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Public acceptance in direct potable water reuse: a call for incorporating responsible research and innovation

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ABSTRACT

As global issues such as climate change and diminishing resources become increasingly pressing, water recycling has moved into the focus. However, the successful implementation of Direct Potable Water Reuse (DPR) projects hinges on securing public acceptance, which remains challenging. This paper aims to flesh out possible reasons for the lingering public rejection of DPR. We will do so by conducting a literature review on how public acceptance is understood and what approaches are proposed to enhance it. These approaches are analyzed using Responsible Research and Innovation principles and the `opening up', `closing down' and `leaving ajar' approaches. Our research identifies an overreliance on the controversial information deficit model, closing down large parts of public engagement. We advocate for becoming more inclusive through the `leaving ajar' approach. Particularly, attention should be paid to *reflexivity* and *responsiveness* to public concerns to ensure meaningful public engagement.

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Direct potable reuse; responsible research and innovation; public acceptance; information deficit model; public participation

Introduction

Increasing water demand due to growing populations and climate change has strained global water resources (Bates et al. 2008). The World Health Organization (2019) projects that by 2025, half the world's population will reside in water-stressed areas. In response, sustainable innovations and strategies to increase freshwater availability have gained substantial attention.

One such strategy is Direct Potable Water Reuse (DPR), a socio-technical system that utilizes advanced treatment technologies to reuse wastewater as a source of freshwater. DPR has the potential to contribute to sustainability by conserving freshwater sources, decreasing pollution, and reducing the carbon footprint (Burgess et al. 2015). However, despite these advantages, DPR remains a highly controversial water reuse system, primarily due to the explicit connection between wastewater and drinking water (Binz et al. 2016; Leverenz, Tchobanoglous, and Asano 2011). This explicit link has resulted in low public acceptance, posing challenges to the successful implementation of DPR.

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To address this issue, scholars have increasingly studied public acceptance in the context of DPR and proposed approaches to enhance it. Unfortunately, these approaches primarily rely on the information deficit model, assuming that the public lacks sufficient understanding of the benefits of a particular technology. The limitations of the information deficit model have been extensively discussed as inadequate in various domains (Rodhouse et al. 2021; Scruggs, Pratesi, and Fleck 2020). Also, in DPR research, studies have demonstrated that simply providing information is insufficient to address the challenge of public rejection. Consequently, by relying on this model, DPR continues to face implementation failure.

This research advocates aligning DPR implementation approaches with Responsible Research and Innovation (RRI) principles. There appear to be only a few RRI studies of water reuse technologies, and only one, conducted by Dotson (2019), can be considered similar to this study. Dotson (2019) explored whether intelligent trial and error practices can help innovations such as recycled oil and gas wastewaters proceed more responsibly and has found significant gaps in RRI alignment. The authors highlighted substantial concerns, such as the dominance of dubious scientific data, the exclusion of specific stakeholders, and the omission of pivotal information. Our study resonates with these findings, further underscoring the need for incorporating RRI, especially within the context of DPR, which has yet to engage this discourse.

To move a step closer to DPR's alignment with RRI principles, we first conducted a literature review examining the concept of public acceptance in the context of DPR and identifying proposed approaches to enhance it. The identified strategies were subsequently evaluated to the extent they align with the principles of RRI discussed through the 'opening up', 'closing down' and 'leaving ajar' approach proposed by Russell et al. (2022).

The paper is structured into five sections. Following the *Introduction*, the *Methodology* section situates this study into the RRI literature and introduces the framework that will guide the analysis of the literature review findings. Furthermore, key concepts, literature research and coding strategy are outlined. The *Review Results* section presents the literature review findings, highlighting the current understanding of public acceptance of DPR and the proposed approaches to address it. Then, the *Discussion* section discusses the extent to which the proposed approaches align with the goals of RRI. Finally, the *Conclusion* section provides some concluding remarks on the review and suggests future research directions.

Methodology

This section serves to situate this research article within the RRI scholarship and introduces definitions of wastewater and water reuse concepts. Furthermore, it outlines the literature review process.

Responsible research and innovation

RRI offers guidelines to ensure that technological developments align with societal values and needs (Boenink and Kudina 2020) and rests on the view that including diverse perspectives not only enhances democratic principles but also improves decision quality by incorporating a more comprehensive range of knowledge (Stirling 2008).

RRI aims to prevent technological failures by providing pre-emptive measures to mitigate potential adverse effects of innovations that emerge from technology introduction (Von Schomberg 2011). One of the most used frameworks within the RRI scholarship is the AIRR framework, which focuses on *Anticipation, Inclusion, Reflexivity,* and *Responsiveness.* These dimensions are designed to address emerging social and ethical concerns of technology innovation and serve as handholds in the innovation process. As such, the framework acknowledges the dynamic relationship between technology and society, recognizing that technology both shapes and is shaped by society (Bijker 1994).

We will apply the AIRR principles by building upon the approach presented by Russell et al. (2022). The authors identify two primary extremes of public engagement in technological advancements: the 'opening up' and 'closing down' approach. In this, 'opening up' advocates widening the knowledge base in decisions related to new technologies by including the concerns and perspectives of non-experts and affected groups (Stirling 2008). Consequently, the meaningful *inclusion* of new perspectives through 'opening up' engagement is the most fundamental aspect in this framework, enhancing the democratic level of decision-making and, as such, determining the success or failure of aligning with RRI principles.

Diversifying the knowledge base can better prepare innovation projects to navigate unforeseen challenges, thereby increasing its *anticipatory* capacity and providing a more comprehensive understanding of local societal contexts. Such a broad view allows for more informed decision-making, enabling the exploration of alternative paths and discovering previously unconsidered solutions (Cuppen and Pesch 2021). As such, 'opening up' engagement encourages *reflecting* on the innovation process and equips decision-making parties to *respond* to the public's needs and concerns. It stands out that such 'opening up' engagement reaches beyond the deliberation of a single technology; it also questions the desirability and appropriateness of such technology.

Conversely, 'closing down' refers to resorting to traditional measures to convince the public of a technology's benefits through, for example: 'emphasizing the severity and urgency of the problem, presenting [the technology in focus] as the best solution, avoiding more contentious applications' (Russell et al. 2022, 157).

