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Acceptance of new sanitation: The role of end-users' pro-environmental personal norms and risk and benefit perceptions

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ABSTRACT

Current sanitation systems are inherently limited in their ability to address the new challenges for (waste)water management that arise from the rising demand to restore resource cycles. These challenges include removal of micropollutants, water (re)use, and nutrient recovery. New opportunities to address these challenges arise from *new sanitation*, a system innovation that combines elements of source separation, local treatment and reuse, and less use of water. New sanitation is applied, but not yet widespread, in several residential areas in Europe. Implementation is hindered by the lack of insight into the general public's willingness to engage in new sanitation, and the resulting uncertainty about this among decision makers and other stakeholders in wastewater management. Using value-belief-norm theory as a conceptual lens, this paper addresses the individual motivations (pro-environmental personal norms) and personal drivers (benefits) and barriers (risks) for acceptance of new sanitation by the Dutch general public. The results of an online survey (N = 338) indicated that both pro-environmental personal norms and risk and benefit perceptions predict consumers' willingness to accept new sanitation. More specifically, they showed that consumer acceptance is driven by perceived risks relating to the housing market and the need to change behavior, but also by environmental benefits. Overall, new sanitation was favorably evaluated by respondents: 64% indicated that they would likely use new sanitation if they were owner-occupiers. The results of this explorative study are discussed in light of the development of novel sanitation systems that are sensitive to perceptions of end-users and other key stakeholders.

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1. Introduction

State-of-the-art sanitation systems are very effective in preventing human infection from pathogens present in feces and in processing sewage to wastewater treatment effluents that have acceptable ecological effects only when discharged to surface water. However, contemporary sanitation systems fuel several issues. First, sewage contains high loads of nitrogen and phosphorus – nutrients that are not only critical for agricultural production, but also rely on finite or geopolitically sensitive resources: ammonia production requires the use of fossil fuels, and phosphorous is mined from the earth's crust in a limited number of countries. Secondly, sewage increasingly contains micropollutants, like pharmaceutical residues and hormones, which represent partially still unknown risks for the environment (Schwindt et al., 2014). Removal of these pollutants in the current sanitation system requires large additional investments and additional energy and chemical costs (Davis, 2008). So, the currently used systems entail devaluation of (human) waste, loss of nutrients, waste of water, and emission of residual pollutant loads to the environment, and it is therefore increasingly questioned whether they are future-proof (Larsen et al., 2016).

To address these issues, *new sanitation* was developed in the Netherlands and elsewhere (Hernández-Leal et al., 2017; Londong, 2013). The new sanitation design aims at maximum recovery of energy and resources from (domestic) wastewater and at minimizing potable water use and emissions (like pharmaceutical residues) into the surface water (Tuantet et al., 2014), using a systems approach rather than the end-of-pipe approach. In new sanitation, wastewater collection and treatment take place at local level, keeping individual source flows like grey and black water separate, thereby offering new options for minimizing resource use and restoring resource cycles. For one thing, water use is minimized –

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for instance by using vacuum toilets. Also, the minimal amount of water yields a more concentrated wastewater flow from which it is more cost-effective to remove harmful micropollutants such as pharmaceuticals and hormones (De Wilt et al., 2016), and it becomes more feasible to recover valuable components (De Graaff et al., 2011) like nutrients. Thus, implementing new sanitation offers more opportunities for restoring the nutrient cycle. Finally, energy can be saved with source separation and decentralization in two ways (Rittmann, 2013): directly, by producing renewable energy in useful forms (heat, methane) and indirectly, for example by lowering energy use for treatment and transport.

Despite its potential, new sanitation is not yet widely used. This can partly be attributed to the currently used sanitation system – sewers and centralized treatment plans – which results from decades of development and investments. Switching to a new, decentralized system would mean abandoning these investments; and applying new decentralized infrastructure requires new investments, resulting in a lock-in (Cordell et al., 2011). Moreover, sanitation is a systemic phenomenon, embedded in a highly complex network of diverse stakeholders. Thus, a multitude of stakeholders along the sanitation chain need to accept changes and adapt their behavior and practices in order to foster successful adoption of new sanitation; this is a complex challenge. Important stakeholders in the Netherlands include the end-users (general public), property developers, (local) governments, water boards, and users of the recovered resources (e.g. agriculture and industry). One of the current bottlenecks for the development of new sanitation is the uncertainty among property developers (and other stakeholders) about end-users' acceptance of new sanitation (Swart and Palsma, 2013). However, whether the general public would accept new sanitation and its consequences for housing and daily practices, like using vacuum toilets, is currently largely unknown. One recent study looked into university residents' willingness to pay and general support for urine source separation at a US campus (Ishii and Boyer, 2016), but it is important to extend those analyses to other types of sanitation systems among different publics, such as people who live in houses on a more permanent basis. Therefore, this study focuses on the general public's perception of new sanitation, and especially homeowners and potential homeowners. Several pilots, demonstrations, and full-scale implementations in the field of new sanitation have been undertaken in the Netherlands and elsewhere (Augustin et al., 2014; Hernández-Leal et al., 2017; Londong, 2013). For some of these projects, actual users' perceptions were studied (Lienert and Larsen, 2010; Naus and Van Vliet, 2012). In these projects, users were mostly positive about the use of new sanitation (Naus and Van Vliet, 2012). However, these studies did not look into the perceptions of the *general* public and whether they would be willing to commit themselves, as homeowners, to the pro-environmental behavior of becoming a first-time new sanitation user. In our study, Stern's (2000) value-belief-norm (VBN) theory and people's risk and benefit perceptions are used to explore the Dutch general public's intention to accept new sanitation. The results of this study are discussed in relation to existing literature to ascertain implications for practice and future research.

