Water Reuse

Water Reuse Vol 00 No 0, 1 doi: 10.2166/wrd.2023.010

Key perceptions associated with attitudes towards water reuse in a Swedish town

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ABSTRACT

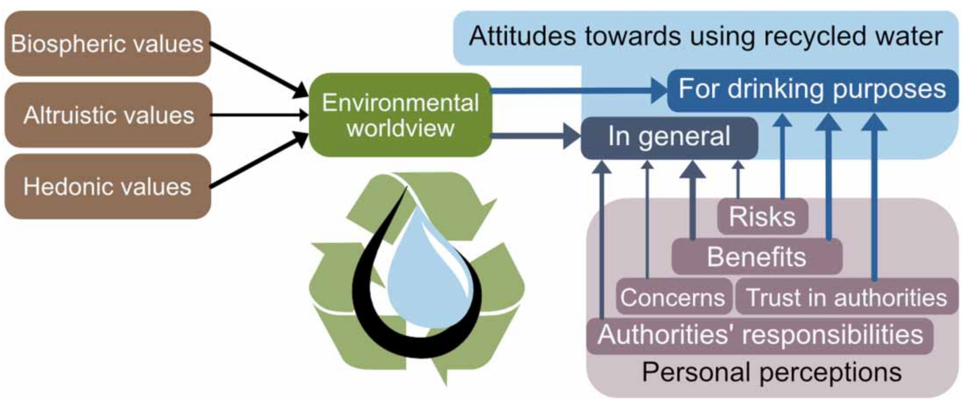
As climate change and urbanization affect current water management systems, new solutions and approaches rooted in public acceptance are needed to ensure future water supply. In this study, we examine public attitudes to reuse of recycled water and associated worldviews, values, and perceptions in a site without historical water issues. A survey of 143 randomly sampled residents in the municipality of the growing Swedish town Knivsta revealed that 81.4% of the respondents had a positive attitude towards using recycled water in general. The results did not indicate any differences in attitudes between those living in and outside the municipality's urban areas. Perceived benefits and risks were found to be significantly related to both attitudes towards using recycled water in general and to the extreme case of using it for drinking purposes. Additionally, trust in public authorities was highly predictive of attitudes towards drinking recycled water. Furthermore, attitudes were found to be related to an environmental worldview and underlying biospheric, altruistic, and hedonic values. This indicates a need to consider the intended purpose as well as engaging with underlying values as part of the technology legitimation process for improving the chances of successful implementation of water recycling technologies.

Key words: environmental worldview, participatory planning, public acceptance, recycled water, technology legitimation, value-belief-norm theory

HIGHLIGHTS

- Examining public attitudes to water reuse in a site without historical water issues.
- More than 80% had a positive attitude towards using recycled water in general.
- Nuanced relationships uncovered between public attitudes and perceptions.
- Attitudes also related to alignment with an environmental worldview and values.
- Tailoring approaches and engaging with values is key in the technology legitimation.

GRAPHICAL ABSTRACT



INTRODUCTION

Background

Population growth as well as changes in water patterns due to climate change is expected to increase pressure on finite water resources (Schewe *et al.* 2014; Kummu *et al.* 2016; IPCC 2022). This evokes a need for improved resource management to keep within the planetary boundary and secure future supply (Dawadi & Ahmad 2013; Gerten *et al.* 2013). Some authors have questioned the current paradigm of urban water systems, arguing that it obstructs recovering and reusing valuable resources and, in a broader sense, disregards environmental problems as well as social equity issues (Guest *et al.* 2009; Larsen *et al.* 2013). One innovative approach is the so-called fit-for-purpose, referring to adapting the level of purification to the water quality needed for its application. This may entirely shift conditions for water management, enabling new sources of water supply such as treatment and reuse of wastewater or collecting and using rainwater as well as decreasing consumption of energy and chemicals for treating unnecessarily large amounts of water to drinking standard. It also facilitates harvesting and treatment closer to the consumption, namely decentralized, on-site solutions, and may thereby decrease pressure on the centralized water supply. Although challenges remain, water reuse has environmental benefits, lower costs, and provides a stable flow with the possibility of producing high-quality fit-for-purpose water (Saurí & Arahuetes 2019).

In places with historically abundant freshwater resources, implementation of new, more sustainable water solutions for water savings and reuse may face resistance due to limited public understanding and acceptance for such solutions. As acceptance is a necessity for the success of water innovations (e.g., Dishman *et al.* 1989; Hurlimann & Dolnicar 2010), it is vital to better understand public attitudes as well as associated perceptions and values that interventions to build acceptance might target. Furthermore, a sociotechnical perspective of public responses is useful to understand the processes for successful implementation of alternative water solutions, such as water reuse (Smith *et al.* 2018). In this perspective, public attitudes concerning recycled water are embedded in a social and cultural context co-evolving with a complex process of technological innovation and technology legitimation. Implementation of technology should consider this social context and acknowledge currently dominating values and beliefs when choosing appropriate solutions (Harris-Lovett *et al.* 2015). Thus, implementation of water reuse technologies is not mainly a question about addressing and managing public attitudes but rather about renegotiating practices and processes within the water management system and being open to consider fundamental changes, such as a collaborative, participatory form of decision-making (Ormerod & Scott 2013; Harris-Lovett *et al.* 2015). Binz *et al.* (2016) described this as an *institutional work* within the technology legitimation process. This means that not only is the technological system changing with technological innovation but also rules and norms within the social landscape.

Adding to the literature on technology legitimation, this study adopts a sociotechnical perspective to examine public attitudes towards water reuse in a growing middle-sized municipality in Sweden, specifically contributing with insights about acceptance and related factors to this in a site without historical water issues. The sociotechnical perspective aims to account for the multifaceted interplay between technological innovation, design, and adoption on the one hand, and the users on the other hand (i.e., their attitudes, perceptions, worldviews, and values, as well as socioeconomic and demographic variables). Water reuse is here understood as using treated wastewater as a resource where water recycling describes the process and application of technologies for recycling and where recycled water is the product from this, as defined by Levine & Asano (2004). This study includes but is not limited to decentralized water reuse, where decentralization is considered as recycling closer to the consumption. The study also partly includes attitudes towards using rainwater as a comparison.

There are several reasons for Sweden providing an interesting context for advancing a sociotechnological understanding of the transition towards more sustainable water systems. First, it is a country with comparatively large trust in authorities (see, e.g., Rothstein & Stolle 2003; OECD 2020), which may affect perceived legitimacy of innovative water projects. Second, as most Swedish citizens have enjoyed ample access to freshwater resources (Stensen *et al.* 2019), it provides an interesting example for other countries with a historical abundance of freshwater as well as an opportunity for comparison with sites with more historical experience of water shortages. Despite the historical sufficiency of freshwater resources, increasing future risks of droughts evoke a need to manage the water resources with greater care, in Sweden as well as in other countries. Using recycled wastewater is practiced to some extent in agriculture and industry but is currently uncommon in Swedish households (Flyborg *et al.* 2010).