Between the two extremes of 'opening up' and 'closing down', Russell et al. (2022) suggest a third approach to public engagement, called 'leaving ajar'. In this approach, engagement is utilized to make a particular technology innovation project socially acceptable by being 'responsive to public views, but with a pragmatic focus on creating the conditions that might allow the technology to be successfully deployed' (Russell et al. 2022, 160).

Wastewater and water reuse

To avoid misunderstandings and increase the clarity of this research, this section provides some definitions of key concepts of the wastewater and water reuse domain.

Wastewater. Wastewater is commonly defined as water that domestic homes, industry or agriculture have used previously, containing human faeces, oils, soaps, chemicals and the like.

Types and purposes of water reuse. Traditional drinking water technologies use groundwater or surface water as a source. Water reuse technologies allow for alternative sources of drinking water, such as industrial and domestic wastewater.[1] Water reuse refers to the beneficial use of treated wastewater (Kayhanian and Tchobanoglous 2016). Wastewater treatment varies in intensity depending on its purpose, especially whether it will be potable or non-potable. Although our research focuses on DPR, we briefly introduce two other types of water reuse – IPR and de facto reuse – as they are often mentioned alongside DPR technology.

Indirect potable reuse. With IPR, treated water is discharged into an environmental buffer (Gerrity et al. 2013) into an environmental buffer can be a body of water (e.g. surface or groundwater). Currently, IPR is used in several locations around the world, foremost in the US and Australia (Santos et al. 2022).

Direct potable reuse. DPR does not use an environmental buffer between the wastewater treatment and the piping of the purified water to consumers (e.g. Boyer, Hopkins, and Moss 2017; Lahnsteiner, Van Rensburg, and Esterhuizen 2018; Moya-Fernández et al. 2021). This technology is, therefore, a viable option in regions where buffers are unavailable or inefficient due to high run-off or evaporation rates.

A schematic of DPR and IPR can be found in Figure 1. Both depend on similar rigorous technology that treats wastewater to meet the expected potable water norms. The main difference between them is the presence or absence of an environmental buffer (Gerrity et al. 2013).

De facto reuse. De facto reuse, also called unplanned reuse, refers to the involuntary reuse of treated wastewater from upstream settlements (Kayhanian and Tchobanoglous 2016). Throughout the world, sources of potable water often already contain wastewater discharged by upstream settlements (Gerrity et al. 2013; Meeker and Tricas 2015). This daily practice is often unacknowledged (Nagel 2015).

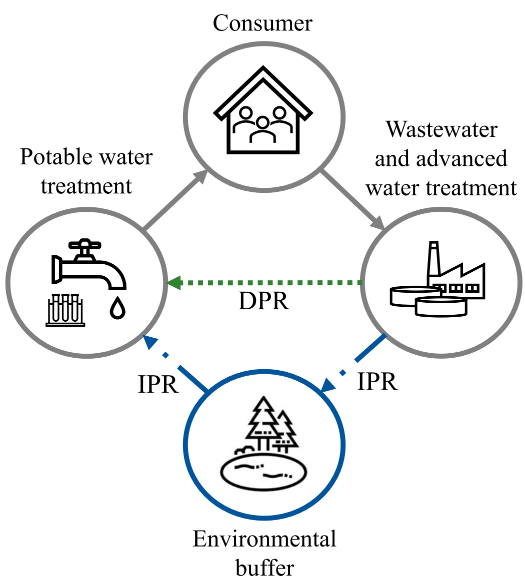

Figure 1. Schematic of the DPR and IPR treatment processes. Adapted from Eden et al. (2016). 'Potable Reuse of Water,' Water Resources IMPACT, vol. 18, no. 4, pp. 10-11.

Search strategy

A review of the literature on the social impacts of DPR was conducted, following the process described by Moher (2010). The literature was assessed in three stages: search, screening and selection (see Figure 2). Each stage narrowed down the number of papers until a set of 67 papers remained. Of these, 55 papers were included as the remaining 10 contained relevant information already provided by the other papers, and 2 papers were literature reviews closely related to the topic at hand.

