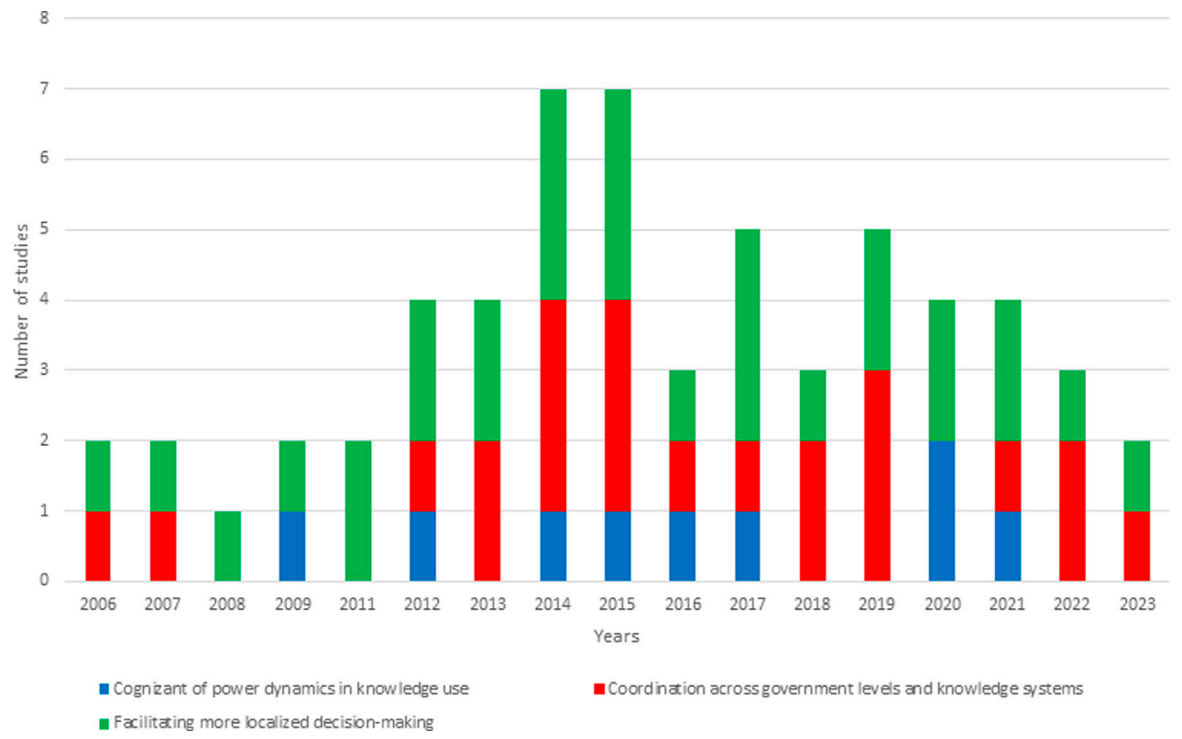

FIGURE 10
Ways to improve the inclusion of knowledge, as mentioned as recommendation in publications over time. Publications in the review before 2006 (n = 2) did not mention a specific recommendation for knowledge inclusion.

regarding the permissible scope of activities, particularly with regard to post-construction financial support for communities.

Apart from unclear provisions, a lack of legal provisions may also affect the use of knowledge. Kennedy-Walker et al. (2015), reflecting on difficulties experienced by the LWSC as a specialized authority to provide services, points to the dearth of legal provisions on the management of fecal sludge from on-site systems as a major reason for the persistence of service deficiencies. Furthermore, a lack of provisions may render it difficult for the public to speak up about pollution issues (Jordan, 1998; Nare et al., 2006; Kedzior, 2011; Karpouzoglou et al., 2018) or inadequacies in wastewater treatment technologies (Deelder, 2013; Baijius and Patrick, 2019). In addition, the lack of legal provisions can restrict stakeholder engagement (Al'Afghani et al., 2019). Kedzior (2011) reports one such case, where Indian authorities chose to limit engagement to businesses and NGOs that aligned with government's priorities on economic development and where the lack of regulations made it difficult to challenge this.

