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Acceptance of on-site wastewater treatment and reuse in Bengaluru, India: The role of perceived costs, risks, and benefits

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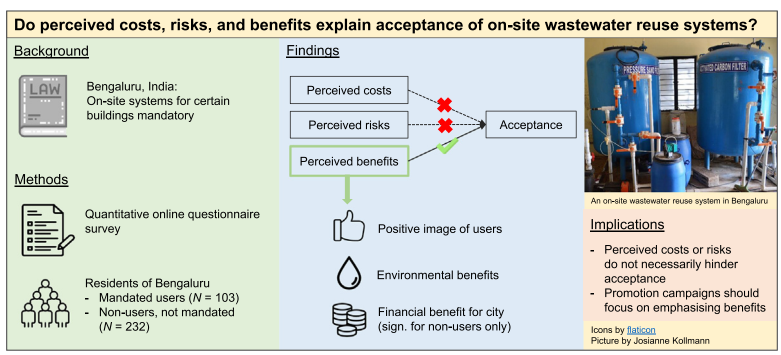
HIGHLIGHTS

- Lack of public acceptance can impede successful implementation of on-site systems.
- The study analysed whether perceived costs, risks, and benefits explain acceptance.
- Perceived environmental benefits and positive user image explain acceptance.
- Among non-users only, perceived financial benefit for the city explains acceptance.
- Emphasising benefits could help promoting on-site systems.

GRAPHICAL ABSTRACT



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ABSTRACT

In dealing with water pollution and freshwater scarcity, on-site treatment and reuse of domestic wastewater has shown to be a promising solution. To increase on-site wastewater treatment and reuse, some cities, among them Bengaluru in India, have mandated the installation and use of the necessary technology in certain building types. However, even with a mandate, a successful and sustainable implementation of the technology, including reliable operation, monitoring, and maintenance, depends on the acceptance (i.e. positive valuation) of the technology and its use by the (prospective) users. Literature on technology acceptance indicates perceived costs, risks, and benefits of the respective technology as key predictors of acceptance. Therefore, the present online study assessed this relationship for on-site systems in Bengaluru. The relation was analysed separately for mandated users of on-site systems ($N = 103$) and current non-users (i.e. potential prospective users, should the mandate be expanded; $N = 232$), as the perceptions might differ between the two groups, due to the personal experience with the technology among users. The results show that for mandated users and non-users, acceptance of on-site systems is explained by perceived benefits only, namely a positive image of users, environmental benefits, and, only for non-users, also financial benefits for the city. The findings suggest that interventions aimed at promoting on-site systems should include emphasis on the benefits of on-site systems. Whenever possible, interventions should be tailored to the target group's individual cost, risk, and benefit perception.

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1. Introduction

Many low- and middle-income countries face rapid urban population growth, leading to various environmental and health challenges (Kookana et al., 2020; Sun et al., 2020). Among the most pressing ones is insufficient wastewater treatment. Conventional, centralised (i.e. sewer-based) wastewater treatment systems are often either lacking, or have limited coverage or treatment capacity (Khatri et al., 2008; Kuttuva et al., 2018; Lüthi et al., 2020). As a consequence, insufficiently treated or untreated wastewater is released into the environment, causing pollution and poor hygiene. Yet, retrofitting or expanding centralised systems in low- and middle-income contexts is often either too costly or not practicable (Klinger et al., 2020; Larsen et al., 2016; Massoud et al., 2009).

One solution to this challenge consists in on-site wastewater treatment systems that collect and treat the wastewater near its source of generation, for example within an individual building or a small cluster of buildings (Hering et al., 2013; Hoffmann et al., 2020; Rabaey et al., 2020). As a result, less wastewater is released into the environment, reducing pollution and increasing hygiene. In addition, the treated wastewater can be reused on premises for either potable or non-potable purposes (e.g. toilet flushing or irrigation). This saves freshwater resources and thus increases water security, both for users of the systems and the larger population (Garcia and Pargament, 2015; Gikas and Tchobanoglous, 2009).

Despite their advantages, on-site wastewater treatment and reuse systems (henceforth called on-site systems) are not frequently implemented. To increase their use, some local governments, for example the city of Bengaluru, India, have mandated the installation of on-site systems for certain building types. Yet, in Bengaluru, many of the installed on-site systems are not working properly, which results in a low quality of the treated water. As a consequence, this water is often not reused but discharged into the stormwater drains, which leads to a continued pollution of Bengaluru's waterbodies and groundwater (Kuttuva et al., 2018). Such operational issues might partly be caused by a lack of user acceptance,[1] which can be a barrier to a successful implementation of new water treatment and reuse technologies (Hurlimann and Dolnicar, 2010; Kenney, 2019). In the case of Bengaluru, user acceptance of on-site systems might be particularly important, as the users were mandated to instal the systems and have not voluntarily taken this decision. Thus, without user acceptance, the mandate itself is not sufficient to ensure that on-site systems are successfully implemented and reliably operated, monitored, and maintained.

A key reason for low user acceptance of on-site systems might be that they also entail costs and risks to be borne particularly by the users. These include, for example, monetary costs of investment and operation, time, and responsibility spent on operation, monitoring, and maintenance (OMM), as well as health or financial risks in the case of a system failure (Eggimann et al., 2016; Kuttuva et al., 2018; Voulvoulis, 2018; Watson et al., 2016). However, research indicates that an important predictor of user acceptance might not so much be the *objective* costs, risks, and benefits of on-site systems as estimated by experts, but rather how they are *perceived* by users (as well as by potential future users). More specifically, it has been shown that perceived costs, risks, and benefits explain acceptance of new technologies in general (e.g. Bearth and Siegrist, 2016; Liu et al., 2019) and of centralised wastewater treatment and reuse in particular (e.g. Mankad and Tapsuwan, 2011; Nancarrow et al., 2009). Initial evidence also suggests this for the acceptance of on-site systems (Amaris et al., 2020; Domènech and Saurí, 2010; Nancarrow et al., 2010; Portman et al., 2022; see also Contzen et al., 2023). Notably, users' perception of costs, risks, and benefits in particular as well as perceptions by lay persons more generally do often not match the more objective expert estimations (e.g. Savadori et al., 2004; Slovic et al., 1985). Hence, to better comprehend and predict user acceptance of on-site systems, a fuller understanding of the costs, risks, and benefits as perceived by users is necessary. This knowledge could then give insights with regard to the design of future technical, psychological, and political interventions to increase user acceptance of on-site systems. Moreover, acceptance not only by currently mandated users but also by people who might in future be mandated to use a system (i.e. current non-users) is of interest (henceforth called non-user acceptance). This is because in low- and middle-income countries dealing with rapid urbanisation and water scarcity, the use of on-site systems is steadily increasing and it is likely that existing mandates will be expanded or new mandates will arise. User and non-user perceptions might differ as experience with and knowledge about sustainable technologies can influence cost, risk, and benefit perceptions and thus acceptance levels (Amaris et al., 2020; Huijts et al., 2012; Schuitema et al., 2011). For example, health risks could be perceived as higher among users having experienced system failures. Yet, they could as well be perceived as lower if the users do not experience any adverse health effects. Accordingly, in interventions aiming at increasing acceptance, currently mandated users and potential future mandated users may have to be addressed in a different fashion, tailored to their respective perceptions.

So far, most studies examining costs, risks, and benefits and acceptance of wastewater treatment and reuse have looked at water reuse in general (Fielding et al., 2019; Ross et al., 2014) or at *centralised* systems (e.g. Hartley, 2006; Marks et al., 2008; Moya-Fernández et al., 2021; Nancarrow et al., 2009; for an overview, see Mankad and Tapsuwan, 2011). These findings are not directly transferable to on-site systems because centralised and on-site systems differ in central aspects such as the required personal monetary investment in the system or responsibility and effort for maintenance. Research on user perceptions of *on-site* systems in particular is scarce: So far, only four studies have analysed perceived costs, risks, and benefits of on-site systems and their relation to acceptance among either users (Domènech and Saurí, 2010) or non-users (Amaris et al., 2020; Nancarrow et al., 2010; Portman et al., 2022). Three of them examined this for greywater (i.e. wastewater from sinks, showers, washing machines, dishwashers etc. but not from toilets) and showed that on-site systems were perceived less acceptable if the water quality was perceived to be poorer (e.g. colour and odours; Amaris et al., 2020; Domènech and Saurí, 2010) or the risk of a health threat or system failure to be higher (Domènech and Saurí, 2010; Portman et al., 2022). Moreover, Amaris et al. (2020) found higher financial benefits from the reuse of the treated wastewater to be related to increased acceptance.[2]

In cities of low- and middle-income countries that have no or only partial sewerage networks and centralised treatment facilities, the entire wastewater – greywater and blackwater (i.e. wastewater from toilets) – has to be treated to achieve a comprehensive solution for wastewater management and the protection of the environment and public health. From a psychological perspective, perceptions of such a combined wastewater treatment and reuse might differ from those of an exclusive greywater treatment and reuse because a combined treatment and reuse may lead to increased perceptions of health risks and thus to lower levels of acceptance (Rozin et al., 2015). Thus, the findings on perceptions of greywater treatment may not be transferable to perceptions of combined grey- and blackwater treatment.