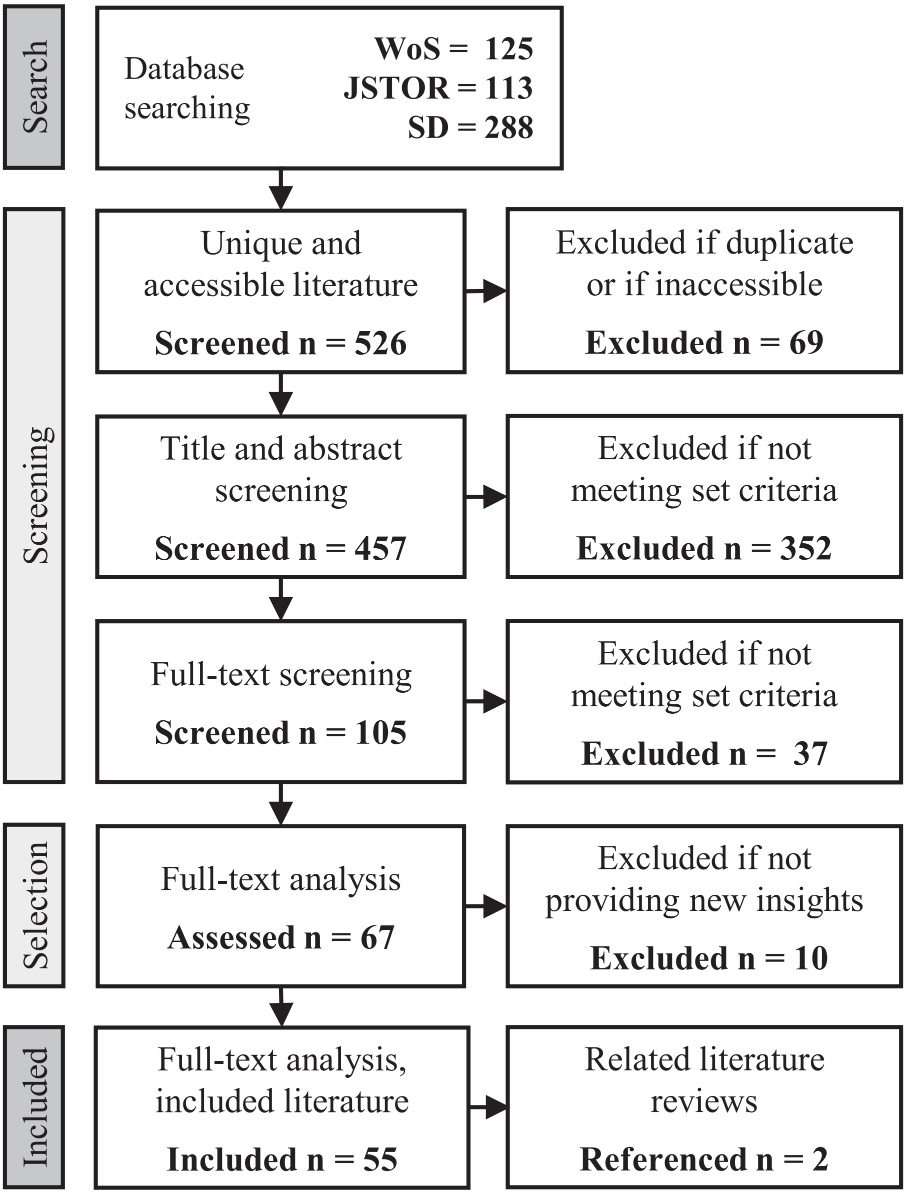

Figure 2. Literature selection process based on Moher (2010).

The literature collection was limited to three research platforms: Web of Science (WoS), JSTOR and Science Direct (SD). These platforms were chosen because they contain a large number of social studies. In addition, WoS was selected for its accuracy, high reproducibility and large number of databases, JSTOR for its wide range of popular research and SD for its large number of unique, relevant documents. We chose not to use the Scopus platform because it has many of the same articles as WoS, and many of its articles are inaccessible.

For the literature search, we used the query '*Direct Potable Reuse' OR 'Direct Potable Water*' searching in the title, keyword and abstracts of all three databases:

WoS: ALL = ('Direct Potable Reuse' OR 'Direct Potable Water') AND PY = 2009-2021

JSTOR: 'Direct Potable Reuse' OR 'Direct Potable Water'. [Filter > 2009]

SD: TITLE-ABS-KEY ('Direct Potable Reuse' OR 'Direct Potable Water') AND PUBYEAR > 2009

Since the focus is on relatively new water reuse technologies, we limited the publication year to 2010 and later. Before 2010, DPR did not receive much attention from scholars. The search phase resulted in 526 documents. Each title and author was collected in a single file and assessed manually; no data mining platforms were employed. This manual screening method was possible as a significant portion of the papers were on technical aspects and could be discarded early in the process through mere title screening. The initial sample could have been reduced by using stricter filter criteria, but beginning with a large sample minimized the chances of missing important literature.

The screening phase started with removing duplicates and inaccessible documents, leaving 457 documents. The abstracts, titles and keywords were then screened using the following exclusion criteria:

(1) The focus is not on DPR or potable water reuse. Here, it must be noted that the selected literature focused predominantly on DPR to provide a clear picture of DPR's core research on social challenges. This means that this review may be missing some relatable insights from other technologies, such as Indirect Potable Water Reuse or Desalination.
(2) The focus is not on societal aspects.

Many popular research articles did not provide an abstract and keywords. In these cases, we used cross-reading, which led to a lower rejection level and the need for closer inspection in the full-text screening phase. The abstract and title screening reduced the documents to 105.

The same exclusion criteria were applied in the full-text screening phase, leaving us with 67 relevant documents. These were again read closely. In this last phase, documents were excluded if they did not contain any new insights or were literature reviews themselves, which left a final number of 55 documents for this review.

Of these 55 articles included in this literature review, 40 (roughly 73%) were scientific, including transitional and social sciences studies. The remaining 14 papers (roughly 25%) were published in popular magazines and were often opinion pieces or of an educational nature, introducing DPR or wastewater reuse to a lay audience.

Literature categorization and coding

The literature analysis was conducted without predefined categories. Instead, the categories were deducted from the literature at hand. We found that public acceptance is generally understood as an overarching complex indicator of different public concerns. These factors, however, are not always agreed upon, which is often explained by its case dependency (Al-Saidi 2021).

With the low number of papers regarding public acceptance and DPR, there is also a lack of acknowledged predefined categories. Hence, we chose to create categories during the review synchronously and refrained from making categories based on prior knowledge to avoid bias early on.

During the review process, we found that the different aspects of public acceptance can be sorted into two categories, technology and context-dependent factors, which is in line with the research of, for example, López-Ruiz et al. (2021) and Distler, Scruggs, and Rumsey (2020). Each of these two categories contains unique subcategories that we will call public acceptance factors, or factors in short, as seen in Table 1. This setup of categories and factors will be used as a general framework for the first part of literature review.

As a second step in the screening phase, we identified proposed approaches to increase public acceptance (hereafter: 'approaches'). Again, the categories and subcategories emerged during the literature review process and were not predefined. Some categories were further specified into subcategories (Table 2).

Review results – DPR's public acceptance as a complex phenomenon

In this review, a relatively large number of factors were considered to influence public acceptance of DPR. Their respective importance was highly case-dependent (cf. Al-Saidi 2021). Factors of public acceptance were often split into two main categories: technology-dependent and context-dependent (e.g. Distler, Scruggs, and Rumsey 2020; López-Ruiz et al. 2021). For technology-dependent factors, the literature has a focus on two broad aspects: Safety and risk and the Yuck Factor. On the other hand, the context-dependent factors are more fine-grained and deal with trust, knowledge, urgency, culture and religion, justice and legitimacy. While some scholars have made a more detailed distinction between the contextual factors for this paper, the broader

Table 1. Categorization of Public Acceptance Factors.