Previous studies

Public attitudes towards water reuse have been studied for decades (see, e.g., Bruvold 1988; Hartley 2006; Buyukkamaci & Alkan 2013; Hurlimann & Dolnicar 2016; Taher *et al.* 2019), where the uses for the technology and its design have been identified as important aspects. For example, willingness to use recycled water or rainwater depends on what it is used for, with acceptance decreasing with increased degree of personal contact (e.g., Bruvold 1988; Mankad & Tapsuwan 2011; Wu *et al.* 2012; Hurlimann & Dolnicar 2016). In other words, alternative sources for watering the garden or flushing toilets are generally more acceptable than for personal washing. At the other end of the pipe, public acceptance is affected by the selected source of water, such as rainwater or recycled wastewater (Dolnicar *et al.* 2014; Hurlimann & Dolnicar 2016). Furthermore, acceptance of reuse seems to increase with proximity of the collection of wastewater to be recycled, exemplified by people being more likely to accept reusing water from their own household than when it is mixed with water from their neighbours (Jeffrey 2002). Attributes of the water itself, such as smell and colour, can also influence preferences (e.g., Hurlimann & McKay 2007; Wu *et al.* 2012). Beyond tangible, physical properties such as smell and colour, resistance to using recycled wastewater has also been ascribed to the yuck factor – an emotional experience of repugnance and disgust. This may explain differences in attitudes towards different water sources, even in the case of identical water quality, as the water will be *perceived* as influenced by its source regardless of actual contamination (Callaghan *et al.* 2012).

Acceptance of water reuse is also tied to different psychosocial aspects such as underlying attitudes (Amaris *et al.* 2021) and underlying personal norms and values (Poortvliet *et al.* 2018). The value-belief-norm (VBN) theory (Stern *et al.* 1999; Stern 2000) describes how these are related, where values serve as guiding principles that affect more specific beliefs and, in its turn, norms and attitudes. From Schwartz's (1992, 1994) original 10 value types, Stern (2000) argued that three value orientations, i.e., egoistic, altruistic, and biospheric, are most important for understanding beliefs related to environmental attitudes and behaviours. Based on Schwartz's value system and the VBN theory from Stern (2000), de Groot & Steg (2008) suggested an instrument to measure these values, which in a later study was further developed adding hedonic values as a fourth value orientation (Steg *et al.* 2014).

Within water management, Poortvliet *et al.* (2018) used VBN theory to predict intention to accept new sanitation, which they explain includes maximizing recovery of different resources from wastewater, and extended the model to include perceptions of risks and benefits. They found that both pro-environmental personal norms and perceptions of risk and benefit contributed to explain users' acceptance. Other studies have also found that emotional responses, for example related to risk perception, are important for understanding public attitudes (e.g., Marks *et al.* 2008; Mankad 2012). Trust in authorities responsible for water supply is connected to lower perceptions of risk and higher level of acceptance (Hurlimann 2007; Ormerod & Scott 2013; Ross *et al.* 2014). Beyond experience of risks connected to the recycled water, risk perception may also be relevant regarding the experienced threat and awareness of water issues such as water scarcity problems. Gómez-Román *et al.* (2020) studied acceptance of decentralized wastewater treatment systems, including wastewater reuse, in a region without problems with water scarcity and found that awareness was a critical factor for acceptance. Similarly, Dolnicar *et al.* (2011) showed that awareness of water scarcity as well as prior experience with alternative water solutions increased public acceptance. In projects for establishing new water solutions such as on-site water reuse, message framing can influence emotions and interpretation of threat and thereby affect acceptance and adoption (Mankad 2012).

In terms of water reuse as a matter of sociotechnical legitimation, these seemingly individual attitudes and perceptions are interrelated with social and cultural contexts. For example, the yuck factor described above has been argued to be rooted in social and cultural norms and perceptions rather than being a purely psychological, innate aversion (Marks *et al.* 2008; Callaghan *et al.* 2012; Ormerod & Scott 2013). Ormerod & Scott (2013) argued that sociocultural and political factors in water management, such as sense of ownership and participation in decisions about the water system, are important for acceptance of water reuse. Similarly, Russell & Lux (2009) suggested a sociological framework considering users' practices in the sociotechnical water management system to explain and address public responses. Ormerod (2016) highlighted the importance of considering a sociocultural lack of awareness, captured in the 'flush and forget' mindset, as most people take the water management system for granted and do not reflect on the related processes and costs. This mindset could, arguably, be a result from the history of being largely disconnected from water management and relying on authorities managing the water system, making trust in these institutions an important factor for acceptance and sense of security. However, Ormerod also stated that recycling technologies may provide an opportunity to disrupt this mindset.

Previous research has thus defined acceptance of water reuse as a sociotechnical issue and identified a number of factors relating to the public acceptance of water reuse. However, fewer studies have considered a broad variety of perceptions and values and how the most important factors for acceptance depend on the intended use of the recycled water, particularly with a sociotechnical perspective. Also, not much research on public acceptance on water reuse has so far focused on attitudes in countries with historical abundance of water resources and, to the authors' knowledge, this issue has not yet been studied in Sweden.

In this paper, attitudes are regarded as individual opinions and essentially correspond to personal norms in VBN theory, but we also interpret this as an estimation of the level of acceptance and willingness to reuse water. Acceptance and willingness are therefore used interchangeably referring to positive attitudes. This is a simplification as these are rather intentions, but as we evaluate acceptance in a case with currently no decision or plans for implementation, attitudes are seen as the best achievable approximation. We here refer to values as regarded in VBN theory (see, e.g., Steg & de Groot 2012), whereas perception is used in a very broad sense to encompass a range of how people *perceive* risks, benefits, their own experience, and so on.

METHODS

This study was carried out in Knivsta municipality, a middle-sized Swedish municipality (cf. Figure 2). Situated about 55 km north of Stockholm (Sweden's capital and largest city) and about 20 km south of Uppsala (Sweden's fourth largest city), it serves as a commuter town for many inhabitants. The municipality today houses approximately 20,000 inhabitants, but due to its attractive location it is estimated to grow to more than 27,000 inhabitants by 2035. The average income in the municipality is higher than the Swedish average (Statistics Sweden (SCB) 2022a) and the education level is slightly higher with a larger share of the population holding a university degree (Statistics Sweden (SCB) 2022b). In Sweden, the municipality has a legal responsibility for owning and managing water infrastructure, although this may be operated by the municipality itself, a municipally owned company, or a cooperatively owned company in a larger region. The water utility company in Knivsta is jointly owned by several municipalities and operates as a separate company but with a local steering committee. Although the municipality has taken some initial steps to review possibilities and conditions for alternative water management solutions, they have been explored as supplements rather than alternatives to current management practices. Furthermore, there is no evident penetration and consensus for these ideas within the municipality and local water management company, neither have any real-life tests or pilot projects been made. In that sense, water reuse may be considered as in an early niche stage, i.e., as a technological innovation.