The only study on combined grey- and blackwater treatment and reuse (Nancarrow et al., 2010) found a higher perceived general risk to the family, the public, and the environment to be related to lower acceptance. However, the study was not conducted in a low- or middle-income country,[3] which means that the findings may not be directly transferable to such a context (for similar argumentations, see Henrich et al., 2010; Muthukrishna et al., 2020). Moreover, only one of the four studies has investigated the role of perceived benefits for acceptance[4] and none has

[1] We define 'user acceptance' as a positive valuation of on-site systems and their use by the mandated users (Contzen et al., 2023).

[2] However, this result should be interpreted with caution due to methodological issues. The study used hypothetical monetary savings in a discrete choice experiment as actual payment mechanism for participants. Therefore, the impact of the variable is potentially overestimated.

[3] Also of the studies on greywater treatment, only one was conducted in such a context, namely the study by Amaris et al. (2020).

[4] While Domènech and Saurí (2010) did include two benefits (monetary savings and environmental benefits) in their study, they did not assess their distinct relation with acceptance, as the benefits were combined in a scale with other variables.

systematically analysed which costs, risks, and benefits were most predictive of acceptance. Specifically, they considered only a small and selective number of costs and risks, allowing only partial conclusions about the overall issue. Thus, from the evidence at hand, only limited conclusions can be drawn as to the perception of costs, risks, and benefits and the acceptance of on-site systems with a combined grey- and blackwater treatment and reuse in general and their application in low- and middle-income countries in particular.

1.1. The present study

The aim of the present study was to assess the perceived costs, risks, and benefits of on-site systems for combined grey- and blackwater treatment and reuse as well as their relation to acceptance of these systems, while distinguishing between mandated users and current non-users (i.e. potential future mandated users). Specifically, we expected higher perceived costs and risks to be related to lower acceptance and higher perceived benefits to be related to higher acceptance. We studied this in a city of a lower middle-income country (OECD, 2022) that faces rapid urbanisation and insufficient infrastructure for centralised wastewater treatment, namely Bengaluru, in the state of Karnataka, India. In Bengaluru, a mandate to instal on-site systems exists for certain building types, which results in part of the population being mandated users and part of the population being non-users (i.e. potential future mandated users).

2. Methods

2.1. Study location

Bengaluru is one of the fastest growing cities in India. New neighbourhoods often have no connection to the centralised sewer system that predominantly serves the central core of the city. In addition, due to the steep population growth, increasingly large amounts of wastewater have to be treated, exceeding the capacity of the centralised system. As a consequence, untreated or only partially treated wastewater is being discharged into the lakes and waterbodies of Bengaluru, causing environmental pollution and health risks to residents living downstream of the discharge points (Jamwal et al., 2015). Moreover, with increasing population and climate change impacts, Bengaluru faces freshwater scarcity, which is likely to increase even further in the coming years (Unnikrishnan et al., 2017). To address these challenges, a mandate for the entire state of Karnataka was issued in 2004 (followed by a specific mandate for Bengaluru in 2016) that requires the installation of on-site systems for grey- and blackwater treatment and the full reuse of the treated water in new and existing residential buildings above a certain size,[5] applying mainly to apartment complexes. The majority of residents in such apartment buildings belong to the (upper) middle class (Kuttuva et al., 2018). The mandate led to the installation of over 3000 on-site systems in Bengaluru, which could provide a crucial contribution to the city's wastewater management (Klinger et al., 2020; Ulrich et al., 2021). However, as stated above, many of these on-site systems are not working properly (Kuttuva et al., 2018). One of the reasons for this malfunctioning is improper OMM or use (e.g. waste disposal in the drain), which might be caused by a lack of user acceptance. As on-site systems are generally located inside or very close to the users' homes, they require users to engage with the system by supporting its OMM or at least use it passively (by reusing the treated water) and correctly (e.g. not throwing garbage in the drain) (Contzen et al., 2023). Thus, user acceptance of on-site systems might be particularly important.

Due to the mandate, most users in Bengaluru originally became users because they were mandated to instal an on-site system, not because they voluntarily decided to do so. At the same time, most non-users did not actively decide against installing an on-site system. In the current mandate, small buildings are exempt as it is more efficient and more beneficial for the environment if an on-site system treats the larger wastewater amount of a bigger building than that of a smaller building. Yet, it is possible that the mandate will be expanded and cover also smaller buildings. Moreover, even if people preferred an on-site system, those living in apartment buildings could not take this decision individually, as on-site systems are only available for entire buildings and not for single apartments and the authority to instal a system at the building-level rests solely with the residents' association of the respective building. Yet, current non-users may become mandated users in future, for example if the mandate is expanded to cover more buildings, for example smaller ones, or when non-users move into a building that is covered by the current mandate.

2.2. Procedure and sample

Data was assessed through an online questionnaire, which was programmed with Unipark and distributed between November 2021 and February 2022 via the panel company Bilendi as well as via personal contacts and local Facebook and LinkedIn groups. Participation took around 20 min and all participants gave informed written consent prior to participation. Participants recruited via Bilendi received a financial compensation directly from the company. All other participants were eligible to receive a voucher for a local food delivery company. The study protocol was approved by the institutional review boards of Eawag and ATREE [IRB/CSEI/0002/NC-SN/09/2021].

Residents of Bengaluru above the age of 18 and proficient in English were eligible for participation. Moreover, participants either had to be covered by the mandate and have an on-site system installed in their building (mandated user sample) or they had to be not covered by the mandate and should not have an on-site system (non-user sample). That is, people covered by the mandate but without a system were excluded, as were those with a system but not covered. Whether residents were covered by the mandate and had a system installed was assessed via self-report after presenting a description of on-site systems and the mandate, including the types of buildings it covers.

Of the 895 people starting the survey (by giving consent to participation), 206 were screened out because they were not eligible, for example because they did not live in Bengaluru or because the respective age and gender quotas of the sample were full (the quota restriction was lifted later during data collection to reach the required number of participants). In addition, 251 participants were screened out because of incorrect answers to multiple-choice questions on the content of an information text on on-site systems (see Section 2.3). After data collection, participants were removed from the sample because of repeated participation (as could be concluded from identical open text entries; $n = 11$) or speeding (defined as being faster than one third of the sample median; $n = 5$). A further 70 participants did not complete the questionnaire. Of the remaining 352 participants, eight were excluded because they had an on-site system but indicated that they were not covered by the mandate or were unsure whether they were covered. Further nine participants who did not have a system or were unsure about it were excluded because they indicated to be covered by the mandate.

The final sample consisted of 335 participants, with $N = 103$ users and $N = 232$ non-users (sociodemographic characteristics are reported in the results section). A sensitivity power analysis (Faul et al., 2007) was conducted for linear multiple regressions with 8 predictors, given a power of .80 and an $\alpha = 0.05$ (Faul et al., 2009). For the omnibus F-test, the smallest effect sizes we were able to detect were $f^2 = 0.16$ (mandated user sample) and $f^2 = 0.07$ (non-user sample), which corresponds to a small to medium and a small effect, respectively (Cohen, 1992).

2.3. Questionnaire and measures

The questionnaire was carried out in English and assessed the participants' perceived costs, risks, and benefits of on-site systems as well as

[5] The Bengaluru specific mandate states (after its amendment in 2018) that the following residential buildings have to instal on-site systems: New residential buildings (built after January 2016) with 20 households or more or a total built-up area above 2000 square metres. Existing residential buildings (built before 2016) with 50 households or more or a total built-up area above 5000 square metres (Ulrich et al., 2021).

their acceptance of such systems. The first page of the survey included information on the study and the consent to participation. This was followed by questions on the participants' sociodemographic data. As the following part of the questionnaire required a basic understanding of on-site wastewater treatment and reuse, an information text about on-site systems and the mandate in Bengaluru followed. Only those participants who subsequently answered two multiple-choice questions on the content of the information text correctly could proceed with the questionnaire. Subsequently, perceived costs, risks, and benefits as well as acceptance of on-site systems were assessed. The design of all items was adapted from previous studies on acceptance on wastewater treatment and reuse (Domènech and Saurí, 2010; Hurlimann et al., 2008; Nancarrow et al., 2009).