Category	Technology-dependent factors	Context-dependent factors	
Codes	• Safety & Risk • The Yuck Factor	• Knowledge • Trust • Urgency	• Culture & Religion • Justice • Legitimacy

Table 2. Categorization of approaches to enhance public acceptance.

Category	Educating	Public outreach
Codes	• Conventional education • Unconventional education • Pilot projects • Criticisms & inconsistencies	• Clear message & reframing • Enhancing trust • Public engagement Understanding & adapting

categorizations suffice because we aim to give a broad overview of current research rather than a detailed investigation of individual studies.

Technology-dependent factors

Technology-dependent factors are those directly related to the working and aims of a technology. Two main factors were identified: safety and risk and the Yuck factor.

Safety and risk

The concerns for safety and risk associated with DPR and water reuse were one of the most mentioned challenges in the reviewed literature (e.g. Duong and Saphores 2015; Fuenfschilling and Truffer 2016; Ormerod, Redman, and Kelley 2019). Safety and risk are related to the degree of human contact and to different risk perceptions.

Degree of human contact. The degree of human contact with treated wastewater was repeatedly seen as being of major importance for public acceptance (e.g. Adapa, Bhullar, and Valle de Souza 2016; Boyer, Hopkins, and Moss 2017; Ormerod, Redman, and Kelley 2019). There seemed to be a negative correlation between the degree of human contact and public acceptance – the higher the degree of human contact, the lower the public acceptance (Moya-Fernández et al. 2021). This association, however, did not hold for all cases. A survey in South Africa resulted in the opposite finding – potable reuse received more support than non-potable reuse (Prins et al. 2022). Also, Kandiah, Berglund, and Binder (2019) doubted whether the degree of human contact is closely related to public acceptance.

Risk perception. Researchers seemed to agree on the importance of this issue for technology acceptance and consequent adoption. Duong and Saphores (2015) distinguished between several types of risk: scientific-objective, cultural-relativist and realist, a combination of the other two types. According to these authors, the first two, in particular, are based on different premises and can, therefore, lead to conflict (Duong and Saphores 2015).

The scientific-objective perspective is technical, describing potential risks derived from empirical evidence. Within wastewater management systems, including DPR, challenges such as microbiological pathogens, pharmaceuticals and personal care products in the effluent are increasing (Cotruvo 2016; Voulvoulis 2018). Pathogens are challenging to detect and remove during treatment (Duong and Saphores 2015; Kandiah, Berglund, and Binder 2019; Roccaro and Verlicchi 2018). Additionally, the treatment process can create by-products that must be removed with additional treatment (Hummer and Eden 2016). The high level of scientific uncertainty about the degree of contamination and its potential effects raises safety concerns (Hummer and Eden 2016).

The cultural-relativist perspective refers to the experiences and emotions of those affected and is one of the main factors that dominate acceptance concerns (Duong and Saphores 2015). According to Fielding and Roiko (2014), perceptions of risk in this view are subjective regarding the likelihood and magnitude of adverse outcomes. Cultural-relativist risk is interwoven with symbolic meanings such as ‘purity’ and depends on the current social order (Duong and Saphores 2015) and trust in authorities (Duong and Saphores 2015; Voulvoulis 2018).

The realist perspective combines the scientific-objective and cultural-relativist perspectives by using empirical evidence while acknowledging social considerations such as trust in authorities and fear (Duong and Saphores 2015).

The Yuck factor

The 'Yuck factor' has been mentioned by various researchers as a primary impediment to public acceptance (e.g. Bichai, Kajenthira Grindle, and Murthy 2018; Moya-Fernández et al. 2021). Notably, water reuse projects have been halted or abandoned due to this factor (Askin 2016; WWAP 2017). Bioethicists first used the concept to reject human tampering with the natural order (Duong and Saphores 2015). In the context of DPR, however, the concept is used with a somewhat different focus, highlighting three main notions: disgust, aversion to new technology, and violating social norms.

Disgust appears to be the most frequently referenced aspect, which Duong and Saphores (2015) characterized as 'repugnance triggered by the idea of consuming the water that was once flushed down a toilet' (200). Ormerod, Redman, and Kelley (2019) expanded this definition by connecting it to social and cultural risk perceptions (see also Kandiah, Berglund, and Binder 2019). Villarín and Merel (2020) propose that this factor involves 'trust, subjective social norms, perceived control, and emotional aversion' (16) and potable recycled water clashes explicitly with the social norm of separating drinking water and wastewater (Duong and Saphores 2015).

Additional factors contributing to the Yuck factor include a lack of knowledge (Tennyson, Millan, and Metz 2015) and public squeamishness (Bufe 2013a; Katz and Tennyson 2015; Tennyson, Millan, and Metz 2015), with the latter prominently discussed in popular research articles. Despite elaborate research, overcoming the Yuck factor remains a challenge (Leong and Lebel 2020)

Context-dependent factors

Despite technology-dependent factors, public acceptance is considered a highly context-dependent phenomenon (Al-Saidi 2021). Five main factors that influence public acceptance were identified in this review: trust, knowledge, urgency, culture and religion, and justice.

Trust

In discussions on public acceptance of water reuse, scholars emphasize the pivotal role of trust. While trust is conventionally associated with interpersonal relationships (McLeod 2006), in the DPR literature, it is multi-faceted, extending to authorities (Boyer, Hopkins, and Moss 2017; Fielding and Roiko 2014; Voulvoulis 2018) and institutions (Moya-Fernández et al. 2021; Mukherjee and Jensen 2020).

According to Harris-Lovett et al. (2015), engineers and implementing authorities often link public trust to well-designed technologies and monitoring. For instance, the Long Angeles DPR project indicated general uncertainty about water sciences and the technology employed (Lejano and Leong 2012). Moreover, trust in technology hinges on trust in its operators, as the technology's ability to function adequately 'provides no assurances without an enforcement mechanism' (Martorana 2016, 42). Therefore, the success of technology relies on trust in authorities and institutions, contingent on their risk-management capabilities and sound decision-making processes (Harris-Lovett et al. 2015). As such, trust, particularly in authorities, proves fragile and can rapidly erode during contamination (Mukherjee and Jensen 2020).