To elicit the attitudes of Knivsta inhabitants regarding water reuse, a questionnaire was sent out on 1 March 2022 to 1,001 residents from age 18 and above in Knivsta municipality, randomly selected from the municipality's population register. The invitations to participate in the study were sent via post to the respondents' home addresses and they contained instructions for how to complete the survey online. A reminder mail was sent out on 25 March.

Questionnaire design

The survey questions were designed to cover six main themes (see Supplementary material, Appendix A). The questionnaire items for all questions except for the basic demographic characteristics were measured on a 7-point Likert-type scale. The full questionnaire (translated to English) is found in Supplementary material, Appendix B.

In terms of attitudes, the respondents were first asked about their general opinion towards using recycled water. They were also asked to report their opinion on using recycled water or rainwater for different purposes (e.g., drinking, hand washing, toilet flushing) and using recycled water from different sizes of catchment areas (e.g., their own household, neighbourhood, or city level), provided that the water was clean and safe to use. These matters have previously been highlighted as important factors (Bruvold 1988; Jeffrey 2002; Mankad & Tapsuwan 2011; Wu *et al.* 2012; Hurlimann & Dolnicar 2016). In the information to the respondents, water recycling was explained as a more immediate reuse in contrast to that, in practice, all water is reused through the water cycle, where already used water is collected and purified to a degree that is clean enough and safe to use for its intended purpose. This was also exemplified with both a centralized and a decentralized possibility. The alternative to use rainwater was only described in terms of collecting and using rainwater without specifying the approach for this. The choice to not provide more detailed descriptions and definitions of these water sources in the questionnaire was to avoid information overload, but also to enable studying the attitudes towards these sources in general rather than towards a specific solution and setup for how this could be implemented.

For measuring personal perceptions of different risks with recycled water, the chosen risk factors (e.g., health risks, increased costs, environmental impacts) were inspired by Poortvliet *et al.* (2018) and Hurlimann (2007). These were complemented with questions about perceived benefits (largely mirroring the risks) and the respondent's trust in some stakeholders involved in the water system, as well as their perceptions about these stakeholders' responsibility within water issues such as ensuring access to water of good quality and providing correct information. The stakeholders included were the municipality, the water utility company (again, also municipally governed but a separately organized institution), national authorities (legislators and governmental agencies), suppliers of water solutions (private enterprises retailing or installing water solutions), housing and building enterprises (including real estate companies), academic researchers (e.g., universities), and other experts such as private consultants.

As an attention check, the respondents were asked about their interest in environmental issues and how they estimated their environmental awareness with Likert-scale values for answers being flipped in relation to the other questions. The assumption about the historical abundance of clean water in Sweden and the 'flush and forget' mentality with limited awareness about water issues was measured with questions about the respondents' personal experiences as well as their concerns about being affected by water shortages and poor water quality within their lifetime.

To measure value orientations, an adapted version of the Schwartz Value Survey was used based on the 16 value items according to the scale from de Groot & Steg (2008) with additions from Steg *et al.* (2014). Four value orientations were thus measured: altruistic, egoistic, biospheric, and hedonic values. The participants were presented with a list of eight value items (two per value orientation) and asked to indicate the importance of each value as a guiding principle in their lives. Beyond the value orientations and, as a more specific belief that may be related to the underlying values, endorsement of an environmental worldview was measured using five items from the New Ecological Paradigm (NEP) scale (Dunlap *et al.* 2000) that were chosen following Stern *et al.* (1999) and translated to Swedish.

The respondents' home addresses, taken from the population register, were used to explore spatial patterns in attitudes, and as a control variable in addition to the demographic variables measured through the survey.

Analyses

We used descriptive statistics and regression analysis for exploring respondents' attitudes, perceptions, worldviews, and values. The VBN theory was used to structure the analysis (Figure 1). We considered the variables on risks, benefits, trust, responsibilities, knowledge, and experiences (themes 3–5, see Supplementary material, Appendix A) as on the same level as but distinct from attitudes to use recycled water, grouping them under the term 'personal perceptions'. Although relationships between values, beliefs, and attitudes are explored in this study, the emphasis is on relationships within the last step of the theory. This focus was chosen because the primary goal of the study is to explore attitudes towards recycling water from a planning perspective rather than developing psychological theory.

Composite variables for the NEP scale and the four different value orientations were calculated using the average item value, following de Groot & Steg (2008). Internal consistency of the new variables was checked using Cronbach's Alpha for NEP. Cronbach's Alpha requires including at least three items, but each value orientation was represented by only two items; thus, polychoric correlations (i.e., estimated correlations between ordered rank variables) were calculated for each pair of value orientation items.

To get an understanding of the dominant attitudes, perceptions, worldviews, and value orientations, descriptive statistical analyses were carried out in SPSS (version 27.0). The percentage of respondents that reported 5 or higher on the 7-point Likert-scale items were calculated and compared against each other.

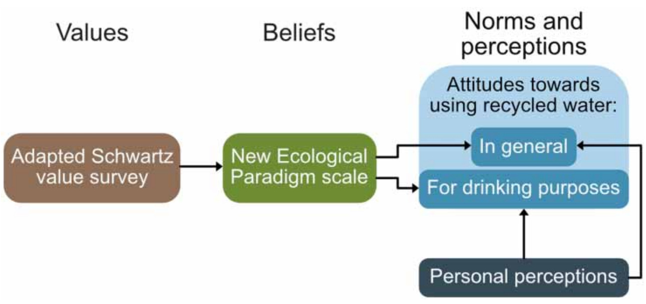


Figure 1 | Conceptual model for how the different variables were managed in the analyses based on the VBN theory.

To explore associations between attitudes, perceptions, worldviews, and value orientations, regression analyses were carried out in R. Based on the descriptive analyses, two dichotomous outcome variables were defined to distinguish both endpoints of an attitude spectrum from the rest of it. First, respondents reporting 4 or lower regarding using recycled water *in general* (i.e., their general attitude was not positive) was defined as a particularly unwilling group. Second, respondents reporting 5 or higher regarding using recycled water *for drinking purposes* (i.e., their attitude in the most extreme case was positive) was defined as a particularly willing group.

Based on the conceptual model presented in Figure 1, five regression models were tested. The two attitude outcome variables were related to personal perceptions and environmental worldview in separate models (four in total). Because the outcome variables were dichotomous, logistic regression models were used, controlling for birthyear, gender, level of education, monthly income, dwelling type, and whether the respondent lived in either of the municipality's two urban areas. In the fifth model, environmental worldview was predicted by value orientations, using Tobit regression with an upper censoring at 7 (because many respondents obtained maximum NEP score). This model contained the same control variables as the first four.