2.3.1. Measures of potential costs, risks, and benefits

The costs, risks, and benefits of on-site systems included in the study were selected on the basis of qualitative interviews conducted with 14 local key stakeholders[6] as well as existing literature and guidelines (Evans et al., 2014; KSPCB, 2021; Kuttuva et al., 2018) and subsequently reviewed by all authors. The list included eight potential costs, four potential risks, and eight potential benefits (for an overview, see Table 1). Participants were asked to rate these for an average apartment household in Bengaluru that is mandated to instal an on-site system. Answers were given on 7-point rating scales ranging from 1 *(low perceived cost / risk / benefit)* to 7 *(high perceived cost / risk / benefit)*. The items can be found in the appendix.

To reduce complexity of the data and the risk of multicollinearity in the regression analysis, item mean scores were created for items with similar content as well as acceptable internal consistency, assessed with Spearman-Brown or Cronbach's Alpha coefficients, respectively (Eisinga et al., 2013). Specifically, means were calculated for monetary costs (for installation and OMM, $\rho_{\text{user}} = .82$, $\rho_{\text{non-user}} = .76$), comfort restrictions (space constraints, odour and noise nuisance, reduced visual appearance; $\alpha_{\text{user}} = .76$, $\alpha_{\text{non-user}} = .79$), and environmental benefits (reduced discharge of insufficiently treated wastewater into the environment, reduced environmental pollution; $\rho_{\text{user}} = .87$; $\rho_{\text{non-user}} = .82$). Means and standard deviations of all study variables for users and non-users are presented in Table 2. The item mean scores were used in correlation and regression analyses but not in initial descriptive analyses.

2.3.2. Measure of acceptance of on-site systems

The dependent variable, acceptance of on-site systems, was assessed by asking participants to rate the item ‘Overall, on-site systems and the reuse of the treated water are…’ on a scale ranging from 1 *(…very unacceptable)* to 7 *(…very acceptable)*. Means and standard deviations for users and non-users are presented in Table 2.

2.4. Statistical analyses

In a first step, stacked bar charts were created for all perceived costs, risks, and benefits (i.e. for each item and not for item mean scores) to facilitate a visual comparison of the distributions of the variables. To test for statistical differences between all of the perceived costs, risks, and benefits, Friedman tests (non-parametric variance analyses by ranks) with subsequent stepwise mean comparisons (based on Lüpsen, 2019) were conducted, separately for costs/risks and benefits as well as for mandated users and non-users, resulting in four tests in total. To test for differences in all variables between mandated users and non-users, Mann-Whitney *U* tests were conducted due to the non-normal distribution of the data. Subsequently, correlation analyses (Pearson) using the item mean scores, were conducted to evaluate the association between perceived costs, risks, and

[6] Semi-structured, virtual interviews were conducted between September and October 2021 with 14 Bengaluru-based key stakeholders, including representatives from the pollution control board and the water utility, builders of on-site systems and owners of maintenance companies, architects, environmental activists, members of residents' associations, building facility managers responsible for the systems' maintenance, as well as residents, both with and without on-site systems in their apartment building.

Table 1
Overview of potential costs, risks, and benefits of on-site systems in Bengaluru.

Costs, risks, and benefits	Background information
Costs	
Monetary costs of installation	For apartment complexes built *after* the imposition of the mandate, the costs of the installation of on-site systems are assumed by the builders (Evans et al., 2014). Therefore, when selecting treatment technologies, the main focus of the builders will usually be on optimising the installation costs, for example by selecting a lower-cost technology, even if this implies higher long-term costs of OMM or reduced water quality, as these will be under the residents' responsibility. For apartment complexes built *before* the imposition of the mandate that need to retrofit on-site systems, installation costs (as well as costs of OMM) are assumed directly by the apartment owners.
Monetary costs of OMM	Monetary costs of OMM include electricity costs (mostly for pumps and blowers), salaries of operating personnel, costs of water quality analyses (laboratory costs or costs of test kits), and replacement of system parts (Kuttuva et al., 2018). OMM costs are assumed by the residents.
Responsibility of OMM	In principle, responsibility for OMM is assumed by the residents. However, depending on the technology provider and the size of the apartment complex, responsibility may be taken over by the provider through yearly contracts. In other cases, residents may outsource OMM by hiring an OMM company.
Time for OMM	In the (upper) middle-class context of Bengaluru, OMM work is usually outsourced. Residents invest time for strategic discussions and decision-making, e.g. to decide on changes in the treatment technology but do not personally implement these operations.
Space constraints	Depending on the implemented technology, on-site systems can be placed on the ground floor, in the underground below or next to the apartment complexes, or in independent constructions in the setback area (KSPCB, 2021). Space constraints are mostly an issue when on-site systems need to be retrofitted to existing apartment complexes (i.e. complexes built *before* the imposition of the mandate) in which the needed space is not available or already occupied for other purposes.
Odour nuisance	Odour can be a result of inadequate system design, poor OMM, or inadequate ventilation. Especially insufficient aeration during the treatment process or an inappropriate location of the on-site system can be a source of odour (KSPCB, 2021).
Noise nuisance	Noise can be caused by pumps and blowers, but noise nuisance is usually low as the treatment systems are mostly placed below the apartment complexes or in independent constructions in the setback area. It is higher when the systems are placed on the ground floor
Impaired visual appearance of water	Depending on the implemented technology and operation of the on-site systems, the treated water can be slightly coloured, and/or contain particles.
Risks	
Health risk	Insufficient removal of pathogens from the wastewater due to inadequately designed technologies, inadequate OMM or due to treatment disruptions can lead to health risks for the users. Ingestion of the treated water is possible either during routine ingestion, for example, through aerosol formation during toilet flushing, cross connections (i.e. the drinking water pipes are directly or indirectly connected to a non-potable water pipe), or during accidental consumption of non-potable water.
Environmental risk	There is a risk of a pollution of the groundwater and of the waterbodies through insufficiently removed pathogens, nutrients, micro-pollutants (e.g. residues from pharmaceuticals), and heavy metals when the water is used for irrigation or when surplus water is released into stormwater drains.
Financial risk	Technologies are usually selected by the builders with a focus on optimising installation costs rather than the long-term OMM costs (see above; Evans et al., 2014). Residents bear the financial risk for repair and replacement of system parts or the entire system,

Table 1 (*continued*)

Costs, risks, and benefits	Background information
	especially when technologies are not designed for long lifetimes or are an inadequate fit for the specific purpose or context.
Risk of water shortages	Many buildings that are not connected to a sewer are not connected to the piped water system either and rely on groundwater (shortages during the dry season and in increasingly urbanised areas) and/or tanker water (associated with high costs). In the case of a system failure, users might face a temporary water shortage, until they receive water from other sources.
Benefits	
Less wastewater is discharged into environment	In theory, due to the mandate that all wastewater has to be reused on site, less wastewater is discharged into the environment. In practice, however, as the quality of the treated wastewater is often too low and as there are often not sufficient reuse purposes available, some of the treated water is still discharged into stormwater drains, irrespective of the water quality (Kuttuva et al., 2018).
Less environmental pollution	As a reduced amount of untreated wastewater is discharged into the environment, the environmental pollution is reduced (Kuttuva et al., 2018). But see above.
Financial benefit for the city	First, reduced need for capital-intensive sewerage and centralised wastewater treatment infrastructure. Second, reduced cost for freshwater provision due to use of treated wastewater for non-potable applications (Evans et al., 2014).
Increased water security for the city	Reduced consumption of groundwater and river water, due to use of treated wastewater for non-potable applications (Evans et al., 2014).
Increased water security for users	In the case of a disruption of the freshwater supply (e.g. due to natural disasters), users of on-site systems may have a higher water security.
Facilitated accessibility of water for users	24 h non-potable water supply, as opposed to groundwater (which is subject to shortages during the dry season) and tanker water (which needs regular refills).
Financial benefit for users	Reduced expenses for freshwater, especially for households depending on expensive tanker water and during the dry season (Kuttuva et al., 2018).
Positive image of users	Users of on-site systems may be perceived as being innovative and environmentally and socially conscious (as reusing treated wastewater increases the water security of the city).

Note. OMM = Operation, monitoring, and maintenance.

benefits and acceptance of on-site systems. Only those costs, risks, and benefits that correlated significantly with acceptance in at least one of the two samples were subsequently included into the linear regression analyses to identify factors explaining acceptance. Both the correlation and the regression analyses were conducted separately for mandated users and non-users. Due to the non-normal distribution of the variables, both the correlation analyses as well as the regression analyses were conducted using bootstrap estimation with 10,000 replications. Significance was determined based on the bootstrapped confidence intervals (95 %; Wood, 2004). All analyses were undertaken with IBM SPSS Statistics (Version 29).