The significance of trust in institutions, authorities and experts can vary regionally. In southern Spain, the relationship between trust and public acceptance was statistically insignificant (López-Ruiz et al. 2021), while in Africa, low trust in the government and in authorities' capabilities was a major factor (Prins et al. 2022).

Concerns about trusting authorities often stem from past experiences or opaque processes (Harris-Lovett et al. 2015). In an Australian pilot project, the public accused authorities of treating them as 'guinea pigs', keeping them 'in the dark regarding the negative impacts of drinking recycled water' (Fuenfschilling and Truffer 2016, 305).

Knowledge

In this review, public rejection of DPR was often explained by a lack of knowledge (Lejano and Leong 2012). In fact, Khan and Anderson (2018) suggested that a lack of familiarity with the technology was one of the main factors influencing public acceptance. In a study on the willingness to pay for recycled wastewater, the author explained the unexpected outcomes as being due to cognitive dissonance or the inability to comprehend technical information (Boyer, Hopkins, and Moss 2017). In South Africa, citizens were considered to have little to no knowledge about wastewater treatment and distribution (Burgess et al. 2015). As researchers have found, there seems to be a positive correlation between knowledge of the technology and acceptance (Adapa, Bhullar, and Valle de Souza 2016; Furlong et al. 2019; Kandiah, Berglund, and Binder 2019).

Besides knowledge of the technology itself, several other kinds of knowledge were considered relevant by the scholars in this review. These included general knowledge about the hydrological cycle and knowledge about situational factors such as water availability and the quality and origin of the current water supply (e.g. Boyer, Hopkins, and Moss 2017).

Urgency

The feeling of urgency seems to have the capacity to both drive and impede DPR implementation. Some authors suggested that public acceptance is higher in times of drought (Bufe 2013a; Wester and Broad 2021) or in generally arid regions (Scruggs and Thomson 2017). According to Landers (2015), this heightened awareness should be used to overcome negative public resistance to water reuse.

However, evidence suggests that urgency can vary in importance and stability. The former was shown in Australia, where DPR was rejected even though the area involved is highly arid and was experiencing extreme drought (Roccaro and Verlicchi 2018). In this case, a local expert claimed the urgency led to lower acceptance because the public felt forced to implement a technology they did not support (Heffernan 2014).

Katz and Tennyson (2015) warn that linking water reuse projects to drought is not a secure long-term strategy due to drought's unpredictability. This instability was found in Wichita Falls (Texas, US), where a DPR facility was built during a drought. However, the facility was not completed until after the drought ended, and public acceptance had decreased. The plant has been idle for many years (Bufe 2013b).

Culture and religion

The social challenges surrounding DPR vary by country, but they also show large differences within countries (Furlong et al. 2019; Ormerod, Redman, and Kelley 2019). Public acceptance seems to differ in different cultural and religious contexts. Within Asian cultures, the use of faeces receives greater approval because it is often related to 'traditions of frugality' (Kayhanian and Tchobanoglous 2016, 1612). Such usage seems generally rejected in other regions, such as Western and African contexts (Kayhanian and Tchobanoglous 2016) and Latin America (Al-Saidi 2021). Moreover, in communities with large Islamic populations linger uncertainties about the appropriateness of DPR (Bichai, Kajenthira Grindle, and Murthy 2018; Kayhanian and Tchobanoglous 2016) due to, for instance, the halal status of the purified water (Lee and Jepson 2020). The stark differences in acceptance within countries indicate that religion and culture are essential factors, illustrating a region's unique context (Furlong et al. 2019).

Environmental attitude is another factor that can be attributed to a region's culture. Some authors mentioned that positive attitudes towards the environment play a significant role in accepting water recycling (Tchetchik, Kaufman, and Blass 2016). Reusing water is seen as a means of acting responsibly towards the environment because it puts less strain on natural resources (López-Ruiz et al. 2021). A discreet-choice experiment conducted in Israel indicated that a positive attitude towards the environment increases the likelihood of technology adoption (Tchetchik, Kaufman, and Blass 2016). However, a study involving university students in southern Spain could not replicate this finding (Moya-Fernández et al. 2021).

Justice

Justice entails, among other things, uneven exposure to risk (Ormerod, Redman, and Kelley 2019). Questions of justice are, therefore, crucial in DPR. For example, in Los Angeles (California, US), public resistance against a DPR project in the San Fernando Valley was high because residents felt the municipal government was discriminating against them (Lejano and Leong 2012).

One study in this review found that people who rejected stark inequalities were more supportive of DPR (López-Ruiz et al. 2021). This may stem from the 'inherent positive relationship between notions of social justice and the concept of sustainable development' (López-Ruiz et al. 2021, 785). Similarly, the data of Moya-Fernández et al. (2021) showed that people living in a situation with great social injustice in southern Spain were less inclined to support DPR.

Legitimacy

Lastly, in studies of technological innovation systems, acceptance is closely related to the legitimacy of the technology. The legitimacy of new technology could be determined by its fit with current regimes (Harris-Lovett et al. 2015) or by its compatibility with collective action and widely held social norms and beliefs (Binz et al. 2016). Increased legitimacy can be obtained by continuously reshaping the system's practices and institutions. In the case of DPR, Binz et al. (2016) claim legitimacy can be acquired through continuous institutional adjustments, technology improvements and advocacy.

Increasing public acceptance

In the previous section, we showed many factors that may affect public acceptance issues. We now build on these findings by presenting the proposed approaches to overcome public acceptance issues we discovered in the current literature.

Along with the factors influencing public acceptance, this review also found various approaches to increase public acceptance. Such strategies included 'increased education and coordinated public relations; increased consultation; different types of consultation; redesigning policy and infrastructure planning processes to become participatory; and avoiding consultation altogether' (Furlong et al. 2019, 57). Because public perceptions are slow to change, Mukherjee and Jensen (2020) advise that approaches to overcoming acceptance challenges should be implemented early in the process.