Regression models can be biased by the presence of multicollinearity among the predictor variables. To avoid multicollinearity when using personal perceptions as predictors, we employed principal component analysis (PCA), a common method of dimensionality reduction allowing several related variables to be represented by a common principal component. PCA was used on a matrix of tetrachoric correlations between personal perception variables (36 in total). Tetrachoric correlations can be seen as latent correlations of continuous variables represented by dichotomous variables (Jöreskog 1994). We chose to dichotomize the variables in order to include 'Do not know' responses, consequently coding scores 5–7 (answers including 'large', 'very large' or 'extremely large') as 1 and all others as 0. Eight principal components were extracted from the PCA, as these together explained more than two thirds of the variance among the variables and as we assessed that eight components provided a fair balance between a too simplified and a too complex set of predictors. As the principal components are abstract constructs without meaningful scales, they were transformed into z-scores before the regression, meaning that odds ratios correspond to respondents being one standard deviation apart. This allows comparisons of the relative strengths of predictor variables' associations with the outcome.

Absence of multicollinearity in the regression models was verified by calculating variance inflation factors. The Tobit regression assumes normality and heteroskedasticity of residuals; this was assessed with the Shapiro–Wilks test and the studentized Breusch–Pagan test.

To see whether the geographical location of the respondents impacted the results, the Likert-scale values from the answers were interpolated in ArcGIS Pro (ESRI) using the inverse distance weighted method (settings: power 1.5, maximum number of points 12, maximum distance 1,500 m, cell size 750 m). Regressions were made for all survey items (questions) to see if the Likert-scale values change with increasing distance from the urban area (the distance as the independent variable and the Likert-scale value as the dependent variable; urban area as defined in Figure 2). For each item the coefficient of determination (R^2) was also calculated.

RESULTS

Sample characteristics

The survey gathered 143 respondents, giving a response rate of 14.3%. Figure 2 shows that respondents mostly reside in the municipality's urban areas but are also spread out over large parts of its non-urban areas. Sample characteristics are provided in Table 1. There was a relatively equal division between the genders. However, people aged 18–39 were underrepresented, while those aged 60 or older were overrepresented. In terms of education, those without a university degree were underrepresented and vice versa.

Descriptive analyses of attitudes, perceptions, worldviews, and values

The survey revealed 81.4% of the respondents had a positive attitude towards using recycled water in general, with no considerable differences between genders, forms of housing, occupations, education levels or monthly incomes. Group-wise attitudes are provided in Supplementary material, Appendix A. In terms of geospatial patterns, no survey item showed any significant correlation between distance from the urban area and the Likert-scale value (the highest correlation being $R^2 = 0.11$).

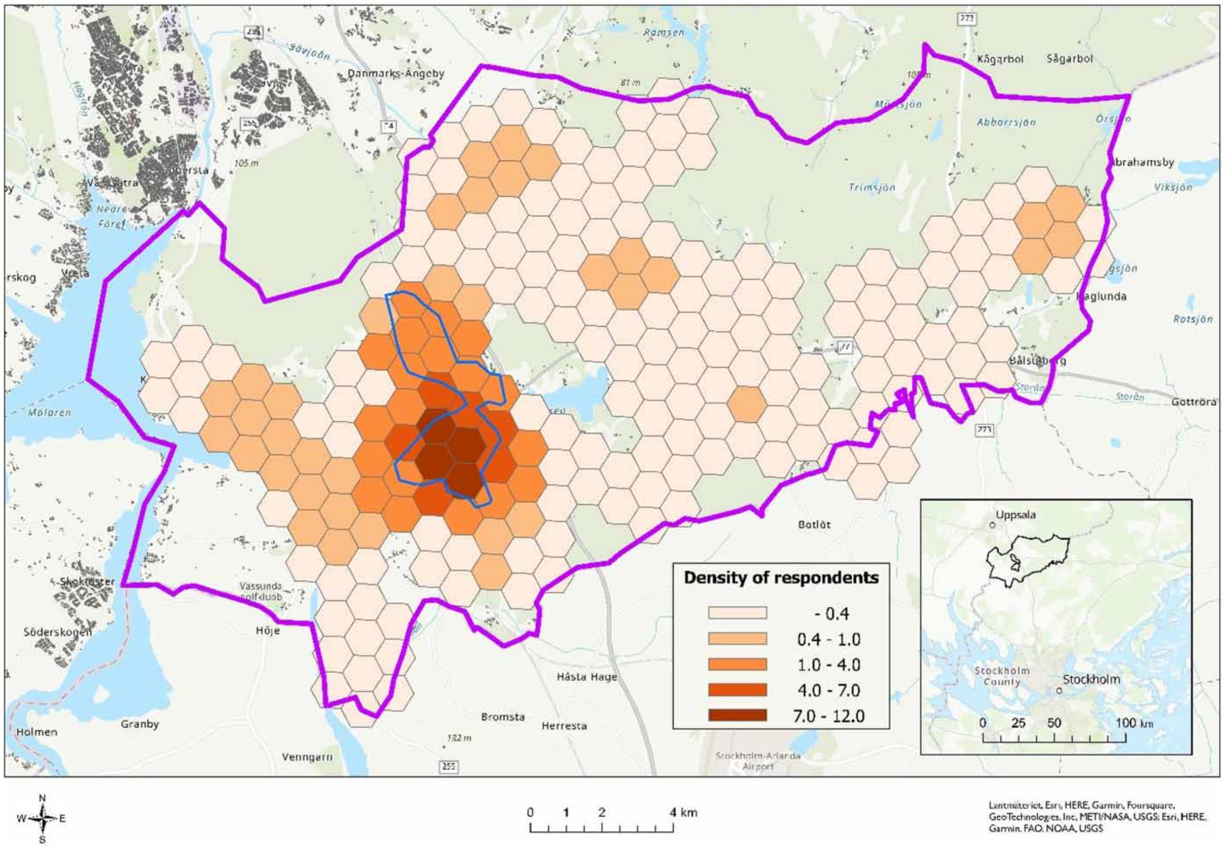


Figure 2 | Distribution of the respondents (number of respondents per km^2, where 91 reside inside and 52 outside the urban areas Alsike and Knivsta, as defined in this study (blue border)).

Table 1 | Sample characteristics compared to average values for the inhabitants from 18 years in Knivsta municipality

Characteristic		Respondents (%)	National statistics for Knivsta municipality (%)
Gender	Female	45	49
	Male	55	51
Age	18–29	5	17
	30–39	10	20
	40–49	25	21
	50–59	17	17
	60+	43	25
Education[a]	Primary education	8	17
	Secondary education	19	38
	Post-secondary education other than university	13	N/A
	University education without degree	5	14
	Undergraduate university degree	22	26
	Graduate university degree	24	
	Licentiate or doctoral degree	8	4
	Other	0	2

[a]Level of education in the national statistics are given for an age group from 16 years.