3.5 Potential ways to improve knowledge inclusion

The previous sections have reviewed the different management strategies used in wastewater management, and the common factors that inform the use of knowledge by decision-makers across strategies. In this section, the different approaches suggested to improve the inclusion of knowledge in decision-making will be discussed. Three main categories of approaches were formulated based on those discussed in the studies reviewed. The categories of approaches and their occurrence in studies across years are shown in Figure 10.

The most commonly suggested approach to improving knowledge inclusion is by *facilitating more localized decision-making*. While this review has identified challenges associated with contemporary implementation of such strategies, studies have also highlighted specific benefits that can be gained. Facilitating more localized decision-making enables for a more thorough consideration of political and cultural dynamics by local decision-makers, shaping aspects such as stakeholder representation, who benefits from privatization and potential divisions between socio-economic or ethnic groups. This would help to avoid overly general or one-size-fits-all initiatives that may not be locally feasible or well received by local decision-makers and communities, and can help to encourage more direct engagement of stakeholders to find local solutions to wastewater issues (e.g., Lippi et al., 2008; Zakiya, 2014; Bardosh, 2015; Vila, 2017). It is this potential for more direct stakeholder engagement, and specifically the integration of knowledge held by community members into wastewater management initiatives, that makes this approach often considered. It is anticipated that this will foster stakeholder commitment and ownership ensuring increased long-term positive impacts of management (e.g., Mehta et al., 2007; Annamalai et al., 2016; Hendriksen, 2019; Sibanda et al., 2022). Arrangements to facilitate this include the development of monitoring schemes or infrastructure by incorporating

indigenous knowledge (Nare and Odiyo, 2013; Harriden, 2022), the establishment of community associations or management committees to help inform decision-making by bringing people together (Zimmer, 2012; Cairns, 2014), and the integration of formal and informal (community-led) sanitation practices when formal management practices do not suffice (Randhawa and Marshall, 2014; Putri and Moulaert, 2017). However, an important precondition to truly achieve increased stakeholder engagement is to provide entry points throughout the decision-making process. In other words, rather than being an afterthought, stakeholder engagement must be facilitated from the outset in order to identify needs, develop management objectives, and implement appropriate evaluation schemes (e.g., Kroon et al., 2009; Amokwandoh et al., 2020; Turley and Caretta, 2020; Naidoo, 2022).

Another approach that has been mentioned more consistently from 2012 onwards to improve the inclusion of knowledge entails the *coordination across government levels and knowledge systems*. For bridging disparate knowledge systems, such as scientific knowledge and local knowledge, studies propose a variety of ways to improve inclusion. Freitag (2013) and Fam and Sofoulis (2017) found that respondents in their studies saw great value in people who are capable to bridge different knowledge systems. These "boundary spanners" or "knowledge brokers" have established good relationships with different stakeholders over time, are well aware of differences in perceptions and understanding, and in that capacity are able to bring different stakeholders together. A complicating factor is that while it may be challenging to bring together disparate knowledge systems, it may be equally challenging to address the dynamics within knowledge systems, showing the need for careful consideration. First of all, certain community dynamics may be at play, a common one being gender roles. To account for such dynamics, studies suggest collecting sex- and age-disaggregated data for sanitation needs assessment (Mosello et al., 2018), implementing quotas for gender representation and gender-specific actions (Vila, 2017), and making commitments to ensure equal access to management committees for different economic classes, ethnicities and genders (Cairns, 2014). Apart from such community dynamics, there may also be disciplinary constraints when experts from different backgrounds, such as social scientists and engineers, are involved in decision-making processes. These groups may have very different understandings of wastewater issues and the ways to solve them, which may not necessarily be compatible to one another, leading to rejection or incomplete understanding. To counter this, Hendriksen (2019) emphasizes the importance of ensuring disciplinary diversity in expert groups in order to enable a continuous dialogue and obtain complementary insights from different kinds of expertise. Similarly, Mehta et al. (2007) and Karpouzoglou (2012) suggest to extend risk assessments across scientific disciplines in order to obtain a better understanding of wastewater issues and management needs.