Educating

Education is seen as the most traditional way to increase public acceptance (Furlong et al. 2019). Scholars in this review suggested that citizens are more likely to accept DPR and other water reuse technologies when receiving more technical information about them (Boyer, Hopkins, and Moss 2017; Fielding and Roiko 2014; Nagel 2015). Even a small amount of information in the form of an educational video increased public acceptance in Australia (Law 2016). Prins et al. (2022) suggested that, especially for people with little knowledge of alternative water sources, education can help increase general acceptance.

Education comprises conventional education methods such as information on technology and related subjects, unconventional education methods and pilot projects. Bufe (2013a) suggests that education should come from different sources to increase its reach rather than just from the government.

Conventional education

This review found conventional education the most common method for increasing public acceptance. In this, Harris-Lovett et al. (2015) criticized that water authorities and other project planners often provide merely technical information to convince the public of the technology's benefits despite evidence that the public demands broader information such as social and environmental costs or risk considerations (Harris-Lovett et al. 2015). Other approaches suggested incorporating more types of information, such as safety risks (Fielding and Roiko 2014), water scarcity and shortage (Duong and Saphores 2015), the hydrological cycle (Burgess et al. 2015) and de facto reuse (Boyer, Hopkins, and Moss 2017; Furlong et al. 2019; Leverenz, Tchobanoglous, and Asano 2011). Information on de facto reuse, in particular, was said to put 'the risk of chemicals in the water in perspective' (Fielding and Roiko 2014).

Unconventional education

Unconventional education methods are those that go beyond simple information provision. Some scholars in this review suggested using the media, including social media, to increase reach and awareness (Scruggs, Pratesi, and Fleck 2020). They also warned that media education and relationship-building should be started early in the process (Scruggs, Pratesi, and Fleck 2020).

More creative forms of education can be found in the US. In Oregon and California, local brewers tried to increase awareness and public acceptance by producing beer with recycled water (Martorana 2016; Stratton-Childers 2015). At the University of San Diego, students worked with water utilities to enhance education on water reuse and its acceptance by younger generations (Eidson 2015).

Pilot projects

Another often-mentioned way to speed up DPR implementation is by increasing the number of pilot projects (Wilcox et al. 2016). Pilot projects are said to increase acceptance because they prove that the technology system works successfully with no adverse health impacts (Katz and Tennyson 2015; Martorana 2016). Wilcox et al. (2016) even claim that without an increase in pilot projects, public perceptions may not improve.

One example from this review is San Diego's (California, US) efforts towards implementing IPR. The IPR plant in the nearby region of Orange County is said to have significantly influenced public acceptance (Heffernan 2014). Another inspirational example is the DPR system used in the International Space Station (Beutler 2016).

Criticisms and inconsistencies

Interestingly, not all information seems to influence public acceptance. A survey conducted in four cities across the US showed that providing information on drinking quality standards and regulations about drinking water and DPR did not have an impact on acceptance (Ishii et al. 2015). Moya-Fernández et al. (2021) argued that although there may be a relationship between information and acceptance, there is no statistical evidence of one when it comes to the potable use of recycled water in Spain. Also, in Australia, providing information did not increase acceptance (Mukherjee and Jensen 2020). According to Furlong et al. (2019), these diverse study outcomes may be because education alone is insufficient to increase public acceptance.

Public outreach

Burgess et al. (2015) argue that extensive outreach programs and campaigning have greatly increased public acceptance in the US. In fact, almost all the scholars in this review mention awareness and trust-raising campaigns as essential actions to increase public acceptance (e.g. Alspach, Flancher, and Gerling 2016; Katz and Tennyson 2015; Voulvoulis 2018).

Outreach is also often related to marketing strategies (Duong and Saphores 2015; Ormerod, Redman, and Kelley 2019) and can be structured as a communication plan. Such a plan can provide consistency, transparency and structure to communication efforts (Beutler 2016). The communication plan can also be an overarching framework for implementing education efforts and building trust (Beutler 2016). To ensure effectiveness, Alspach, Flancher, and Gerling (2016) advise that campaigning should start at the outset of projects to allow sufficient time for building trust, creating credibility and reputation and setting up communication channels.

Clear message and reframing

Several empirical studies have shown that clear and coherent communication can increase public acceptance (Katz and Tennyson 2015; Villarín and Merel 2020). A coherent narrative that appeals to a wide range of concerns can increase collaboration potential and public deliberation (Lejano and Leong 2012). Approaches include using easy-to-understand vocabulary, establishing common terminology and reframing the debate. Additionally, communication should target the audience that needs to be reached (Distler, Scruggs, and Rumsey 2020; Harris-Lovett et al. 2015).

Common terminology. Terminology matters in the public debate about DPR. The terminology should be easy to understand, and overly technical terms should be avoided (Katz and Tennyson 2015). A common terminology should be established to ensure clear and understandable communication (Kayhanian and Tchobanoglous 2016).

The narrative 'toilet-to-tap' seems to be a public acceptance killer (Al-Saidi 2021). To avoid such framing, coherent use of positively inclined, reassuring vocabulary should be used. For example, scholars in this review suggested avoiding terms such as 'treated wastewater' or 'effluent' and instead using terms such as 'recycled water' or '(advanced) purified water' because these words were successful in earlier projects (Villarín and Merel 2020) and public opinion surveys indicate these terms are favored (Tennyson, Millan, and Metz 2015). The word 'treatment' is often related to sickness and disease and is therefore increasingly avoided by water agencies (Katz and Tennyson 2015).

Reframing. Reframing the discourse on DPR offers a strategic approach to shift the narrative away from negative connotations. Generally, the public often perceives water extracted from the environment as natural, pure, and superior (Lohman 1987) compared to recycled water, which is perceived as less pristine. This narrative is often seen as unhelpful in the DPR discourse. As such, reframing strategies are proposed.

Leverenz, Tchobanoglous, and Asano (2011) challenge this perception, arguing that current wastewater discharging practices pollute traditional water sources. Others use the hydrological cycle to argue that essentially all water has been wastewater at some point in time (Katz and Tennyson 2015). Similarly, it is suggested that communication should be based on the narrative that all water is essentially reused *de facto,* but its use is often overlooked or disregarded (Meeker and Tricas 2015; Mercer 2016).