Table 2 presents the percentage of respondents with a positive attitude towards using recycled water or rainwater for different purposes. For all purposes except drinking, most respondents have positive attitudes towards using both rainwater and recycled water. A tendency can be seen that attitudes are less often positive with increasing proximity and human contact.

Table 2 | Positive attitudes to using rainwater and recycled water for different purposes in percentage that has reported 5 or higher on a 7-point Likert-scale

Purpose	Rainwater (%)	Recycled water (%)
Irrigation in public spaces, for example parks and golf courses	95.8	93.7
Irrigation in the own garden	95.1	95.1
Toilet flushing	94.4	92.3
Laundry	88.8	82.5
Hand washing	83.8	69.0
Showering/bathing	76.1	65.5
Drinking	53.2	41.7

The results regarding personal perceptions, beliefs, and values are presented in Table 3. The table summarizes the percentages of respondents that have reported 5 or higher on the Likert-scale. In terms of personal perceptions, reporting 5 or higher means that they perceived the risks, benefits, levels of trust, responsibilities, their own experiences, and so on as large, very large, or extremely large, whereas for environmental worldview and value orientations, it represents a high level of alignment with these beliefs and values. Some key observations relating to specifically the scope of this study will be presented below.

In terms of the view on water management practices, the respondents expressed different levels of responsibility for different stakeholders, although with a large emphasis on public authorities including the municipality (98.6%), the water utility company (97.9%), and national authorities (90.0%). These high numbers are contrasted by the share of respondents reporting a high level of trust for the stakeholders. For all stakeholders except academic researchers, a larger percentage of the respondents designate responsibility than express trust. The generally high level of trust in authorities in the Swedish population (Rothstein & Stolle 2003; OECD 2020) was thus arguably not observed in this study, as percentages of respondents reporting high trust in public stakeholders only ranged between 40 and 70%. Relating to the perception of water reuse as a technological innovation, few respondents reported a large knowledge about the technology for using recycled water and rainwater (9.2%), although the majority believed that it will be standard in new residential areas in 50 years (79.9%).

Regarding awareness and underlying values, few respondents reported ample own experience of water shortage (4.2%) and poor water quality (12.7%), which confirms that the sample has generally had a reliable access to clean freshwater. Slightly larger percentages were observed for personal concerns about being affected by water shortages (20.0%) and by poor water quality (22.9%); 71.6% of the respondents had a mean NEP score of 5 or higher – corresponding to a high alignment with an environmental worldview. Of the four value orientations, the biospheric values had the highest percentage of 5 or higher (95.1%), followed by altruistic (89.4%), hedonic (76.6%), and egoistic values (34.1%).

Principal components of perceptions

Eight principal components (PC1–PC8) were extracted from the PCA (Figure 3), together explaining 73% of the variation among the 36 input variables. PC1 largely corresponds to benefits (but not decreased costs), while PC2 corresponds to all risks. PC3 relates to trust for stakeholders. These three components together explained 38% of the variance. PC4 reflects previous personal experience as well as knowledge about water-related issues. Perceptions of responsibilities among stakeholders are split up into two components, with PC5 including the real estate company, experts, and universities, while PC6 includes suppliers, the municipality, and the water utility company. PC7 reflects concerns, while PC8 only has benefits of decreased costs clearly loading onto it.

Regression analyses

Logistic regression revealed both similarities and differences in components' associations to unwillingness to reuse water and willingness to reuse water for drinking purposes, respectively (Table 4). A general unwillingness to reuse water was best predicted by low scores on PC1 (perceived benefits), followed by low scores on PC6 (authorities' responsibilities), high scores on PC2 (perceived risks), and low scores on PC7 (concerns; note that p-value > 0.05, although 95% confidence interval <1). A willingness to reuse water for drinking purposes was best predicted by high scores on PC1 and PC3 (trust in authorities),

Table 3 | Highly graded questionnaire items relating to personal perceptions and alignment with environmental beliefs and values in percentage of respondents that has reported 5 or higher on a 7-point Likert-scale

Personal perception of…	Questionnaire item	Percentage of respondents reporting this questionnaire item as large, very large, or extremely large (%)
Risks		
	Health risks	44.0
	Risks with new technology	30.2
	Increased costs	29.9
	Odour/taste/colour	27.0
	Environmental impacts	17.4
	Discomfort/need for behavioural change	15.0
Benefits		
	Decreased risk for future water shortages	83.9
	Decreased environmental impacts	78.5
	Environmental identity/sense of personal contribution to a better environment	76.7
	Contribution to technological development	65.6
	Decreased costs	41.4
	Comfort/not needing behavioural change	40.0
Level of responsibility		
	The municipality	98.6
	The water utility company	97.9
	National authorities/regulators	90.0
	Suppliers of water solutions	84.9
	Academic researchers (e.g., universities)	57.1
	Housing and building enterprises	45.3
	Experts, such as private consultants	41.3
Level of trust		
	Academic researchers (e.g., universities)	69.9
	The water utility company	67.2
	The municipality	60.2
	National authorities/regulators	51.2
	Suppliers of water solutions	43.8
	Experts, such as private consultants	33.3
	Housing and building enterprises	18.4
Interest and knowledge		
	Estimated probability that these solutions will be standard in 50 years	79.9
	Interest in environmental issues	70.2
	Personal environmental awareness (reversed)	63.4
	Personal knowledge	9.2
Experiences and concerns related to water problems		
	Personal concern about poor water quality	22.9
	Personal concern about water shortages	20.0
	Personal experience of poor water quality	12.7
	Personal experience of water shortage	4.2

(*Continued.*)

Table 3 | Continued

Personal perception of...	Questionnaire item	Percentage of respondents reporting this questionnaire item as large, very large, or extremely large (%)
Experiences of alternative solutions		
	Personal experience of using rainwater	24.8
	Personal experience of using recycled water	4.3
Worldview and value orientations	**Percentage of respondents with a high level of alignment (%)**	
Environmental worldview		
	NEP scale (mean value)	71.6
Value orientations		
	Biospheric values (mean value)	95.1
	Altruistic values (mean value)	89.4
	Hedonic values (mean value)	76.6
	Egoistic values (mean value)	34.1

Note: Data arranged in descending order.