1.1. Value-belief-norm theory

Value-belief-norm theory (Stern et al., 1999; Stern, 2000) proposes a causal chain of factors that lead from personal values to pro-environmental behavior (Fig. 1). As its name suggests, these factors are people's *values*, *beliefs*, and *norms*, and each of these is elaborated below. To begin with, individuals hold different value orientations in life and each of these may have smaller or bigger weights for how they serve as stable guiding principles in their life (Schwartz, 1992). Three values are included in VBN theory (Stern et al., 1999; Stern, 2000). First, (1) *biospheric values* reflect people's belief that it is worth protecting nature because of its intrinsic value. Second, (2) *altruistic values* deal with the welfare of others, for example people that are close to a person. Finally, (3) *egoistic values* are geared toward one's own welfare and tend to be negatively related to so-called green consumer behavior, whereas both altruistic and biospheric values have positive associations (De Groot and Steg, 2008; Nordlund and Garvill, 2002). According to VBN theory, the three values predict the next variable in the causal chain, beliefs.

Three kinds of beliefs are included in VBN theory: (1) *the new ecological paradigm*: people's ecological worldview, representing their belief regarding the extent to which they think they can change or affect nature (Dunlap and Van Liere, 1978), (2) the *awareness of adverse consequences* for valued things: people's awareness of threats to the environment (Han, 2015), and (3) *ascription of responsibility*: people's belief that their own actions could counter those threats.

Finally, ascribed responsibility has a direct effect on pro-environmental *personal norms*. These personal norms determine one's moral obligation to act in order to prevent negative impacts on the environment. Therefore, pro-environmental personal norms are the last part of the VBN causal chain that predicts people's behavior (Stern et al., 1999).

1.2. Risk and benefit perceptions

According to literature reviews, VBN theory explains 19%–35% of the variance in actual behavior (Stern et al., 1999; Kaiser et al., 2005); this suggest that other factors are also important in predicting people's ecological behaviors. The current study aims to explore people's willingness to accept new sanitation, which for most people is a novel technology. When it comes to acceptance of new technology, perceptions of risk and benefit are generally important, if not crucial (e.g., Hurlimann, 2007; Otway and Von Winterfeldt, 1982; Van Dijk et al., 2017). Hence, it is likely that the general public's evaluation of risks and benefits relating to new sanitation will be important predictors of their acceptance of this technology. Hurlimann (2007) gives examples of situations in which risk perception stood in the way of public acceptance of new technologies in specific countries, like nuclear technologies and genetically modified food. Low public acceptance of a new technology often has negative consequences for its commercialization. Gupta et al. (2012) suggest that this explains why research on societal acceptance of technology has been increasingly focused on risk and benefit perceptions.

The general public's risk perceptions are typically based on factual information, but also importantly on feelings, ethics, preferences, and attitudes (Daughton, 2004), and can be ambiguous (Gregory et al., 1995). Perhaps not always fact-based, decision making concerning technologies is influenced by risk perceptions; and these perceptions are based on a frame of reference and (sometimes incomplete) knowledge about the risk (Weisenfeld and Ott, 2011). Perceived risks and benefits of a technology are not fixed concepts; rather, they are constantly subject to change and mediated by the current cultural understandings of acceptable risks: a new technology may be perceived as risky, but, when it is embedded in routine behavior, the perception of it can change to not risky (Flynn et al., 2006). Furthermore, perceived risks and benefits also influence each other; the level of perceived benefits influences the acceptability levels of the perceived risks (Fischhoff et al., 2000).