Dynamics can also be found at the government level, where different government offices, such as environmental management and public services offices, may fail to coordinate with one another. This occurs both within a specific government level (e.g., province) as well as between different levels (e.g., national and regional). This can be problematic, for instance, in the context of environmental permitting processes, where cooperation may facilitate a more comprehensive consideration of the cumulative impacts of new projects or management initiatives (Naidoo, 2022). To counter such cases and improve coordination, Yinusa and Wehn (2016) and Karpouzoglou (2012) suggest the creation of fora which are regular and structured meetings where government offices come together for exchange and decision-making. Such fora can not only benefit the permitting processes, but can also facilitate, for example, the co-development of sector-specific indicators for wastewater, aiding management evaluation and regulatory compliance.

An important aspect to bridge dynamics between knowledge systems or government levels is the explicit delineation of stakeholder roles. Hahn et al. (2023), Al'Afghani et al. (2019), Abeysuriya et al. (2019) and Kennedy-Walker et al. (2015) emphasize the necessity of establishing clarity regarding responsibilities and expectations from the outset of wastewater management initiatives to ensure that stakeholders can fulfil their intended roles. Failure to do so can be a serious obstacle, for example, when pursuing community-led management. From another perspective, Karpouzoglou (2012) and Juric (2018) stress that setting clear roles is an important step towards more inclusive and diverse assessments of wastewater pollution, which otherwise risk being limited to a very narrow scope due to disciplinary divides.

A third approach to improving knowledge inclusion, which emerged from this review but was less consistently mentioned, is for *decision-makers to be more cognizant of the role of power dynamics in the use of knowledge*. Some studies make a general call for a better understanding of the repercussions of knowledge use in terms of how wastewater issues are addressed and what perpetuates existing patterns of knowledge use. Importantly, these studies emphasize the plurality of knowledge around wastewater in a political and power-laden context that has evolved over time, leading to certain knowledge being privileged over others (Mehta et al., 2007; Himley, 2014; Kennedy-Walker et al., 2015; Karpouzoglou et al., 2018; Turley and Caretta, 2020; Rusca et al., 2022). Other studies are slightly more specific by calling on decision-makers to increase the transparency of decision-making processes and to make the role of power and vested interests in the use of knowledge more visible. These authors stress that decision-makers should find ways to more clearly illustrate if and how knowledge is being used, how it shapes management practices and priorities, and who has access to decision-making processes and who does not (Kroon et al., 2009; Karpouzoglou, 2012; Karpouzoglou and Zimmer, 2016; Amokwandoh et al., 2020).

The importance of understanding the role of power dynamics in knowledge use has also been illustrated throughout this review. For example, it has been shown that power asymmetries can render decentralization, privatization and participatory management initiatives less effective than intended. Many factors can play a role, including among others that lower government levels do not have the authority they need in decentralized arrangements, that governance arrangements are poorly prepared to accommodate participatory management, or that groups of lower socio-economic status are excluded in privatized management settings. From another perspective, it has been shown that awareness-raising or disciplinary actions may be motivated by perceptions that particular groups are unwilling or unable to adopt "correct" behavior. The determination of what should be learned or corrected and by whom gets informed by, among other things, social class differences and political objectives,

which may also reveal underlying motivations such as authorities relinquishing responsibility for wastewater pollution or delaying broad stakeholder participation until the time stakeholders are "aware." Similarly, this review has shown how reactive management can be informed by political objectives such as economic growth, leading to reduced regulatory pressure or lax enforcement to stimulate further development.