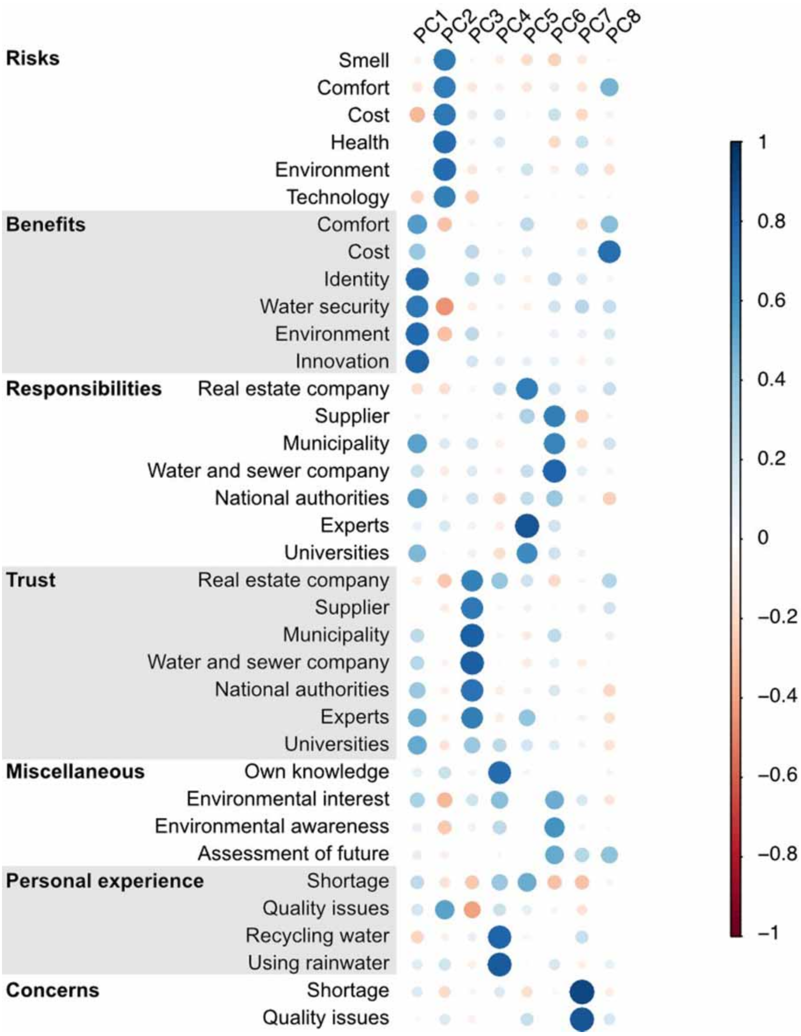


Figure 3 | Matrix showing how the 36 input variables of the PCA load onto the eight extracted principal components (PC1–PC8). Colour of circles corresponds to loadings (see legend to the right), and size of circles is also proportional to loadings.

Table 4 | PCA components' associations with willingness to use recycled water generally and for drinking purposes

	Generally unwilling to reuse water OR (95% CI)	Willing to reuse water for drinking purposes OR (95% CI)
Principal components		
PC1 (perceived benefits)[a]	0.27*** (0.14–0.47)	2.83*** (1.71–5.10)
PC2 (perceived risks)[a]	1.70* (1.03–2.87)	0.47** (0.27–0.75)
PC3 (trust in authorities)[a]	0.64 (0.33–1.18)	2.38*** (1.55–3.83)
PC4 (personal experience)[a]	0.56 (0.25–1.06)	1.00 (0.64–1.55)
PC5 (experts' responsibilities)[a]	0.77 (0.40–1.40)	0.92 (0.59–1.43)
PC6 (authorities' responsibilities)[a]	0.41** (0.20–0.72)	1.57 (0.94–2.84)
PC7 (concerns)[a]	0.50 (0.22–0.99)	1.27 (0.81–2.01)
PC8 (perceived cost benefit)[a]	0.75 (0.44–1.31)	1.13 (0.74–1.73)
Control variables		
Age[b]	0.98 (0.65–1.52)	1.01 (0.76–1.35)
Gender (man)	2.18 (0.54–9.91)	1.31 (0.51–3.41)
Dwelling (condominium)[c]	0.37 (0.04–3.10)	2.12 (0.39–12.7)
Dwelling (villa)[c]	0.51 (0.08–3.37)	1.34 (0.30–6.57)
Dwelling (farm or other)[c]	1.06 (0.05–21.5)	1.62 (0.18–15.3)
Education (undergraduate)[d]	1.45 (0.40–5.51)	1.77 (0.61–5.38)
Education (graduate)[d]	0.53 (0.08–2.99)	2.27 (0.66–8.14)
Income	0.94 (0.75–1.19)	0.90 (0.76–1.05)
Urban living (binary)	1.70 (0.41–8.00)	0.90 (0.30–2.64)

Note: OR, odds ratio; CI, confidence interval.
*p-Value < 0.05.
**p-Value < 0.01.
***p-Value < 0.001.
[a]Models based on 1 z-score unit increase.
[b]Models based on a 10-year unit increase.
[c]Models based on a rental dwelling baseline.
[d]Models based on a baseline of no higher education.

followed by low scores on PC2 (all risks). None of the remaining components or control variables displayed any significant associations.

Furthermore, the environmental worldview predicted willingness to reuse water, both generally and for drinking purposes (Table 5). As expected, respondents endorsing an environmental worldview were more accepting of water reuse, thus less likely to be generally unwilling to reuse water and more likely to be willing to reuse water for drinking purposes. Tobit regression revealed that environmental worldview was in turn positively associated with biospheric and altruistic values, and negatively associated with hedonic values (Table 5).

The diagnostic tests did not reveal any issues with any of the models. No variance inflation factors reached above 2.5. Residuals of the Tobit regression displayed normality ($W = 0.995$, $p = 0.961$) and did not suffer from heteroskedasticity (Breusch-Pagan test statistic $(13) = 12.7$, $p = 0.473$).

DISCUSSION

Our analysis revealed generally positive attitudes among respondents towards water reuse, even though most had little personal experience or concerns about water issues. Acceptance seems to decrease with increased proximity to human contact, in line with previous research in other countries (Bruvold 1988; Mankad & Tapsuwan 2011; Wu *et al.* 2012; Hurlimann & Dolnicar 2016). Only for one reuse purpose, drinking, did most respondents not have positive attitudes. Defining non-positive attitudes towards water reuse generally and positive attitudes towards reuse for drinking purposes as extreme cases, we found different sets of personal perceptions to predict these two ends of the spectrum. Moreover, these were strongly related to

Table 5 | Associations between willingness to use recycled water and environmental worldview (as measured by NEP), modelled by logistic regression, and association between environmental worldview and biospheric, altruistic, hedonic, and egoistic values, modelled by Tobit regression

Predicting	Environmental worldview[a] OR (95% CI)
Generally unwilling to reuse water	0.39*** (0.22–0.65)
Willing to reuse water for drinking purposes	2.07*** (1.39–3.23)
Predicted by	**β (SE)**
Biospheric values[a]	0.45** (0.14)
Altruistic values[a]	0.31* (0.13)
Hedonic values[a]	−0.28** (0.09)
Egoistic values[a]	0.16 (0.09)

Note: Associations between environmental worldview and biospheric, altruistic, hedonic, and egoistic values, modelled by Tobit regression. Control variables are omitted (see Supplementary material, Appendix A for parameters for all included variables).
OR, odds ratio; CI, confidence interval; β, beta coefficient; SE, standard error.
*p-Value < 0.05.
**p-Value < 0.01.
***p-Value < 0.001.
[a]Models based on 1 mean Likert-scale unit increase.

alignment with an environmental worldview, which in turn was related to biospheric, altruistic, and hedonic values. The absence of geospatial patterns indicates that people's attitudes, perceptions, beliefs, and values are unrelated to where they live, at least within Knivsta municipality. This may be due to Knivsta's unique geographical situation, being a small municipality between the larger cities Uppsala and Stockholm. In the following discussion, we expand on the implications of these results in two sections, elaborating first *what* is important to address relating to public attitudes, and then *how* these issues could be addressed based on a sociotechnical viewpoint. We also outline some limitations of the study, before suggesting directions for future research to build on the findings uncovered here.