Quezada et al. (2016) studied the adoption of decentralized water systems in Australia, which can be considered a form of new

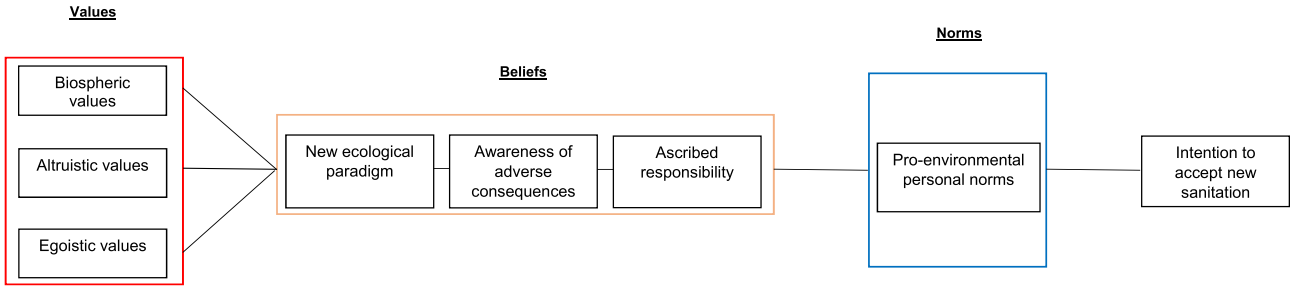

Fig. 1. Value-belief-norm model to predict intention to accept new sanitation.

sanitation. They interviewed different stakeholders (government officials, property developers, planning authorities, consultants, and technology providers) and identified several drivers (benefits) and barriers (risks). Reducing costs, creating a green marketing position and enhancing a sustainable image (and thus attracting more buyers), water security, and environmental impact were identified as drivers. Furthermore, a driver that was fueled by necessity was identified: an increasing bulk water price. Quezada and colleagues also identified barriers (or risks) to the development of decentralized wastewater systems: first, a perceived technology risk, which consisted of financial and reliability risks; secondly, concerns about public health and water quality; thirdly, concerns about the governance, regulation, and legislation of the decentralized systems. Inspired by these findings, we confronted people with potential benefits and risks relating to new sanitation to find out whether these are important in predicting the acceptance of the technology.

2. Methods

2.1. Sample

In order to answer our research questions, an online self-administered survey was conducted in January 2017 and distributed via various social media such as public social media pages (LinkedIn, Facebook, Yammer: 96.4%) and the second author's personal network (1.7%). Targeted social media channels were diversified to prevent bias towards the author's personal networks. The survey was aimed at the Dutch general public aged 18 years and older. In order to increase response, three vouchers from a well-known Dutch online store, worth €10, were raffled among participants. In total, 338 completed questionnaires were collected.

2.2. Procedure

The survey consisted of several factors discussed in the theoretical section. The questionnaire started off by asking questions about the participants' value orientations, the new environmental paradigm, awareness of adverse consequences, ascription of responsibility, and pro-environmental personal norms (see supporting information for the survey items).

Then, a brief description of new sanitation was presented. This description (244 words in total, in Dutch) included an explanation of the concept vis-à-vis conventional sanitation systems. Furthermore, possible gains of new sanitation were discussed – the example of phosphorus recovery from human urine was given – and some practical consequences for end-users were mentioned (e.g. use of vacuum toilet, kitchen grinder, higher initial costs).

After the description, participants answered questions about perceived risks, perceived benefits, and intention to accept new sanitation. Finally, demographic characteristics were assessed. Unless otherwise stated, the questionnaire items were measured on 7-point Likert scales (Matell and Jacoby, 1971), a question format in which participants were asked to react to statements by indicating their level of agreement (1 = 'completely disagree', 7 = 'completely agree').

2.3. Measures

Value orientations were measured using Steg and colleagues' items (Steg et al., 2005), and respondents were asked to indicate the importance they attached to a list of value objects. Each value orientation was represented by four items. We checked the internal reliability of the set of items representing a variable, and these items were collapsed into a single index after verifying that the Cronbach alpha values (Cronbach, 1951) were found to be 0.6 or higher. A sample item on the *biospheric value* scale is 'preventing pollution' (1 = very unimportant, 7 = very important; Cronbach's $\alpha = 0.72$), for the *altruistic value* subscale 'social justice' (Cronbach's $\alpha = 0.78$), and for the *egoistic value* subscale 'wealth' (Cronbach's $\alpha = 0.72$).

New environmental paradigm was measured with a 14-item scale based on the Revised NEP scale (Dunlap et al., 2000). A sample item is 'humans are meant to rule over the rest of nature' (Cronbach's $\alpha = 0.79$).

Awareness of adverse consequences was measured using three statements based on previous VBN research (De Groot and Steg, 2008; Ryan and Spash, 2012) and adjusted for the present context so that they were directly relevant for new sanitation. An example of an item is 'without proper precautions, we will face the threat of insufficient clean (drinking) water in the future' (Cronbach's $\alpha = 0.65$).

Ascription of responsibility was assessed using six items based on Steg et al. (2005) and De Groot and Steg (2008). An example of a statement is 'I can do something to reduce water pollution' (Cronbach's $\alpha = 0.73$).