3. Results

3.1. Preliminary analyses

Before conducting the main analyses, we checked for differences in demographic characteristics between the two samples to rule out that differences in the main analyses are caused by demographic differences. Of the mandated users, 59.2 % were male,[7] and one person preferred not to indicate their gender. Their age ranged from 18 to 73, with a mean age of 36.15 years ($SD = 10.48$). All participants had completed higher secondary education, with 97.1 % having completed tertiary education (Bachelor's degree or higher). Of the non-users, 59.5 % were male. Their age ranged from 19 to 74, with a mean age of 35.76 years ($SD = 12.69$). All but two participants had completed higher secondary education, with 94.8 % having completed tertiary education. The user sample matched the non-user sample with regard to age ($t(231.64) = 0.35, p = .73$), gender ($\chi^2(2) = 2.26, p = .323$), and education level ($\chi^2(4) = 5.38, p = .251$).

3.2. Perceived costs, risks, and benefits of on-site systems

The distribution of perceived costs and risks of on-site systems is presented in Fig. 1a-b. The Friedman tests indicated significant differences between the perceived costs and risks both among users ($\chi^2(11) = 243.217, p < .001$) and among non-users ($\chi^2(11) = 547.916, p < .001$). The post-hoc mean comparisons (see Table S3a) indicated that both mandated users and non-users perceived the responsibility for maintenance as significantly higher than all other costs or risks ($M_{\text{users}} = 5.91$, $SD = 1.16$ and $M_{\text{non-users}} = 5.85$, $SD = 1.09$). The lowest perceived cost or risk in the mandated user sample was the risk of a water shortage ($M = 3.50$, $SD = 1.61$), which was perceived as significantly lower than all other costs and risks except for perceived noise nuisance and health risks. Non-users perceived noise nuisance ($M = 3.71$, $SD = 1.49$) and the risk of a water shortage ($M = 3.79$, $SD = 1.65$) as significantly lower than all other costs or risks. Interestingly, non-users perceived significantly higher financial and health risks than users (financial risk: $U = 10{,}113.00$, $Z = -0.23$, $p = .008$ with $M_{\text{users}} = 4.69$, $SD = 1.54$ and $M_{\text{non-users}} = 5.13$, $SD = 1.30$; health risk: $U = 9465.50$, $Z = -3.08$, $p = .002$ with $M_{\text{users}} = 3.95$, $SD = 1.75$ and $M_{\text{non-users}} = 4.61$, $SD = 1.66$). No other significant differences in perceived costs and risks were found between users and non-users.

The distribution of perceived benefits of on-site systems is presented in Fig. 2a-b. As indicated by the Friedman tests, significant differences between the perceived benefits occurred in both samples (users: $\chi^2(7) = 24.357$, $p < .001$; non-users $\chi^2(7) = 55.018$, $p < .001$). While the perceived image of users was perceived as the highest benefit in both samples ($M_{\text{users}} = 5.48$, $SD = 1.39$ and $M_{\text{non-users}} = 5.37$, $SD = 1.32$), the post-hoc mean comparisons (see Table S3b) indicated that for mandated users it was only significantly higher than the perceived financial savings on the users' freshwater bills. For non-users, it was additionally perceived as significantly higher than the facilitated water accessibility and the water security for users and the city. The lowest perceived benefit was the financial savings for users ($M_{\text{users}} = 5.48$, $SD = 1.39$; $M_{\text{non-users}} = 4.75$, $SD = 1.70$). However, it was only perceived as significantly lower than the positive user image, the reduced environmental pollution, and, for non-users only, the reduced amount of wastewater discharged into the environment. No significant differences in perceived benefits were found between users and non-users.

3.3. Determinants of acceptance of on-site systems

Overall, acceptance of on-site systems was high and did not differ between mandated users and non-users ($U = 11{,}755.50$, $Z = -0.25$, $p = .805$ with $M_{\text{users}} = 5.93$, $SD = 1.10$ and $M_{\text{non-users}} = 5.87$, $SD = 1.20$). The correlation analyses (see Table 2) revealed that in both samples, higher perceived environmental benefits, higher financial benefits for both the city of Bengaluru and for users, and a more positive image of users were significantly associated with higher acceptance of on-site systems. Additionally, in the mandated user sample, comfort restrictions and a higher perceived environmental risk were significantly related to lower acceptance. For non-users, a perceived increased water security for Bengaluru and facilitated accessibility of water were also significantly associated with higher acceptance. Only those costs, risks, and benefits correlating significantly with acceptance in at least one of the two samples were included as predictors in the regression analyses.

The results of the linear regression analyses are presented in Table 3. For the mandated user sample, the different cost, risk, and benefit factors accounted for 35.5 % of variance in acceptance of on-site systems ($F(8, 102) = 6.46$, $p < .001$). Two factors explained acceptance significantly:

[7] We were not able to investigate the research question separately for gender due to the inevitably resulting small sample size and lack of statistical power.

Table 2
Correlations of study variables, mandated user sample (below diagonal) and non-user sample (above diagonal).

	M	*SD*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
M			5.87	5.24	5.85	5.15	4.24	4.61	4.78	5.13	3.79	5.30	5.21	4.91	5.06	5.06	4.75	5.37
SD			1.20	1.06	1.09	1.22	1.18	1.66	1.61	1.30	1.65	1.37	1.23	1.34	1.54	1.35	1.70	1.32
1. Acceptance	5.93	1.10		.09	.05	−.02	.01	−.14	−.12	−.10	−.10	.46[a]	.45[a]	.36[a]	.09	.25[a]	.35[a]	.45[a]
2. Monetary costs	5.03	1.27	−.12		.42[a]	.53[a]	.36[a]	.28[a]	.21[a]	.45[a]	.21[a]	.14[a]	.23[a]	.17[a]	.12	.33[a]	.09	.07
3. Responsibility (OMM)	5.91	1.16	−.01	.33[a]		.54[a]	.19[a]	.17[a]	.09	.27[a]	.13[a]	−.003	.30[a]	.12	.13	.20[a]	−.06	.12
4. Time (OMM)	5.09	1.42	−.05	.64[a]	.40[a]		.40[a]	.28[a]	.18[a]	.35[a]	.24[a]	−.01	.26[a]	.02	.05	.12	−.07	−.08
5. Comfort restrictions	4.21	1.25	−.20[a]	.39[a]	.16	.52[a]		.52[a]	.34[a]	.43[a]	.52[a]	.02	.16[a]	.14[a]	.14[a]	.21[a]	.04	−.02
6. Health risk	3.95	1.75	−.17	.28[a]	.05	.39[a]	.66[a]		.28[a]	.52[a]	.49[a]	.07	−.02	.02	.15[a]	.08	−.10	−.13
7. Environmental risk	4.57	1.74	−.23[a]	.39[a]	.30[a]	.47[a]	.59[a]	.58[a]		.50[a]	.40[a]	−.10	−.06	−.04	.15[a]	.19[a]	−.10	−.08
8. Financial risk	4.71	1.54	−.12	.48[a]	.35[a]	.56[a]	.47[a]	.48[a]	.59[a]		.27[a]	.02	.04	−.01	.13	.14	−.08	−.03
9. Water shortage risk	3.50	1.61	−.08	.25[a]	.13	.37[a]	.47[a]	.63[a]	.50[a]	.307[a]		−.07	.060	.14[a]	.11	.16[a]	.01	−.12
10. Environmental benefit	5.27	1.44	0.47[a]	−.15	.04	−.14	−.14	−.18	−.20	−.17	.01		.31[a]	.32[a]	.17[a]	.25[a]	.45[a]	.54[a]
11. Financial Benefits, city	5.15	1.55	.26[a]	−.09	−.05	−.08	−.16	−.08	−.20	−.04	−.02	.20		.34[a]	.10	.38[a]	.29[a]	.31[a]
12. Water security, city	4.83	1.53	.17	−.08	−.01	−.07	.12	.05	−.06	−.12	.11	.33[a]	.24[a]		.06	.28[a]	.37[a]	.30[a]
13. Water security, user	4.98	1.48	−.07	.11	.10	.01	.13	.30[a]	.18	.13	.18	−.12	.17	.17		.40[a]	.14	.23[a]
14. Facilitated accessibility	5.23	1.34	.11	.01	.25[a]	.05	.12	.09	.03	.13	.04	.12	.07	.31[a]	.30[a]		.30[a]	.33[a]
15. Financial benefit, user	4.70	1.70	.37[a]	−.14	−.02	−.16	−.08	−.13	−.21	−.236	−.03	.40[a]	.34[a]	.32[a]	.07	.28[a]		.42[a]
16. Positive image, user	5.48	1.39	.51[a]	−.12	.03	−.14	−.13	−.24[a]	−.21[a]	−.15	−.23[a]	.43[a]	.41[a]	.16	.06	.14	.50[a]	

Note. *M* = Mean, *SD* = Standard Deviation, OMM = Operation, monitoring, and maintenance.
[a] Significant based on confidence intervals (95 %) with BCa-Bootstrapping with 10,000 replications (for confidence intervals, see supplementary material S2).

the more users believed that using an on-site system provides a positive image and the more they believed that the environment benefits from the use of on-site systems, the more they accepted the on-site systems.