The *what*: key factors for addressing public attitudes

Logistic regression revealed that some components from the PCA are strongly associated with attitudes towards using recycled water in general and for drinking purposes. These factors may be important to target with interventions aiming to build acceptance. Interestingly, two components uniquely predicted either a general unwillingness to use recycled water or a willingness for drinking purposes as an extreme case. This implies that different strategies emphasizing different aspects are needed for different purposes. For example, making water recycling for hand washing and showering a standard solution across the municipality might require raising awareness about risks for future water issues, whereas more extreme implementations of using recycled water for drinking purposes might instead benefit from trust-building activities.

Our results shed new light on the respective roles of perceived benefits and risks of water recycling. Previous studies have found risk perception to be an important aspect relating to the attitudes and acceptance of using recycled water (Marks *et al.* 2008; Mankad 2012; Poortvliet *et al.* 2018). Some earlier findings appear conflicting, as Poortvliet *et al.* (2018) found perceived benefits to be a stronger predictor of acceptance than risks, whereas Price *et al.* (2015) found that communication around risks is more critical than around benefits in the case of recycling for drinking purposes. Our findings align well with both these observations, as perceived benefits was the best predictor both for an unwillingness to reuse water in general and for a willingness to reuse water for drinking purposes, whereas perceived risks was a better predictor in the latter case compared to the former. We interpret this as perceived benefits being a generally important factor, whereas the perception of risk tends to increase as the use of recycled water becomes increasingly personal, which aligns with Hurlimann (2007).

As expected, due to Sweden's historical abundance of freshwater resources (Stensen *et al.* 2019), we observed a lack of experience with shortages and poor water quality among respondents. The regression analysis furthermore showed that concerns for future issues are positively related to a willingness to use recycled water. Awareness of water issues has been highlighted as important for public acceptance by Dolnicar *et al.* (2011), exploring previous experience with water restrictions in Australia, and by Gómez-Román *et al.* (2020), focusing specifically on regions without water problems. In the Australian case, Dolnicar *et al.* (2011) emphasized providing geographically close examples of current water scarcity in public communication for fostering acceptance. This may be increasingly relevant in the Swedish case where, despite the historical abundance, there have been recent experiences of drought and restrictions. Gómez-Román *et al.* (2020) suggested instead to highlight the usefulness of the solutions from a broader perspective, such as environmental benefits. Communicating benefits could stress the relevance and urgency of the issue and thereby lay the ground for people to be influenced by other messages that could increase acceptance (Price *et al.* 2015). Thus, a focus on emphasizing benefits seems appropriate also based on the context with a historical lack of awareness.

The *how:* public attitudes as part of a technology legitimation process

Considering the introduction of water recycling technologies as a technology legitimation process, sociopsychological aspects such as attitudes and perceptions of risks, benefits, and trust are seen as part of an ever-changing landscape of opinions and ideas within a sociotechnical system which are also influenced by previous experiences and values. Due to this dynamic landscape, it is vital to consider *how* the process for planning and decision-making in the management practices is carried out and if it captures ongoing changes in attitudes, perceptions, and values. The importance of trust for the legitimacy of water reuse, also indicated in this study in terms of drinking purposes, could here be explained by the current 'flush and forget' mindset (Ormerod 2016) where users today have little awareness and engagement in the water management practices and rely entirely on public authorities to take care of these issues. The role of core values may be particularly important to consider when planning for new solutions as these deeply rooted values may be difficult to change rapidly within individuals (Steg & de Groot 2012), and as the importance of underlying values, beliefs, and attitudes for acceptance of water reuse is supported by previous research (Poortvliet *et al.* 2018; Amaris *et al.* 2021) as well as the regression models based on VBN theory in this study.

One possibility to address public attitudes and values is to move away from merely sharing information and promoting the solutions for building acceptance to pursuing deeper public engagement by renegotiating the processes and practices for water management and introducing more collaborative decision-making (Guest *et al.* 2009; Ormerod & Scott 2013; Harris-Lovett *et al.* 2015). Participatory planning can acknowledge users as important stakeholders and sources of knowledge and continuously capture attitudes and values that are important to the public. Incorporating users in the planning also allows for the *formation* of beliefs and attitudes based on their values, side by side with the identification of suitable solutions in the process to address present and future water issues. As it is possible to 'activate' certain values if they are central to the person's identity in order to influence the formation of more specific personal norms or choices (Verplanken & Holland 2002), it may be useful to address benefits, risks, conflicts, and decisions in initiatives for water reuse *in relation* to public values; even other values than those connected to an environmental worldview.

Moreover, the involvement of users in planning processes could contribute with increasing awareness which, as discussed above, may be particularly important in places without historical water issues. Shared responsibility for managing water resources could also entail a greater sense of ownership and an increased likelihood for agreement with the necessity and legitimacy of rules and actions (cf. Schlager & Ostrom 1992). Furthermore, the participatory process will likely itself provide conditions for establishing relational resources and building trust between stakeholders and for the procedures. Here, some situations provide windows of opportunity that are particularly suitable for system changes such as implementation of new water management technology and practices. An example is that people are more likely to change their views and behaviours in connection to moving to a new place (Verplanken & Roy 2016). For this reason, planning and building new areas may be a unique opportunity for fostering emergent attitudes if recycling of water is implemented from the start when people are more open to change.

In sum, participatory planning may facilitate acceptance through several diverse pathways, including increasing awareness about water issues, building trust, building on underlying values, and fostering a sense of ownership. The impact from participatory practices also goes beyond technology legitimation. They can improve understanding, learning, collaboration, and trust and thereby strengthen the societal adaptive capacity (Folke *et al.* 2005; Lebel *et al.* 2006), which is paramount for creating resilient societies in a dynamic and uncertain world (Fazey *et al.* 2007) and particularly in dynamic social–ecological systems such as water management systems. As water recycling technologies may provide an opportunity to disrupt the 'flush and forget' mindset (Ormerod 2016), recycled water may be a useful entry point for increasing the public's understanding of and participation in the water management system in general and thus provide an opportunity for resilience-building.