Pro-environmental personal norms were assessed using six items based on De Groot and Steg (2007) and Steg et al. (2005). A sample item is 'I feel obliged to live as environmentally friendly as possible' (Cronbach's $\alpha = 0.85$).

Perceived risks regarding new sanitation were assessed with 16 items, developed for the purpose of this study, reflecting potential risks: health risks, technical risks, risks for daily use in the household, risks for the housing market, and environmental risks. Participants were asked to grade each of these items from 1 (very low risk) to 7 (very high risk; Cronbach's $\alpha = 0.92$). Only the responses of house proprietors and participants who expected to be a homeowner within three years were included ($N = 241$). We followed that procedure in order to ensure that questions around financial risks on the housing market would be relevant to the participants.

Perceived benefits regarding new sanitation were assessed with

17 items reflecting benefits for daily use in the household, the environment, the housing market, safety benefits, and cost benefits. The participants rated each item on a 7-point Likert scale ranging from 1 (no benefit) to 7 (very high benefit; Cronbach's $\alpha = 0.92$). The number of responses ($N = 241$) collected to measure perceived benefits was the same as the number for risk perception, and for the same reason: we were careful to ensure that items on perceived benefits regarding sales value and attractiveness to the housing market were relevant to the participants.

Intention to accept new sanitation was measured with four items that reflect Stern's typology of four different pro-environmental behaviors in VBN theory (Stern, 2000). To gage reaction to these items, respondents were instructed to assume that new sanitation would be available in the Netherlands. A sample item is 'I would use new sanitation in my own house' (Cronbach's $\alpha = 0.78$).

2.4. Analyses

2.4.1. VBN model

To test whether VBN theory can be used to predict acceptance of new sanitation, the VBN causal chain was tested using a series of regression analyses (Hoeksma et al., 2017; Steg et al., 2005). Following the causal chain of factors that lead from personal values to pro-environmental behavior (see Fig. 1), each variable was regressed onto its preceding variable in five phases (see Table 1). Within each phase, step 1 and step 2 were tested. First, the variable that directly influenced the dependent variable was entered in the regression analysis and formed step 1, and then the remaining variables from the chain were entered in the regression analysis and formed step 2. For example, the first phase tested the relationship between pro-environmental personal norms and intention (step 1), and then a second regression analysis was conducted that included pro-environmental personal norms plus the more distal predicting variables of the VBN model to predict intentions (step 2). This procedure was repeated in each separate phase, all the way back to the start of the VBN causal chain (see Table 1 for the five phases of regression analyses). Previous research suggests a higher chance on a type I error when multiple regressions are used, and therefore the Bonferroni correction was applied. The significance level used for the analyses was $p < .006$ (0.05 divided by the nine analyses).

2.4.2. Mediation

Following the VBN model, it is assumed that (1) a pro-environmental personal norm mediates the relationship between ascribed responsibility and intention to use new sanitation, (2) ascribed responsibility mediates the relationship between awareness of adverse consequences and pro-environmental personal norms, (3) awareness of adverse consequences mediates the role between the new ecological paradigm and ascribed responsibility, and (4) the new ecological paradigm mediates the role between the three values (biospheric, altruistic, and egoistic) and awareness of adverse consequences. Mediation is indicated when a relationship between an independent variable and a dependent variable runs via a mediating variable – see Fig. 1 for the causal chain of factors that lead from personal values to pro-environmental behavior. This means that the independent variable influences a mediating variable (the mediator), which in turn influences the dependent variable (Baron and Kenny, 1986). Therefore, the mediator provides insight into the underlying process of the relation between the independent and the dependent variable. Following Hoeksma et al. (2017), to formally test for mediation, a bootstrap analysis (Preacher and Hayes, 2004) was employed to test the reduction in the direct effect. This approach involves computing 95% confidence intervals (CIs; 5000 bootstrap resamples) around indirect effects; mediation is indicated by CIs that do not contain zero.

2.4.3. Risk and benefit perceptions

An additional regression analysis was performed in order to test whether an extended VBN model that included risk and benefit perceptions would better predict acceptance of new sanitation. Then, in order to gain more insight into specific types of risk and benefit perceptions, factor analyses were performed to generate clusters of risks and benefits. Finally, the clusters thus obtained were used in a regression analysis to explore which specific risks and benefits were most predictive of acceptance of new sanitation.

3. Results

3.1. Sample

Most respondents were female (63%). The participants' average age was 41.2 years ($SD = 14.6$ years) and ranged from 19 to 82 years. The most reported level of completed education was higher vocational education (38%) and university education (29%: bachelor, master, or PhD). The sample was representative to the general Dutch population in terms of average age and completed level of education. At the time of the survey, 63% of the participants were living in owner-occupied accommodation; 35% were renting their accommodation.