In the non-user sample, 37.6 % of variance in acceptance of on-site systems was explained by the model ($F(8, 231) = 16.77, p < .001$). Three factors explained acceptance significantly: the more non-users perceived benefits for the environment, financial benefits for the city of Bengaluru, and a positive image of users, the more they accepted the on-site systems.

4. Discussion

On-site systems offer a promising solution for water pollution and freshwater scarcity, particularly in rapidly growing cities of low- and middle-income countries (Larsen et al., 2016; Massoud et al., 2009; Rabaey et al., 2020). To increase the use of on-site systems, mandates to instal such systems can be an effective measure. However, such mandates are much more likely to lead to a successful implementation of on-site systems if the (prospective) mandated users accept the technology and its use (Hurlimann and Dolnicar, 2010; Kenney, 2019). As perceived costs, risks, and benefits are key predictors of technology acceptance (Mankad and Tapsuwan, 2011; Nancarrow et al., 2009), the present study assessed the perceived costs, risks, and benefits of on-site systems and their relation to system acceptance in Bengaluru, India, where the installation and use of on-site systems is mandated for certain building types. The analyses were conducted separately for mandated users of on-site systems and non-users (i.e. potential future users), as their perception might vary due to different levels of personal experience with the technology (Huijts et al., 2012; Schuitema et al., 2011).

Both mandated users and non-users perceived the costs and risks of on-site systems as similarly high as the benefits. However, only benefits were found to predict acceptance significantly. Specifically, for both users and non-users, acceptance was higher when participants perceived that the use of on-site systems reduces environmental pollution and that it provides a positive image of users. In the non-user sample only, higher acceptance was additionally (and most strongly) predicted by perceiving a financial benefit for the city of Bengaluru. The fact that only benefits but no costs and risks (which were perceived as similarly high as the benefits) were found to explain acceptance indicates that perceiving costs or risks of on-site systems does not necessarily represent a barrier to accepting them. It further implies that a person's acceptance of on-site systems is not necessarily based on the perceived intensity of certain related costs, risks, and benefits but rather on the subjective relevance of these costs, risks, and benefits to the person. The question is thus, which factors define subjective relevance. Differences in subjective relevance may first be caused by external or structural factors, such as the user status. For example, a positive user image is likely of higher subjective relevance to users than to non-users. In line with this assumption, a perceived positive image was found to be a stronger predictor of acceptance for mandated users than for non-users, while both groups perceived the user image as equally positive. On the other hand, the financial benefit for Bengaluru is potentially more relevant to non-users as they (indirectly) benefit from the fact that the city does not have to expand the centralised system while not having to carry the financial investment for on-site systems. This is mirrored by our findings as the financial benefit for Bengaluru predicts non-user acceptance only, even though users and non-users perceived it as equally high. Next to such structural influences, differences in subjective relevance of costs, risks, and benefits may also be rooted in different core values, defined as general goals that people aspire in life that guide the selection and evaluation of behaviour and events, across situations and time (Schwartz, 1992; Steg and de Groot, 2012). In the context of on-site systems, perceiving environmental benefits of on-site systems might, for example, be especially predictive of acceptance for people with stronger biospheric values, for whom protecting nature and the environment is of relevance (Contzen et al., 2021; Steg et al., 2014). Yet for people with stronger egoistic values, for whom protecting personal resources such as wealth and status is of relevance, personal costs (rather than collective benefits) might be of high subjective relevance. Therefore, perceiving (non-)monetary personal costs of on-site systems might be highly predictive of acceptance in this group. Future research could investigate whether the predictive power of different costs, risks, and benefits of on-site systems differs between people, depending on their core values.

Surprisingly, perceived health risk was not predictive of acceptance in either sample. This contrasts findings by Domènech and Saurí (2010), showing that the higher the users' health risk perception, the lower their acceptance of greywater on-site systems. Yet, in contrast to the authors, we have examined a broad set of costs, risks, and benefits, which most likely included predictors more relevant to acceptance than health risk perception. Interestingly, both health and financial risks were perceived as significantly lower among mandated users than among non-users. In a context in which residents can actively choose to instal an on-site system, this finding could indicate that a pre-existing lower risk perception motivated users to instal an on-site system in the first place. However, in the case of Bengaluru, where users were mandated to instal the systems, this explanation is not plausible. Rather, this finding may indicate that with increasing duration of use, users' perception of the health and financial risk of on-site systems decreases. Potentially, users habituate to the risk over time when no negative consequences (such as a system failure) occur (Brown, 2005; Lima, 2004).

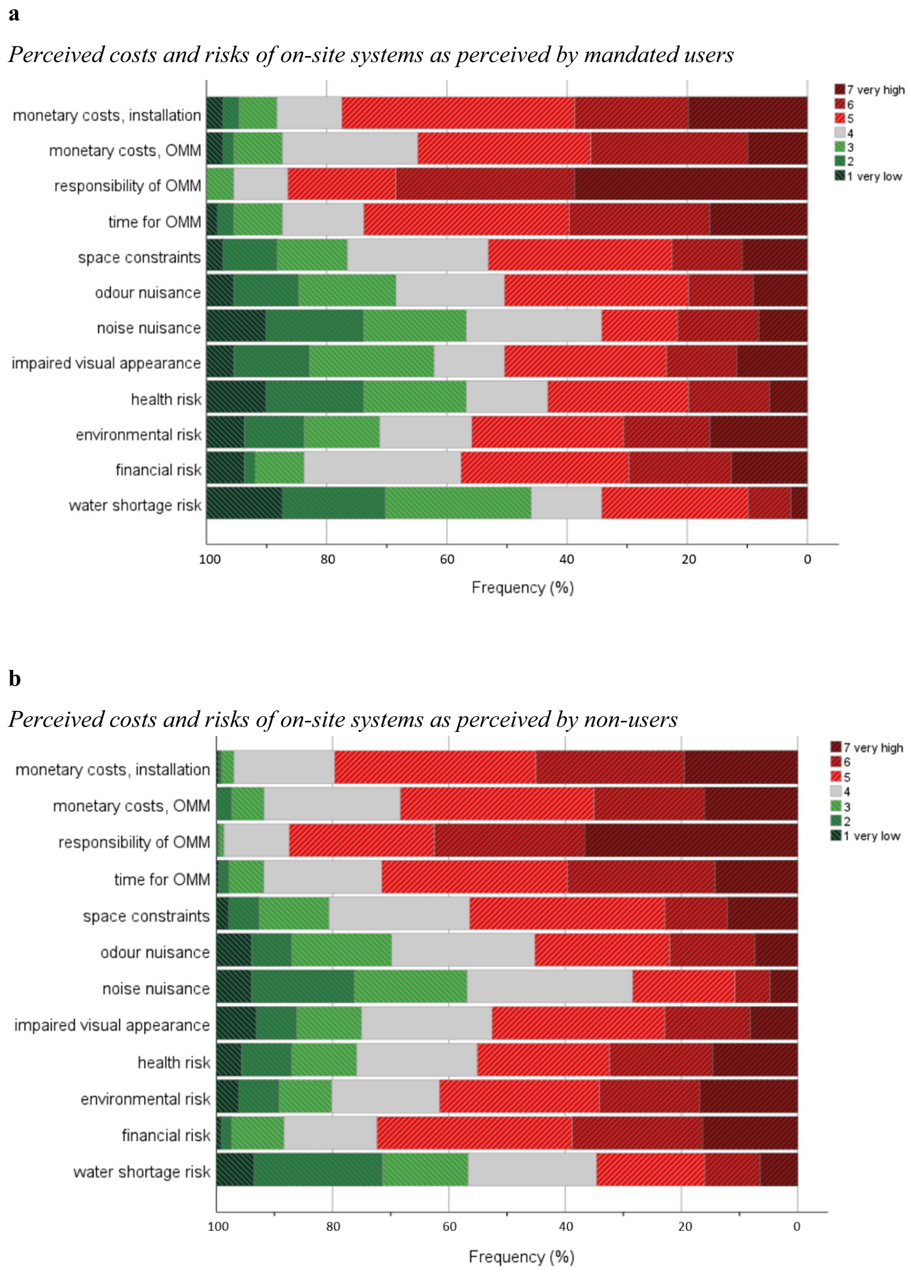


Fig. 1. a. Perceived costs and risks of on-site systems as perceived by mandated users.
b. Perceived costs and risks of on-site systems as perceived by non-users.
Note. OMM = Operation, monitoring, and maintenance.