Alternatively, some advocate for a more assertive frame by presenting DPR as the only viable option to increase a community's water availability (Dolnicar and Hurlimann 2010; Furlong et al. 2019; Wilcox et al. 2016). This framing was applied in the project in Wichita Falls (Wester and Broad 2021), where public acceptance was volatile, leading the plant to stay idle for many years (Bufe 2013b).

Enhancing trust

Low trust poses a significant challenge to the public acceptance of DPR, as shown by the correlation between trust levels and acceptance (Khan and Anderson 2018). Notably, elected officials and media are consistently viewed with scepticism, contributing to heightened distrust (Distler, Scruggs, and Rumsey 2020). To address this, proactive engagement and trust-building efforts are essential (Via and Tchobanoglous 2016).

To bolster tryst, Harris-Lovett et al. (2015) proposed creating legitimacy around DPR through transparent processes, credible participation channels, effective communication of benefits, and comprehensive risk management (Harris-Lovett et al.

2015). Additionally, the communication messenger is crucial for gaining public trust. Here, scholars suggested regulators and experts are favored compared to policymakers, developers or professional public relations consultants (Scruggs, Pratesi, and Fleck 2020).

Public engagement

Numerous authors posit that engaging stakeholders can enhance public acceptance by bolstering project legitimacy and trust in authorities (Boyer, Hopkins, and Moss 2017; Mukherjee and Jensen 2020). Public engagement ranges from educational initiatives to involvement in the decision-making process. Tours and tryouts are frequently recommended as experiences contribute to public confidence (Katz and Tennyson 2015). In California, 88% of survey respondents indicated feeling more comfortable using reclaimed water (Martorana 2016). In Australia, public consultations via information days led to a higher public acceptance from the attendees than those who did not attend (Scruggs, Pratesi, and Fleck 2020).

Involvement in the decision-making process is deemed crucial for building confidence in DPR projects (Matthews 2015). Scholars advocate early and continuous stakeholder inclusion (Boyer, Hopkins, and Moss 2017; Exall and Vassos 2012; Kayhanian and Tchobanoglous 2016; Mukherjee and Jensen 2020) to align the technology with societal needs (Wilcox et al. 2016). At the same time, it is important to manage stakeholders' expectations. Additionally, effective management of stakeholder expectations and incorporating values and emotions in decision-making processes are emphasized (Katz and Tennyson 2015; Khan and Anderson 2018). However, this may require a dramatic change in authorities' current practices (Harris-Lovett et al. 2015).

Not all of the literature we reviewed suggested using public engagement, and some also questioned the efficacy of public engagement. For example, evidence from Australia suggests higher acceptance when the public is not given a choice (Furlong et al. 2019). In other cases, engagement approaches did not seem to be used, such as in the DPR projects in Big Spring and Brownwood, Texas, where a large number of interviewees (40% and 45%, respectively) were not aware of the ongoing projects (Wester and Broad 2021). Additionally, the often cited success stories, such as Windhoek, Namibia, and Tucson, Arizona (US), were established before public participation was considered crucial (Scruggs, Pratesi, and Fleck 2020).

Understanding and adapting

This review showed that while several recurring public acceptance issues have appeared worldwide, many are unique to a specific context (Scruggs and Heyne 2021), and approaches to overcome them should be tailored to local circumstances (Al-Saidi 2021). The local context must first be studied to understand its unique problems and the public's expectations and to identify relevant actors (Katz and Tennyson 2015). A cultural approach grounded in sociology should be used to examine local practices and understand the conflicts between those practices and the use of treated wastewater (Duong and Saphores 2015). Surveys can also be a powerful tool for gaining insight, as is done frequently in the US and Australia (Scruggs and Heyne 2021).

Discussion – ‘closing down’, ‘opening up’ or ‘leaving ajar’?

The literature review showed that most approaches to increase DPR’s public acceptance appear to be geared towards educating and convincing the public about the technology’s benefits (see Figure 3). One of the acceptance-enhancing approaches, educating, already shows many different methods, but also the public outreach category often involves educational elements. For example, public inclusion is often referred to as a participation method. Still, it can also be used instrumentally as another form of treating stakeholders as spectators rather than active participants. Additionally, trust-raising is essential to public outreach but predominantly relies on communication and education.

The strong focus on providing education has created a significant disparity between the current understanding of factors influencing public acceptance in DPR and those addressed in acceptance-enhancing strategies. While the current literature on public acceptance acknowledges its complexity and endeavors to untangle contributing factors, the suggested implementation approaches do not reflect this nuanced understanding but reduce the phenomenon to a lack of knowledge.

‘Closing down’

The focus on providing information and education is a typical indicator of a ‘closing down’ approach. It indicates that the public is assumed to be unaware of the benefits

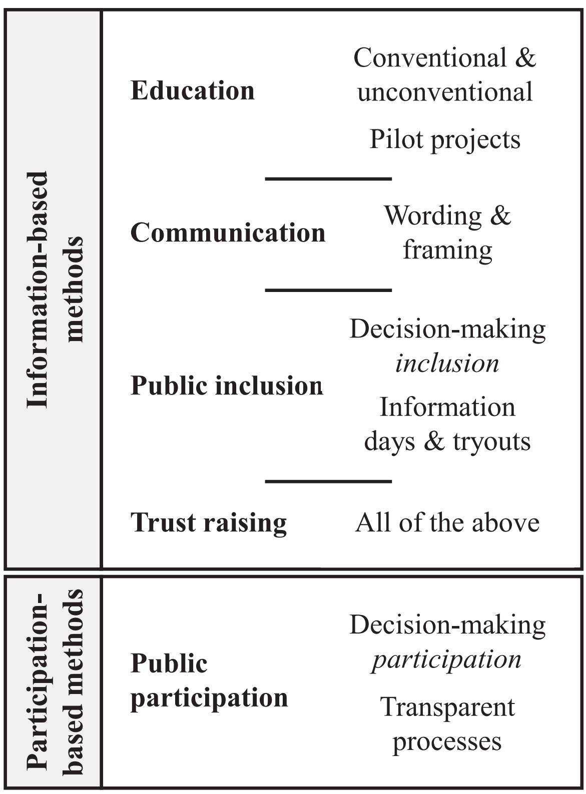

Figure 3. Main approaches to increase public acceptance.

of technology such as DPR. This assumption is also called the 'information deficit model' and has been criticized for being ineffective and leading to implementation problems (Rodhouse et al. 2021; Scruggs, Pratesi, and Fleck 2020).