3.2. VBN model

Means, standard deviations, and correlations of the eight variables in the VBN model are reported in Table 2. On the question of whether they would use new sanitation in their home if available, 64% of the participants gave a positive answer. To test the causal chain of VBN theory, multiple regression analyses were performed

Table 1
Dependent variables and independent variables of Step 1 and Step 2 per phase of the regression analysis of the value-belief-norm model.

Phase	Dependent variable	Independent variables Step 1	Independent variables Step 2
1	Intention	Pro-environmental personal norm	Pro-environmental personal norm, Ascribed reponsibility, Awareness of adverse consequences, New ecological paradigm, Egoistic values, Altruistic values, Biospheric values
2	Pro-environmental personal norm	Ascribed reponsibility	Ascribed reponsibility, Awareness of adverse consequences, New ecological paradigm, Egoistic values, Altruistic values, Biospheric values
3	Ascribed reponsibility	Awareness of adverse consequences	Awareness of adverse consequences, New ecological paradigm, Egoistic values, Altruistic values, Biospheric values
4	Awareness of adverse consequences	New ecological paradigm	New ecological paradigm, Egoistic values, Altruistic values, Biospheric values
5	New ecological paradigm	Egoistic values Altruistic values Biospheric values	

Table 2
Means, standard deviations, and Pearson correlations among variables of the value-belief-norm model.

		M	SD	1	2	3	4	5	6	7
1	Intention	4.14	1.21							
2	Pro-environmental personal norm	4.83	1.08	.49***						
3	Ascribed responsibility	5.48	0.79	.43***	.66***					
4	Awareness of adverse consequences	5.72	0.87	.29***	.49***	.45***				
5	New ecological paradigm	4.76	0.72	.25***	.52***	.50***	.51***			
6	Biospheric values	5.92	0.85	.37***	.58***	.52***	.14***	.44***		
7	Altruistic values	6.11	0.72	.18***	.33***	.27***	.21***	.24***	.47***	
8	Egoistic values	4.67	0.89	-.16**	-.05	-.07†	-.15**	-.15**	.06	.20***

Note. †p < .10; *p < .05; **p < .01; ***p < .001.

(see Table 3). All models were at a significance level lower than 0.001, and therefore the Bonferroni requirement ($p < .006$) is met for all regression analyses. Below, the results per regression analysis are described.

Pro-environmental personal norms were positively associated with intention to accept new sanitation ($\beta = 0.49$, $p < .001$). Pro-environmental personal norms significantly explained 24% of the variance in intention to accept new sanitation ($p < .001$). When the other variables further up the causal chain of the VBN model were added, 29% of the variance in intention was explained. Pro-environmental personal norms contributed the strongest to this model, with $\beta = 0.34$ ($p < .001$). After pro-environmental personal norms, ascribed responsibility explained most of the variance in intention to accept new sanitation ($\beta = 0.16$, $p < .001$), and egoistic values ($\beta = -0.15$, $p < .01$) and biospheric values ($\beta = 0.13$, $p < .05$) also contributed significantly.

In phase 2, pro-environmental personal norm acted as the dependent and ascribed responsibility as the independent variable. In this model, 43% of the variance in pro-environmental personal norm was explained by ascribed responsibility ($\beta = 0.66$, $p < .001$). When the other variables were added to the model (step 2), ascribed responsibility still contributed the most to the variance in pro-environmental personal norm ($\beta = 0.39$, $p < .001$). Biospheric values ($\beta = 0.24$, $p < .001$), awareness of adverse consequences ($\beta = 0.14$, $p < .01$), and new ecological paradigm ($\beta = 0.14$, $p < .01$) also explained significant amounts of the variance in pro-environmental personal norms. This model explained 55% of the variance in pro-environmental personal norm ($p < .001$).

In the next phase, the dependent variable was ascribed reponsibility. Awareness of adverse consequences explained 20% of the variance in ascribed reponsibility ($p < .001$): the stronger awareness of adverse consequences, the stronger ascribed reponsibility ($\beta = 0.45$, $p < .001$). In step 2 of phase 3, 38% of the variance in ascribed reponsibility was explained ($p < .001$). The three factors, biospheric values ($\beta = 0.33$, $p < .001$), new ecological paradigm ($\beta = 0.25$, $p < .001$), and awareness of adverse consequences ($\beta = 0.18$, $p < .001$), positively predicted ascribed responsibility.

Awareness of adverse consequences was the dependent variable in phase 4. In step 1, the independent variable new ecological paradigm ($\beta = 0.51$, $p < .001$) explained 26% of the variance in awareness of adverse consequences ($p < .001$). In step 2 of phase 4, the independent variables new ecological paradigm ($\beta = 0.38$, $p = .001$), biospheric values ($\beta = 0.24$, $p < .001$), and egoistic values ($\beta = -0.11$, $p < .05$) accounted for 31% of the variance in awareness

Table 3
Results of regression analyses of the value-belief-norm model on intention to use new sanitation.