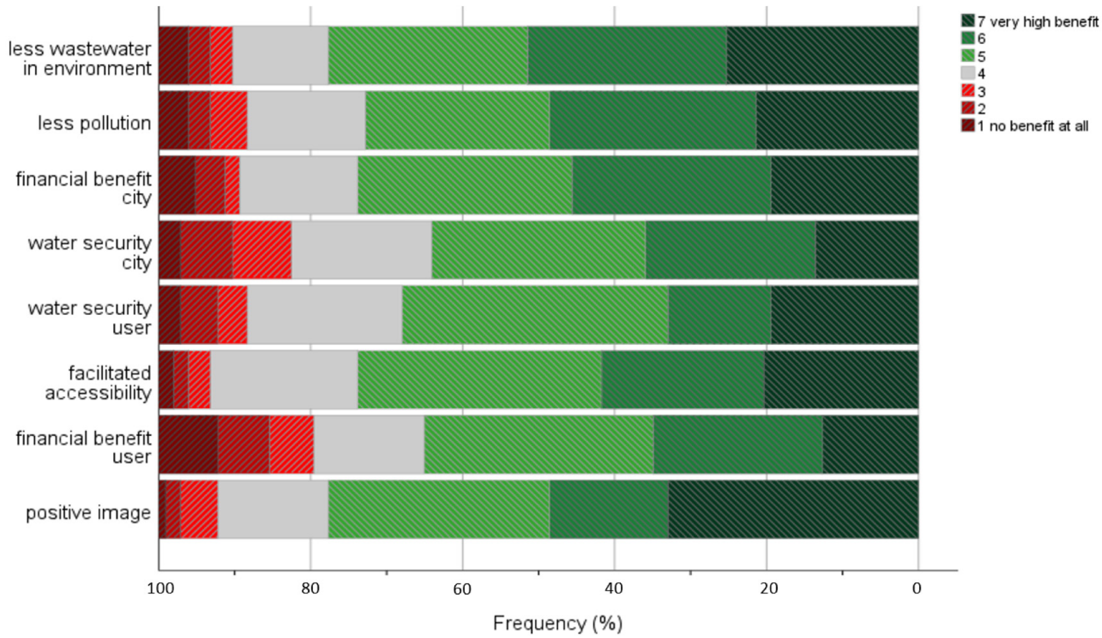
4.1. Practical implications for promoting acceptance of on-site systems

Several practical implications to promote on-site systems can be derived from the findings of the present study. The fact that only benefits and no costs or risks were predictive of acceptance, suggests that emphasising the benefits of on-site systems in communication might be a successful strategy for increasing acceptance. Specifically, a promotion campaign for on-site systems could point out the positive effects on the environment, the financial savings for the city, and the image gain of users. To further increase the effectiveness of such campaigns, interventions could be tailored to match the (partly) different perceptions of mandated users and potential prospective users of on-site systems. For example, pointing out the city's financial savings to already mandated users is unlikely to increase acceptance. On the contrary, it could even increase perceived unfairness among this group, as only mandated users have to bear the direct costs and risks of on-site systems while the population as a whole benefits (Watson et al., 2016). Perceived unfairness has been shown to reduce acceptance of on-site systems (Nancarrow et al., 2010) and of other technologies (Huijts et al., 2022; Siegrist et al., 2012). Thus, emphasising these benefits could even reduce acceptance among mandated users.

Yet, when aiming to promote on-site systems among prospective users – for example in the case that a mandate for the installation of on-site systems is expanded or newly introduced in a city – pointing out financial savings for the community might be a particularly promising strategy, as a perceived financial benefit for the city most strongly explained acceptance of on-site systems among non-users. And finally, as part of implementation campaigns, users of on-site systems could act as testimonials, promoting the use of on-site systems and raising awareness of the benefits. As users are perceived as having a very positive image, they might be perceived by non-users as role models worth emulating.

a

Perceived benefits of on-site systems as perceived by mandated users



b

Perceived benefits of on-site systems as perceived by non-users

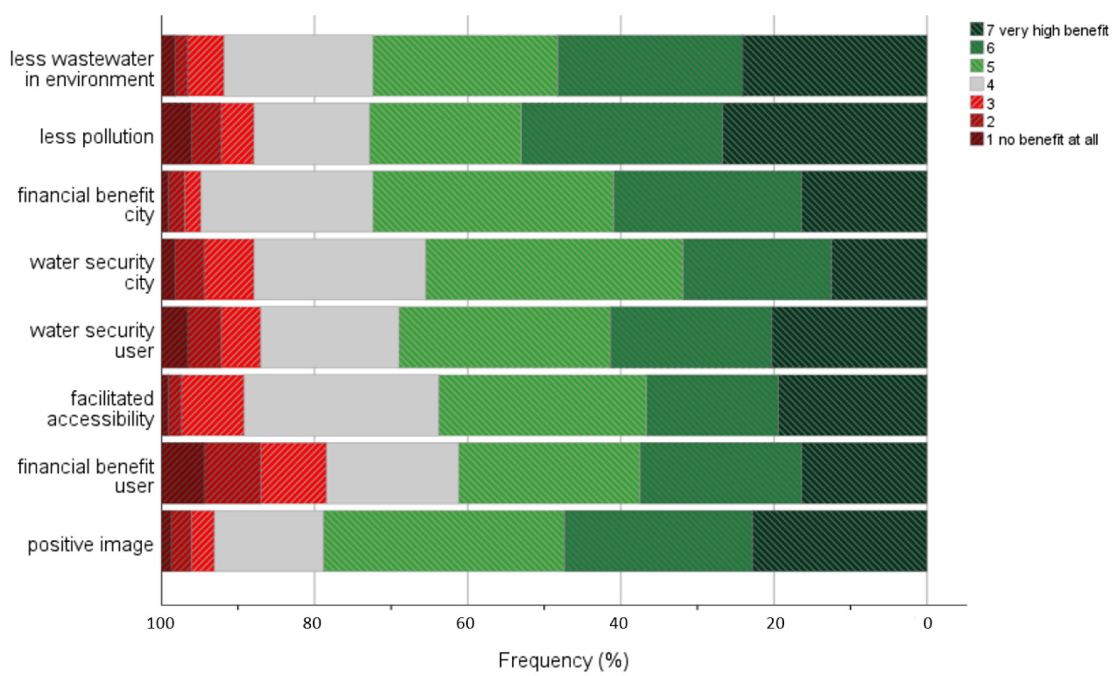


Fig. 2. a. Perceived benefits of on-site systems as perceived by mandated users.
b. Perceived benefits of on-site systems as perceived by non-users.
Note. OMM = Operation, monitoring, and maintenance.

Table 3
Regression analysis explaining acceptance of on-site systems for mandated users and non-users.

	Mandated users					Non-users				
				95 % CI					95 % CI	
Predictors	*B*	β	*SE*	LL	UL	*B*	β	*SE*	LL	UL
Intercept	3.47		0.74	1.99	4.64	2.13		0.44	1.26	2.93
Comfort restrictions	−0.08	−0.09	0.10	−0.26	0.11	−0.04	−0.04	0.06	−0.17	0.11
Environmental risk	−0.02	−0.04	0.07	−0.18	0.12	−0.03	−0.04	0.04	−0.12	0.05
Environmental benefit	0.21[a]	0.27	0.12	0.001	0.43	0.18[a]	0.21	0.06	0.03	0.35
Financial benefit, city	0.02	0.02	0.07	−0.12	0.16	0.27[a]	0.28	0.06	0.11	0.43
Increased water security, city	0.002	0.002	0.07	−0.16	0.23	0.12	0.13	0.05	−0.01	0.24
Facilitated accessibility	0.02	0.03	0.08	−0.13	0.20	−0.01	−0.01	0.06	−0.11	0.10
Financial benefit for users	0.04	0.06	0.08	−0.13	0.21	0.03	0.04	0.05	−0.06	0.13
Positive image of users	0.26[a]	0.33	0.10	0.06	0.43	0.19[a]	0.20	0.06	0.01	0.35

Note. Multiple linear regressions, only predictors correlating significantly with acceptance in either of the two samples were included, B = unstandardised regression coefficient; β = standardised regression coefficient; *SE* = standard error; CI = confidence interval, *LL* = lower limit; *UL* = upper limit; CI and *SE* based on BCa-Bootstrapping with 10,000 replications.

[a] Significant based on confidence intervals (95 %) with BCa-Bootstrapping with 10,000 replications.

4.2. Strength, limitations, and directions for future research

To our knowledge, this is the first study to (a) systematically investigate the relationship between a broad set of perceived costs, risks, and benefits of on-site systems and system acceptance, (b) examine this relationship for on-site systems with a combined treatment of black and greywater in a lower middle-income country, and (c) compare how these perceptions differ between mandated users and non-users. As the study was conducted in a real-life setting, the findings are of high practical relevance.