Limitations

Despite using random sampling by way of a population register, we did not obtain a sample that is representative of the Knivsta population as it is skewed towards elderly and highly educated people. There is also a risk that our sample is not representative in terms of variables that we did not measure. Notably, non-Swedish speakers might be underrepresented because using the municipal registry excludes residents that are not registered in it, such as newly arrived immigrants, and because the questionnaire was provided only in Swedish. Another bias that is difficult to assess relates to personal interests. The chance of responding to the survey might depend on the respondent's interest in water and/or environmental issues. This may be especially relevant in relation to the 'flush and forget' mentality as water issues may not be perceived as a concern for the general public. Thus, the results may not necessarily be representative for the population in Knivsta municipality or of Sweden in general. A particular issue for using these attitudes as decision support when building new city districts is the relative absence of younger respondents, as the future population in such areas will largely consist of those of younger ages today.

There are some important limitations to acknowledge concerning the survey as a data collection method generally. Likert scales can bring about a tendency to choose the middle option (Willits *et al.* 2016) which is evident upon visual inspection for several questionnaire items related to attitudes and perceptions. However, it has been established that not offering a middle category forces respondents to take sides even if they are neutral resulting in an incorrect response, which means that this procedure is still preferable (Willits *et al.* 2016). Another possible source of error is social desirability bias. Although we carefully formulated the invitation letter and questionnaire to avoid leading questions, the survey is likely still perceived as connected to sustainability, environmental protection, and care for future generations. Despite informing respondents that the study will not publish any results that can be traced back to individuals, this could result in responses that they perceive as in line with societal norms. Thus, we advise caution in interpreting our results as absolute values for the prevalence of attitudes, perceptions, beliefs, and values in society, but are nevertheless confident that our analysis reveals meaningful relationships between them.

Future studies

Because this study is limited to attitudes towards recycled water on a hypothetical level and not connected to an actual decision to implement alternative water solutions, future studies should explore attitudes and possible differences among inhabitants in areas where these solutions have been or are going to be implemented. Better yet, a longitudinal study could elicit within-individual change in attitudes as well as related perceptions before and after an initiative to implement solutions for water reuse. This could provide insights around the role of experience for attitudes and their social emergence as well as the importance of institutional factors, such as influences from efforts for participatory decision-making.

Our results also point at interesting topics to explore further regarding psychological and sociocultural aspects, such as exploring views on responsibilities and efforts for the individual. According to the 'flush and forget' mentality – described as a sanitary amnesia (Ormerod 2016) – users may believe that it is up to the authorities to fix the societal challenges and that it is not something that concerns individual inhabitants. This may have distanced people from the resource management and decreased awareness and sense of responsibility for sustainable management. On the other hand, our results revealed a relationship between reporting a high level of responsibilities for authorities and a willingness to reuse water. A possible direction for future research could be to further explore the role of responsibilities for different stakeholders.

CONCLUSIONS

Continued urbanization and climate change-induced extreme weather makes resilient and resource-efficient water management systems urgently needed. This study, conducted in a context without current implementation of water reuse and with overall little experience of water issues, revealed the pivotal role held by local authorities not solely as providers of technical systems but for fostering public acceptance and managing processes for technology legitimation.

With the right approaches, prospects for acceptance of water reuse implementation seem good. The survey revealed that 81.4% of the respondents had a positive attitude towards using recycled water in general, but that level of endorsement is different depending on intended use of the recycled water. Perceived benefits and risks are significantly related to both willingness for using recycled water in general and for drinking purposes. For attitudes to water reuse in general, perceptions of authorities' responsibilities and concerns about future water issues were additionally important, whereas for reuse for drinking purposes as an extreme case, trust in authorities mattered more. These findings are expected to be relevant particularly in a context without historical water issues, with little previous public engagement in planning and decision-making about the water management, and without a consensus among the authorities to aim for a technological shift.

Although the research design does not allow us to establish causality, the significantly related aspects found in this study should be considered by decision-makers as important issues to address in projects to implement new water solutions. Importantly, we recommend tailored approaches to increase acceptance depending on the intended purpose. Benefits are strongly related to both willingness to use recycled water in general and for drinking purposes, and emphasizing benefits could also be a way to raise awareness about future water issues. This could lay the ground for a greater perceived urgency to act on water issues and possibility to also be influenced by other messages, which may be especially relevant in places without much experience in water issues. Risks were found to be another important aspect to address, although this was particularly important in the case of drinking water. This study did not reveal any differences depending on geographic location of respondents. However, this may be due to the size and location of Knivsta municipality, and caution should therefore be paid to generalize this finding to other areas; for example larger cities, rural areas where the distance to larger cities is greater, or other climates.

It was however found that underlying factors such as an environmental worldview and value orientations are playing a role in the formation of attitudes towards water reuse. Biospheric and altruistic values predicted an alignment with an environmental worldview and, in its turn, willingness to reuse water. We conclude that interventions for increasing acceptance should engage with such deeper values that are important for the users, regardless of their alignment with an environmental worldview. Furthermore, we recommend considering participatory processes and moving towards more collaborative decision-making in water management practices to continuously capture public attitudes and values, and ongoing changes in these. Shared ownership in resource management could improve the legitimacy and perceived relevance for rules and new solutions as well as building trust. It also provides conditions for collaboration and learning, which are key aspects to increase the human adaptive capacity and thereby resilience in water management. Resilience-building is particularly important considering the expected changes and increased variations in water patterns due to climate change. Planning and building of new residential areas provide a window of opportunity for new water management solutions and practices as people are more open to change when moving and it provides an arena for participatory planning. If managed correctly, urbanization could shift from not only putting pressure on water management systems but also into an opportunity for more resilient water management.

ACKNOWLEDGEMENTS

The authors wish to thank Malin Andersson for the original idea of this article and for her contributions in the initial stages of the study.

AUTHOR CONTRIBUTIONS

Y.G. contributed to conceptualization and methodology; did formal analysis and investigation of the study; and wrote the original draft. K.S. and S.A.B. contributed to conceptualization, methodology, and visualization; did formal analysis; and wrote, reviewed, and edited the manuscript.

FUNDING

This work has been carried out under the auspices of the industrial post-graduate school Future Proof Cities (grant number 2019-0129), which is financed by the Knowledge Foundation (KK-stiftelsen) of Sweden. We kindly thank the funding body for their financial support.

The specific post-graduate position in this study is co-funded by Knivsta municipality. The municipality has also supported the study with the list of municipal residents from the population register. We also kindly thank Knivsta municipality for their support.

DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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First received 13 January 2023; accepted in revised form 30 August 2023. Available online 16 September 2023