Phase	Dependent variable	Independent variable	β step 1	β step 2	R^2 step 1	R^2 step 2	ΔR^2
1	Intention	PN	.49***	.34***	.24***	.29***	.05***
		AR		.16*			
		AC		.03			
		NEP		-.11			
		EV		-.15**			
		AV		.01†			
		BV		.13*			
2	Pro-environmental personal norm	AR	.66***	.39***	.43***	.55***	.12***
		AC		.14**			
		NEP		.14**			
		EV		-.01			
		AV		.05			
		BV		.24***			
3	Ascribed reponsibility	AC	.45***	.18***	.20***	.38***	.18***
		NEP		.25***			
		EV		-.04			
		AV		.02			
		BV		.33***			
4	Awareness of adverse consequences	NEP	.51***	.38***	.26***	.31***	.06***
		EV		-.11*			
		AV		.03			
		BV		.24***			
5	New ecological paradigm	EV	-.19***		.23***		
		AV	.08				
		BV	.41***				

Note. PN = Pro-environmental personal norm; AR = Ascribed responsibility; AC = Awareness of adverse consequences; NEP = New ecological paradigm; EV = Egoistic values; AV = Altruistic values; BV = Biospheric values.
†$p < .10$; *$p < .05$; **$p < .01$; ***$p < .001$.

of adverse consequences ($p < .001$).

In phase 5, new ecological paradigm was the dependent variable. The three values were the independent variables: biospheric ($\beta = 0.41$, $p < .001$) and egoistic ($\beta = -0.19$, $p < .001$) were significant predictors; altruistic ($\beta = 0.08$, *ns*) was not. Together, they explained 23% of the variance in the new ecological paradigm variable ($p < .001$).

3.3. Mediation

The results of the bootstrap analyses for indirect effects are presented in Table 4. Fully in line with VBN theory, the predicted mediating roles of pro-environmental personal norms, ascribed reponsibility, awareness of adverse consequences, and new ecological paradigm are supported by the bootstrapped estimates, as the value 0 was not included in the respective 95% confidence intervals.

3.4. Risk and benefit perceptions

Means, standard deviations, and correlations of intention to accept new sanitation, pro-environmental personal norms, and risk and benefit perceptions are reported in Table 5. To test this extended model, a regression analysis was performed that included two steps. In the first step, pro-environmental personal norm was entered, as this is the most proximal predictor of intention to accept new sanitation from the VBN model. The second step included risk and benefit perceptions and allowed for testing whether adding these factors could better explain consumers' intentions to accept new sanitation.

The results of this analysis are reported in Table 6. Step 1 of the regression analysis shows that a pro-environmental personal norm was positively related to intention to accept new sanitation. Risk and benefit perceptions were entered in step 2, and this model shows that pro-environmental personal norms and benefit perceptions were positively associated with intention to accept new sanitation, whereas risk perceptions were negatively associated. Importantly, the increase in explained variance rose considerably (from $R^2 = 0.27$ to $R^2 = 0.46$). The standardized regression coefficients furthermore indicated that perceived benefits was the most important predictor of intention to accept new sanitation ($\beta = 0.36$), followed by pro-environmental personal norms ($\beta = 0.34$) and perceived risks ($\beta s = -0.17$).

Factor analyses indicated that five specific groups of risk perceptions (see Appendix A for details) and five specific groups of benefit perceptions (see Appendix B) could be distinguished. In order to test the relative influence of these risks and benefits, a final analysis was performed in which intention to accept new sanitation was regressed on the categories of risks and benefits (see Table 7).

Table 5
Means, standard deviations, and Pearson correlations among variables of the extended VBN model.

		M	*SD*	1	2	3
1	Intention	4.14	1.22			
2	Pro-environmental personal norm	4.91	1.03	.52***		
3	Perceived risk	3.41	0.96	-.48***	-.37***	
4	Perceived benefit	4.42	0.89	.56***	.31***	-.50***

Note. ***$p < .001$.

Table 6
Results of regression analyses of the extended VBN model on intention to use new sanitation.

Step and variables	1	2
1. Pro-environmental personal norm	.52***	.34***
2. Perceived risk		-.17**
Perceived benefit		.36***
ΔR^2	.27***	.19***
R^2	.27***	.46***

Note. Standardized regression coefficients are reported.
**$p < .01$; ***$p < .001$.

Table 7
Results of regression analyses of risk and benefit perceptions on intention to use new sanitation.

Variables	
Risk health	.02
Risk technology	-.02
Risk household	-.29***
Risk housing market	-.09
Risk environment	.02
Benefit household	.08
Benefit environment	.24***
Benefit housing market	.29***
Benefit safety	-.12†
Benefit costs	.04
R^2	.44***

Note. Standardized regression coefficients are reported.
†$p < .10$; ***$p < .001$.