Nevertheless, a few limitations must also be considered. First, the study included only English-speaking residents of Bengaluru with access to the internet and nearly all participants had a university degree. Thus, residents with a low socioeconomic status are not represented in this study, which limits the generalisability of the findings to the general population. However, the sample is likely to be representative of residents covered by the mandate, as they are – due to the building type covered by the mandate – mostly members of the (upper) middle class and therefore well-educated and proficient in English. We aimed to collect a comparable sample among non-covered residents of Bengaluru as this population group is likely to either be covered in a future expansion of the mandate or to move into a building already covered by the mandate. Moreover, only with samples comparable with regard to socioeconomic characteristics was it possible to attribute differences in perception between the samples to differences in user status. Nevertheless, we suggest that future studies on acceptance of on-site systems also include people with a lower socioeconomic status to be able to generalise the findings to lower-income contexts.

Second, the correlational, cross-sectional design of the study does not allow causal conclusions about the relationship between perceived costs, risks, and benefits on the one hand and acceptance of on-site systems on the other. It is as well possible that the level of acceptance predicts perceived costs, risks, and benefits or that the relationship is bidirectional. Future studies could examine this question either by experimentally manipulating the perceived costs, risks, and benefits to analyse their influence on acceptance or in a longitudinal design, by following up changes in perception of users and non-users over time. Relatedly, it could be investigated whether perceptions of current non-users who become (mandated) users change over time due to experience with on-site systems. This could give additional insights into how acceptance of on-site systems among prospective users could be increased.

Third, some of the investigated costs, risks, and benefits are very relevant to Bengaluru (e.g. the reduction of environmental pollution as large parts of the city are not connected to the centralised systems or the space constraints evoked by the mandate to retrofit on-site systems) but might be less predictive of acceptance in other contexts. Therefore, future research could examine the role of various costs, risks, and benefits in other countries or different settings to generate a more holistic picture.

Finally, in both samples, acceptance was rather high and low in variance. Only very few participants found on-site systems (very) unacceptable, indicating that most people in our samples were supportive of on-site systems. This might either indicate an overall high acceptance of on-site systems in Bengaluru or a sampling bias (e.g. from self-selection of environmentally-conscious residents). Yet, despite the high acceptance levels, several benefits explained differences in acceptance levels, indicating their relevance to understanding acceptance. Nevertheless, a study with participants who are more opposed to on-site systems would be necessary to better understand barriers to acceptance.

4.3. Conclusions

Among mandated users and non-users, acceptance of on-site systems was predominantly determined by perceived benefits, namely environmental benefits, a positive image of users, and, for non-users only, also financial benefits for the city. This suggests that strategies to increase acceptance of on-site systems and water reuse might profit from emphasising the benefits of the system rather than downplaying costs and risks. Moreover, communication could be tailored to the benefits perceived by the respective target group, such as mandated users with a low acceptance versus prospective users of on-site systems.

CRediT authorship contribution statement

J.K. and N.C. led the design of the study. J.K. led the data assessment and analysis as well as the conception and writing of the manuscript. N.C. contributed to the data assessment and analysis as well as to the conception and writing of the manuscript. S.N., S.S., and S.B. gave feedback on the questionnaire, contributed to the data assessment, and provided feedback to all parts of the manuscript. E.R. and E.M. provided feedback on the questionnaire and to all parts of the manuscript. E.R. drafted Table 1.

Data availability

Data will be made available on request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2023.165042.

References

Amaris, G., Dawson, R., Gironás, J., Hess, S., Ortúzar, J.D.D., 2020. Understanding the preferences for different types of urban greywater uses and the impact of qualitative attributes. Water Res. 184, 116007. https://doi.org/10.1016/j.watres.2020.116007.

Bearth, A., Siegrist, M., 2016. Are risk or benefit perceptions more important for public acceptance of innovative food technologies: a meta-analysis. Trends Food Sci. Technol. 49, 14–23. https://doi.org/10.1016/j.tifs.2016.01.003.

Brown, S.L., 2005. Relationships between risk-taking behaviour and subsequent risk perceptions. Br. J. Psychol. 96, 155–164. https://doi.org/10.1348/000712605X36703.

Cohen, J., 1992. A power primer. Psychol. Bull. 112, 155–159. https://doi.org/10.1037/0033-2909.112.1.155.

Contzen, N., Perlaviciute, G., Sadat-Razavi, P., Steg, L., 2021. Emotions toward sustainable innovations: a matter of value congruence. Front. Psychol. 12, 661314. https://doi.org/10.3389/fpsyg.2021.661314.

Contzen, N., Kollmann, J., Mosler, H.-J., 2023. The importance of user acceptance, support, and behaviour change for the implementation of decentralized water technologies. Nat. Water 1, 138–150. https://doi.org/10.1038/s44221-022-00015-y.

Domènech, L., Saurí, D., 2010. Socio-technical transitions in water scarcity contexts: public acceptance of greywater reuse technologies in the Metropolitan Area of Barcelona. Resour. Conserv. Rec. 55, 53–62. https://doi.org/10.1016/j.resconrec.2010.07.001.

Eggimann, S., Truffer, B., Maurer, M., 2016. The cost of hybrid waste water systems: a systematic framework for specifying minimum cost-connection rates. Water Res. 103, 472–484. https://doi.org/10.1016/j.watres.2016.07.062.

Eisinga, R., Grotenhuis, M.T., Pelzer, B., 2013. The reliability of a two-item scale: Pearson, Cronbach, or Spearman-Brown? Int. J. Public Health 58, 637–642. https://doi.org/10.1007/s00038-012-0416-3.

Evans, A.E., Varma, S., Krishnamurthy, A., 2014. Formal Approaches to Wastewater Reuse in Bangalore, India, 37th WEDC International Conference, Hanoi.

Faul, F., Erdfelder, E., Lang, A.-G., Buchner, A., 2007. G* Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav. Res. Methods 39, 175–191. https://doi.org/10.3758/BF03193146.

Faul, F., Erdfelder, E., Buchner, A., Lang, A.-G., 2009. Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses. Behav. Res. Methods 41, 1149–1160. https://doi.org/10.3758/BRM.41.4.1149.

Fielding, K.S., Dolnicar, S., Schultz, T., 2019. Public acceptance of recycled water. Int. J. Water Resour. Dev. 35, 551–586. https://doi.org/10.1080/07900627.2017.1419125.

Garcia, X., Pargament, D., 2015. Reusing wastewater to cope with water scarcity: economic, social and environmental considerations for decision-making. Resour. Conserv. Rec. 101, 154–166. https://doi.org/10.1016/j.resconrec.2015.05.015.

Gikas, P., Tchobanoglous, G., 2009. The role of satellite and decentralized strategies in water resources management. J. Environ. Manag. 90, 144–152. https://doi.org/10.1016/j.jenvman.2007.08.016.

Hartley, T.W., 2006. Public perception and participation in water reuse. Desalination 187, 115–126. https://doi.org/10.1016/j.desal.2005.04.072.

Henrich, J., Heine, S.J., Norenzayan, A., 2010. Most people are not WEIRD. Nature 466, 29. https://doi.org/10.1038/466029a.

Hering, J.G., Waite, T.D., Luthy, R.G., Drewes, J.E., Sedlak, D.L., 2013. A changing framework for urban water systems. Environ. Sci. Technol. 47, 10721–10726. https://doi.org/10.1021/es4007096.

Hoffmann, S., Feldmann, U., Bach, P.M., Binz, C., Farrelly, M., Frantzeskaki, N., Hiessl, H., Inauen, J., Larsen, T.A., Lienert, J., Londong, J., Lüthi, C., Maurer, M., Mitchell, C., Morgenroth, E., Nelson, K.L., Scholten, L., Truffer, B., Udert, K.M., 2020. A research agenda for the future of urban water management: exploring the potential of nongrid, small-grid, and hybrid solutions. Environ. Sci. Technol. 54, 5312–5322. https://doi.org/10.1021/acs.est.9b05222.

Huijts, N.M.A., Molin, E.J.E., Steg, L., 2012. Psychological factors influencing sustainable energy technology acceptance: a review-based comprehensive framework. Renew. Sust. Energ. Rev. 16, 525–531. https://doi.org/10.1016/j.rser.2011.08.018.

Huijts, N.M.A., Contzen, N., Roeser, S., 2022. Unequal means more unfair means more negative emotions? Ethical concerns and emotions about an unequal distribution of negative outcomes of a local energy project. Energy Policy 165, 112963. https://doi.org/10.1016/j.enpol.2022.112963.

Hurlimann, A., Dolnicar, S., 2010. When public opposition defeats alternative water projects – the case of Toowoomba Australia. Water Res. 44, 287–297. https://doi.org/10.1016/j.watres.2009.09.020.

Hurlimann, A., Hemphill, E., McKay, J., Geursen, G., 2008. Establishing components of community satisfaction with recycled water use through a structural equation model. J. Environ. Manag. 88, 1221–1232. https://doi.org/10.1016/j.jenvman.2007.06.002.