4 Discussion

In response to an increasing recognition of the political nature of wastewater management, this review has provided an overview of the current state of the literature. It has been shown that the politics of knowledge in wastewater management did not (yet) receive consistent scientific attention, but that existing studies cover varied cases across different regions and consider a range of knowledge holders and knowledge types. The importance of the role of local particularities in shaping management, as emphasized in political ecology, is acknowledged through different perspectives such as the wastewaterscape. Studies have further demonstrated that a broad range of factors, either in isolation or in combination, can determine whose knowledge shapes local management and whose knowledge is excluded. In particular, the factors of knowledge compatibilities, social-economic status, the interpretation of policies and the degree of access to education and media align with the concept of knowledge politics and knowledge legitimacy. This is illustrated by the fact that processes determining whose knowledge is considered correct and/or who is perceived to possess the knowledge required to contribute to management are highly relevant. However, knowledge use is also shaped by more structural or strategic aspects in the form of resource availability, political objectives and interests, and the larger governance structure (e.g., degree of coordination between agencies). Moreover, stakeholders also have a choice to not participate in decision-making (e.g., due to a lack of trust). The diversity of factors is illustrative for the complex nature of the politics of knowledge in wastewater management, which is further expressed by the variety of theoretical frameworks and concepts supporting existing studies. This reflects the intent of previous research to step beyond fixed theoretical frameworks and concepts to generate additional insights and to improve our current understanding. Taking a broader view, the existing literature reveals that decision-making in wastewater management is frequently based on scientific, engineering, and/or legal knowledge, which, while important in guiding decisions, is often not sufficient on its own to ensure effective long-term solutions. Nevertheless, the adjustments that are being made in wastewater governance with the potential for stakeholder empowerment underscore a necessity not only to examine the factors that contribute to the (continued) exclusion of knowledge, but also to gain a deeper understanding of the factors that facilitate its inclusion. It is as important to build on success stories as it is to understand the obstacles to further improvements in management in the future.

An important finding of this literature review is that many studies tend to remain general in their recommendations for better understanding the role of power relationships in the politics of knowledge and improving knowledge inclusion. However, given the political nature of wastewater management, as evidenced throughout this review, and the implications associated with knowledge exclusion in terms of achieving management objectives or exposure to wastewater impacts, this represents an important limitation of current literature. Therefore, there is a need for more specific research and context-specific guidance. Specifically, it would be beneficial to determine ways to enhance the transparency of decision-making processes in terms of the knowledge that is included and excluded, making the role of power relations more visible. Further scientific inquiry on how this can be achieved is much needed to provide decision-makers with the guidance to make the necessary adaptations to decision-making processes. Valuable and transferable lessons may also be obtained from studies around fresh water (access and distribution) with a larger supporting body of literature. However, as this review has also shown, individual cases can greatly differ, which means that apart from general principles it will be necessary to remain aware of local particularities.

Another important observation in this review is the need to consider possible ways to better connect different knowledge systems as well as different levels of government. It has also been shown that there are dynamics within particular groups, such as among different ethnic groups in the community or between different scientific disciplines. Important recommendations include the engagement of knowledge brokers or boundary spanners, the establishment of fora involving regular meetings for government authorities to come together and the clarification of roles among stakeholders involved in management initiatives. At this point, there is a need to further implement such solutions in practice and determine their best application in different contexts. In relation to knowledge brokers or boundary spanners, it will be of interest to determine what qualities are required for someone to bridge different knowledge systems, and how decision-makers can engage such people more systematically.

In conclusion, this review illustrates that different kinds of knowledge about wastewater coexist, including differing views on the severity of the issue and potential solutions. However, these do not exist in a realm devoid of political influence but in a context characterized by power asymmetries and knowledge politics where different factors can influence whose knowledge is perceived as legitimate. The reliance on certain forms of knowledge and the exclusion of others may result in an incomplete understanding of the issue, which could lead to ineffective management or unequal exposure to negative impacts of wastewater pollution. With a better understanding of the diverse factors that shape the use of knowledge in wastewater management, there is a need for more context-specific guidance to identify ways to improve the inclusion of decision-making processes.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Author contributions

RL: Writing – review and editing, Methodology, Writing – original draft, Investigation, Conceptualization, Formal Analysis, Visualization, Data curation, Project administration, Validation. YK: Writing – review and editing, Methodology, Conceptualization, Supervision, Project administration. MF: Funding acquisition, Project administration, Writing – review and editing, Supervision, Conceptualization, Methodology.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The author(s) declare that no Generative AI was used in the creation of this manuscript.

Publisher's note

Supplementary material

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