Three factors were found to contribute significantly to the model: risk for daily use in the household ($\beta = -0.29$, $p < .001$), benefits for the housing market ($\beta = 0.29$, $p < .001$), and environmental benefits ($\beta = 0.24$, $p < .01$). This model explained 44% of the variance in intention to accept new sanitation.

4. General discussion

This research aimed to explore (1) the general public's (risk and

Table 4
Bootstrap analysis of indirect relationships.

Independent variable	Mediator	Dependent variable	Indirect effect	SE	95% confidence interval for indirect effect	
					Lower	Upper
AR	PN	IN	.38***	.07	.25	.51
AC	AR	PN	.30***	.05	.22	.40
NEP	AC	AR	.15***	.04	.07	.22
BV	NEP	AC	.18***	.04	.11	.26
AV	NEP	AC	.14***	.05	.03	.22
EV	NEP	AC	-.07**	.03	-.13	-.03

Note. AR = Ascribed reponsibility; AC = Awareness of adverse consequences; NEP = New ecological paradigm; BV = Biospheric values; AV = Altruistic values; EV = Egoistic values; PN = Pro-environmental personal norm; IN = Intention.
**$p < .01$; ***$p < .001$.

benefit) perceptions of new sanitation and (2) the general public's willingness to accept new sanitation. We did so by using a survey based on VBN theory combined with measures of risk and benefit perceptions for new sanitation. Consequently, this study contributes to the discussions around implementation of new sanitation.

Research on VBN theory applied to other pro-environmental behaviors – e.g. Steg et al. (2005) on acceptability of pro-environmental energy policies and Jakovcevic and Steg (2013) on sustainable transportation – predicted a good fit. The current study confirmed the hypothesized causal chain within VBN theory: each variable was predictive of the variable next in the chain of VBN theory, except for altruistic value orientation, which did not significantly predict any other variable. Thus, an individual who values the environment (high score on biospheric value orientation) scores higher on ecological worldview (high score on new environmental paradigm), is more aware of adverse consequences, feels a higher ascription of responsibility, and ultimately has a higher intention to accept new sanitation. As expected, egoistic value orientation was negatively related to new environmental paradigm, meaning that individuals with a higher score on egoistic value orientation scored lower on environmental concern. This is in line with previous studies (De Groot and Steg, 2007; Hoeksma et al., 2017; Jansson et al., 2011). Altruistic value orientation had no significant relationship with new environmental paradigm; this is consistent with several previous studies (De Groot and Steg, 2007; Lind et al., 2015; Steg et al., 2005). Moreover, in line with previous studies (Hoeksma et al., 2017; Jakovcevic and Steg, 2013), the results showed a mediation effect of all variables for their preceding and subsequent variables.

4.1. Risk and benefit perceptions

The results of the regression analysis on risk and benefit perceptions showed that both risk and benefit perceptions predict acceptability of new sanitation. Surprisingly, the results showed not only that VBN theory and risk and benefit perceptions successfully predict intention to accept new sanitation, but also that, in this case, risk and benefits perceptions improve the VBN model considerably: from 30% explained variance to 50%. Compared with studies that applied VBN theory to other pro-environmental behavior, it stands out that new sanitation is a much more technical and systemic innovation than many other topics involving behavior change, e.g. use of transportation mode (Jakovcevic and Steg, 2013; Lind et al., 2015), acceptance of energy policies (Steg et al., 2005), and donating to foundations (De Groot and Steg, 2008). Consequently, risk and benefit perceptions are crucial in the successful development of technical innovations.

An important result is that benefit perceptions contribute much more (almost three times as much) to intention to accept new sanitation than risk perceptions. This creates a chance to emphasize the opportunities that new sanitation has to offer. For example, it can stimulate property developers to start thinking about new sanitation as a business opportunity by stressing the benefits of new sanitation in their communication, as benefits were found to be the strongest predictor of acceptance. Following up on this finding, factor analyses and additional regression analyses showed that only economic and environmental benefits contributed significantly to benefit perceptions. In contrast, only potentially needed behavioral change was a characteristic that contributed significantly to risk perceptions.

4.2. Implications for practice

The property and land development sector is tangled up in what environmental activist Jonathon Porritt calls a ‘circle of blame’: all stakeholders in the chain are caught up in a path dependency that limits them in stepping away from their traditional role and responsibilities. From this position, they accuse each other for too little growth in sustainable building (Van de Griendt, 2011). Porritt also states that the only way to break through this vicious circle is if at least one of the stakeholders takes the initiative. The present study offers insights into the general public's perceptions regarding the current discussion and can contribute to lowering the barrier to taking such an initiative. In addition, this study provides an overview of critical acceptance issues within new sanitation for decision makers (e.g. municipalities, water boards, and property developers). Decision makers can use this to make better-informed and reasoned choices about new sanitation.