Jamwal, P., Zuhail, T.M., Urs, P.R., Srinivasan, V., Lele, S., 2015. Contribution of sewage treatment to pollution abatement of urban streams. Curr. Sci. 108, 677–685. http://www.jstor.org/stable/24216628.

Kenney, S., 2019. Purifying water: responding to public opposition to the implementation of direct potable reuse in California. UCLA J. Environ. Law Policy 37, 85–122. https://doi.org/10.5070/l5371043643.

Khatri, K., Vairavamoorthy, K., Porto, M., 2008. Challenges for urban water supply and sanitation in developing countries. In: Alaerts, G., Dickinson, N. (Eds.), Water for a Changing World-Developing Local Knowledge and Capacity. CRC Press, pp. 93–112.

Klinger, M., Ulrich, L., Ramprasad, C., Wolf, A.T., Reynaud, N., Narayan, A.S., Siemsen, P., Lüthi, C., Philip, L., 2020. Technology, implementation and operation of small-scale sanitation in India–Performance analysis and policy recommendations. 4S Project Report. vol. I.

Kookana, R.S., Drechsel, P., Jamwal, P., Vanderzalm, J., 2020. Urbanisation and emerging economies: issues and potential solutions for water and food security. Sci. Total Environ. 732, 139057. https://doi.org/10.1016/j.scitotenv.2020.139057.

KSPCB, 2021. New STP Guide.

Kuttuva, P., Lele, S., Mendez, G.V., 2018. Decentralized wastewater systems in Bengaluru, India: success or failure? Water Econ. Policy 04, 1650043. https://doi.org/10.1142/s2382624x16500430.

Larsen, T.A., Hoffmann, S., Lüthi, C., Truffer, B., Maurer, M., 2016. Emerging solutions to the water challenges of an urbanizing world. Science 352, 928–933. https://doi.org/10.1126/science.aad8641.

Lima, M.L., 2004. On the influence of risk perception on mental health: living near an incinerator. J. Environ. Psychol. 24, 71–84. https://doi.org/10.1016/S0272-4944(03)00026-4.

Liu, P., Yang, R., Xu, Z., 2019. Public acceptance of fully automated driving: effects of social trust and risk/benefit perceptions. Risk Anal. 39, 326–341. https://doi.org/10.1111/risa.13143.

Lüpsen, H., 2019. Multiple Mittelwertvergleiche-parametrisch und nichtparametrisch-sowie α-Adjustierungen mit praktischen Anwendungen mit R und SPSS. Version 2.0.

Lüthi, C., Willetts, J., Hoffmann, S., 2020. City-wide sanitation: the urban sustainability challenge. Front. Environ. Sci. 8. https://doi.org/10.3389/fenvs.2020.585418.

Mankad, A., Tapsuwan, S., 2011. Review of socio-economic drivers of community acceptance and adoption of decentralised water systems. J. Environ. Manag. 92, 380–391. https://doi.org/10.1016/j.jenvman.2010.10.037.

Marks, J., Martin, B., Zadoroznyj, M., 2008. How Australians order acceptance of recycled water: national baseline data. J. Sociol. 44, 83–99. https://doi.org/10.1177/1440783307085844.

Massoud, M.A., Tarhini, A., Nasr, J.A., 2009. Decentralized approaches to wastewater treatment and management: applicability in developing countries. J. Environ. Manag. 90, 652–659. https://doi.org/10.1016/j.jenvman.2008.07.001.

Moya-Fernández, P.J., López-Ruiz, S., Guardiola, J., González-Gómez, F., 2021. Determinants of the acceptance of domestic use of recycled water by use type. Sustain. Prod. Consum. 27, 575–586. https://doi.org/10.1016/j.spc.2021.01.026.

Muthukrishna, M., Bell, A.V., Henrich, J., Curtin, C.M., Gedranovich, A., McInerney, J., Thue, B., 2020. Beyond western, educated, industrial, rich, and democratic (WEIRD) psychology: measuring and mapping scales of cultural and psychological distance. Psychol. Sci. 31, 678–701. https://doi.org/10.1177/0956797620916782.

Nancarrow, B.E., Leviston, Z., Tucker, D.I., 2009. Measuring the predictors of communities' behavioural decisions for potable reuse of wastewater. Water Sci. Technol. 60, 3199–3209. https://doi.org/10.2166/wst.2009.759.

Nancarrow, B.E., Porter, N.B., Leviston, Z., 2010. Predicting community acceptability of alternative urban water supply systems: a decision making model. Urban Water J. 7, 197–210. https://doi.org/10.1080/1573062X.2010.484500.

OECD, 2022. DAC List of ODA Recipients, Effective for Reporting on 2022 and 2023 Flows.

Portman, M.E., Vdov, O., Schuetze, M., Gilboa, Y., Friedler, E., 2022. Public perceptions and perspectives on alternative sources of water for reuse generated at the household level. J. Water Reuse Desalin. https://doi.org/10.2166/wrd.2022.002.

Rabaey, K., Vandekerckhove, T., de Walle, A.V., Sedlak, D.L., 2020. The third route: using extreme decentralization to create resilient urban water systems. Water Res. 185, 116276. https://doi.org/10.1016/j.watres.2020.116276.

Ross, V.L., Fielding, K.S., Louis, W.R., 2014. Social trust, risk perceptions and public acceptance of recycled water: testing a social-psychological model. J. Environ. Manag. 137, 61–68. https://doi.org/10.1016/j.jenvman.2014.01.039.

Rozin, P., Haddad, B., Nemeroff, C., Slovic, P., 2015. Psychological aspects of the rejection of recycled water: contamination, purification and disgust. Judgm. Decis. Mak. 10, 50–63.

Savadori, L., Savio, S., Nicotra, E., Rumiati, R., Finucane, M., Slovic, P., 2004. Expert and public perception of risk from biotechnology. Risk Anal. 24, 1289–1299. https://doi.org/10.1111/j.0272-4332.2004.00526.x.

Schuitema, G., Steg, L., van Kruining, M., 2011. When are transport pricing policies fair and acceptable? Soc. Justice Res 24, 66–84. https://doi.org/10.1007/s11211-011-0124-9.

Schwartz, S.H., 1992. Universals in the Content and Structure of Values: Theoretical Advances and Empirical Tests in 20 Countries, Advances in Experimental Social Psychology. vol. 25. Academic Press, San Diego, CA, US, pp. 1–65.

Siegrist, M., Connor, M., Keller, C., 2012. Trust, confidence, procedural fairness, outcome fairness, moral conviction, and the acceptance of GM field experiments. Risk Anal. 32, 1394–1403. https://doi.org/10.1111/j.1539-6924.2011.01739.x.

Slovic, P., Fischhoff, B., Lichtenstein, S., 1985. Rating the risks: the structure of expert and lay perceptions. In: Covello, V.T., Mumpower, J.L., Stallen, P.J.M., Uppuluri, V.R.R. (Eds.), Environmental Impact Assessment, Technology Assessment, and Risk Analysis. Springer, Berlin, Heidelberg, Berlin, Heidelberg, pp. 131–156.

Steg, L., de Groot, J.I.M., 2012. Environmental values. In: Clayton, S.D. (Ed.), The Oxford Handbook of Environmental and Conservation Psychology. Oxford University Press, New York, NY, pp. 81–92.

Steg, L., Perlaviciute, G., van der Werff, E., Lurvink, J., 2014. The significance of hedonic values for environmentally relevant attitudes, preferences, and actions. Environ. Behav. 46, 163–192. https://doi.org/10.1177/0013916512454730.

Sun, L., Chen, J., Li, Q., Huang, D., 2020. Dramatic uneven urbanization of large cities throughout the world in recent decades. Nat. Commun. 11, 5366. https://doi.org/10.1038/s41467-020-19158-1.

Ulrich, L., Reymond, P., Chandragiri, R., Lüthi, C., 2021. Governance of Small-Scale Sanitation in India–Institutional Analysis and Policy Recommendations. 4S Project Report. vol. II.

Unnikrishnan, H., Sen, S., Nagendra, H., 2017. Traditional water bodies and urban resilience: a historical perspective from Bengaluru, India. Water Hist. 9, 453–477. https://doi.org/10.1007/s12685-017-0199-9.

Voulvoulis, N., 2018. Water reuse from a circular economy perspective and potential risks from an unregulated approach. Curr. Opin. Environ. Sci. Health 2, 32–45. https://doi.org/10.1016/j.coesh.2018.01.005.

Watson, R., Fane, S., Mitchell, C.A., 2016. The critical role of impact distribution for local recycled water systems. Int. J. Water Gov. 12, 5–21. https://doi.org/10.7564/15-IJWG109.

Wood, M., 2004. Statistical inference using bootstrap confidence intervals. Significance 1, 180–182.