Relying on the information deficit model is problematic for two reasons. Firstly, it prioritizes scientific, often quantitative information and overlooks other forms of knowledge, such as social and ethical perspectives or local experiences. Also, discussions in the DPR context often focus on technical risks, safety, and water quality standards rather than addressing social or ethical concerns. Such thinking can indicate misalignment with the RRI principles of *reflexivity* and *responsiveness* if relevant concerns are overlooked.

Second, this model assumes that the risks of the technology are acceptably low and outweighed by the benefits, which is not necessarily the case for DPR as there is still ongoing research on risk and safety aspects. Notably, the long-term impacts of emerging contaminants, their acceptable risk levels and the adequacy of water quality testing methods to detect these remain contested (Dotson 2019; Duong and Saphores 2015). Nevertheless, 'DPR poses no risk' and 'recycled water meets drinking water quality' are popular statements to raise trust in DPR, effectively closing the debate on these essential concerns and reducing the opportunity to *anticipate* potential challenges in this area.

Unfortunately, the current approaches to boost public acceptance in DPR show a strong preference for the information deficit model and scientific knowledge, both traditional 'closing down' techniques. Nevertheless, some scholars have emphasized the need to consider local circumstances and embrace a more nuanced understanding of public acceptance and the need for participation in DPR projects.

'Opening up'

In this literature review, we could identify some 'opening up' calls and proposals, for example, increasing calls towards more public involvement (e.g. Boyer, Hopkins, and Moss 2017; Matthews 2015), which should begin at the early stages of the project (Mukherjee and Jensen 2020) and continue throughout the entire life cycle (Kayhanian and Tchobanoglous 2016). Other authors urged understanding the local context and tailoring technical solutions to the location's needs and concerns (e.g. Al-Saidi 2021; Scruggs and Thomson 2017). These aspects align with the endeavors to 'open up' public engagement, as Russell et al. (2022) suggested, and show that research on DPR increasingly recognizes that public participation is crucial for the success of technology implementation.

Yet, these calls remain far outweighed by literature that leans towards 'closing down' engagement. This persisting challenge may be due to the highly ideological nature of public participation endeavors such as those proposed in 'opening up' approaches. While essential for meaning and impactful public engagement in the future, the 'opening up' types of public engagement often face a lack of touch with real-world situations, high costs in terms of time and money and unaccounted-for power imbalances (see, e.g. De Hoop, Pols, and Romijn 2016; Reynolds, Kennedy, and Symons 2023).

'Leaving ajar' as a step towards RRI for DPR?

Consequently, more moderate strategies, such as those proposed through 'leaving ajar' engagement options, might be an initial step for DPR projects to align more with the

RRI principles. ‘Leaving ajar’ essentially aims to balance the ideals of ‘opening up’ approaches and the practical constraints in DPR projects. Technology choices are often severely constrained by financial and geographical factors. Hence, technologies seem to be frequently chosen before public introduction. The primary objective then becomes tailoring DPR solutions to address local concerns rather than liberating on ideal technology implementation processes. While this starting point is less than ideal, applying the AIRR principles can improve the implementation process.

As a first step, decision-makers in DPR projects should prioritize *reflexivity* and *responsiveness* towards public concerns. Here, addressing the misguided belief in ‘no risk’ or ‘DPR as the only option’ is crucial. The debate should shift towards openly discussing uncertainties, safety concerns, alternative technological options, and their societal implications. Moreover, it must be ensured that the deliberations extend beyond scientific aspects to include discussions on social impacts or cultural and religious considerations. With more deliberative discussions, unaddressed issues may emerge, which can also help improve the project’s *anticipation* capabilities.

Recognizing past missteps and a genuine commitment to improvement can also address a significant underlying issue: the erosion of trust. Mistrust in institutions and promises of government officials is especially lingering in many places; in terms of water reuse, this lack is also fueled by past failures (e.g. the Flint Water Crisis; see also Masten, Davies, and Mcelmurry 2016).

The trust-building efforts in DPR projects should move beyond the selective information dissemination tactics to focus on the root problem of officials’ operational practices – lack of trust in operation, maintenance and monitoring processes. Some suggest incorporating external advisory panels for oversight and guidance (Cotruvo 2016). However, assembling knowledgeable members may pose challenges with complex water systems.

Looking ahead, the insights from ‘leaving ajar’ engagement can be the foundational steps for more expansive ‘opening up’ strategies. Moreover, we think that identified issues and concerns of one community are often similar to other communities. Hence, collaborations between communities are another pragmatic way forward that can lead to knowledge exchange and a further ‘opening up’ of public engagement.

Conclusion

This review of the literature aimed to see how much public acceptance endeavors of DPR projects align with RRI principles. We achieved this by conducting a literature review on how public acceptance is understood in DPR and what approaches are suggested to increase it. The findings were subsequently assessed with the approach of ‘opening up’, ‘closing down’, and ‘leaving ajar’. These have shown to be a practical framework for pinpointing current RRI alignment challenges and opportunities of DPR projects when trying to increase public acceptance. Our main finding is that the identified approaches to enhance public acceptance predominantly rely on the highly criticized information deficit model, which oversimplifies the issue and fails to address the multi-faceted factors influencing public acceptance, effectively ‘closing down’ any meaningful engagement.

This approach can also guide how to make the first steps towards becoming more responsible. Here, we urge to move away from strategies involving the information deficit model and towards embracing the principles of RRI. More particularly, future efforts to enhance public acceptance should prioritize fostering an open dialogue that does not seek to convince the public of the technology's benefits and where risks and uncertainties are not downplayed but are communicated clearly and deliberated on.

Note

1. Saline water, which is mainly ocean water, is also an alternative water source, and desalination technology is increasing in popularity. However, because it is not wastewater or water that is 'reused' in the strict sense, it will not be discussed further.

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