Another rather unexpected perception found in this study concerned the hygiene and public health implications of new sanitation. Regarding sanitation, these are important and delicate issues, especially for decision makers who have to ensure a system's hygiene and secure public health. Despite several studies showing that the treatment of black water is relatively straightforward (De Graaff et al., 2010), Dutch water boards, for example, are hesitant to innovate because the innovation could give rise to perceived concerns on these issues. However, in our study, the general public did not indicate that they were highly concerned, as the results showed that hygiene and public health risks do not influence intentions to accept new sanitation. This finding could speed up innovative developments and guide decision making, as it suggests that insecurity about the public's fear of risk to public health may be important but not particularly problematic. Apparently, the public trust that new sanitation, implemented according to good practices, meets hygiene requirements, as it has in numerous projects already.

So, having ascertained that hygiene and public health do not predict the acceptance of new sanitation, we turn to aspects that do play a role. We found that the need to change behavior is the only perceived risk that influences the intention to accept new sanitation: the higher the perceived risk of behavioral change, the lower the intention to accept new sanitation; this is in line with previous literature (Van Vliet et al., 2010). This information is very relevant for technical developers of new sanitation systems: they can address this perceived risk in their design by minimizing behavioral adjustments, or make the design flexible for gradual adjustment over time. This knowledge adds to our findings on public health and hygiene, and is valuable for decision makers who are in the phase of informing the general public about developments or projects. It can guide them on the risks on which to focus as perceived by end-users and that need to be addressed in information provision. However, in doing so, one must be careful and in constant contact with the target group, as perceptions might change and thus also the acceptance of new sanitation.

We found environmental gain to be a perceived benefit. Regarding communicating environmental gains, Bolderdijk et al. (2013) state that communication about environmental consequences is motivational only for individuals who have a strong biospheric value orientation. Therefore, on the basis of these results, we argue for differentiating between target groups. Target groups can be identified using other behavior that results from high scores on value orientations. For example, high scores on biospheric value orientation result in consuming environmentally consciously or being passionate about nature. In addition, implementing new sanitation should be viewed as a sequential process, requiring different types and modes of information tailored to the different target groups in different stages of the process.

The results of this research can be used to inform stakeholders and decision makers in the wastewater field about the public perception of new sanitation. Specifically, the results can be used to

target a specific group of stakeholders: end-users. First, value orientations were found to have an influence on intention to use new sanitation. As discussed, these value orientation can be used to guide communication towards end-users, in order to increase the use of new sanitation if available, and to increase public acceptance and societal agenda setting in general. Biospheric values lead to a higher acceptance, whereas egoistic values lead to a lower acceptance of new sanitation. One way to stimulate pro-environmental behavior (in this case the acceptance of new sanitation), is by strengthening biospheric values in specific situations (De Groot and Steg, 2009). That can be done by presenting information on why the pro-environmental behavior is relevant (De Groot and Steg, 2009), thus in this case information on the environmental gains of new sanitation. According to De Groot and Steg (2009) campaigns often fail to promote sustainable behavior because they neglect to include biospheric considerations, and only focus on egoistic considerations. If new sanitation is already implemented, goal setting can be a stimulant to foster environmental behavior (Abrahamse et al., 2005). Goal setting is more effective if feedback is provided, and at regular intervals (Abrahamse et al., 2005; Becker, 1978). In the case of new sanitation, this feedback (e.g. the amount of energy and water saved, or amount of nutrients recovered) could be provided with smart meters in the future.

Another relevant outcome for new sanitation's decision makers is the high number of participants who were positive about using new sanitation: 64% of them indicated that they were (somewhat) likely to use new sanitation in their own home. This high percentage of positive responses is consistent with previous research on NoMix toilets, a form of new sanitation. In a study on actual NoMix toilet users' perceptions (N = 480), 72% found the idea of NoMix toilets convincing, and 86% were willing to move to an apartment with NoMix toilets (Lienert and Larsen, 2006).

4.3. Future steps

Several avenues for further research deserve discussion. To start with, in the realm of wastewater management – including new sanitation – there are many more stakeholders involved, including property developers, (inter)national and regional governments, water boards, water companies, contractors, investors, and actors in the agricultural sector. All these stakeholders fulfill a role in the development of existing and new sanitation; consequently, each of them could form a bottleneck for progress. That being said, the decision was made to focus this research on the perceptions of end-users. However, the relations with and between the other stakeholders also merit further investigation. For example, it could be explored whether property developers perceive policy and extensive regulations to be barriers to implementing new sanitation systems, and consequently it would be interesting to look into the tensions between property developers and governmental bodies.

Furthermore, the current study proposed an extended VBN model, including risk and benefit perceptions, for technical pro-environmental innovations. This proposed model was developed based on results in the current study, but not tested more widely. Future studies could investigate the applicability of this extended model to other technical pro-environmental innovations, i.e. other circular innovations within the household.

Finally, although 64% of the participants indicated that they were willing to use new sanitation in their home, the cost aspect of new sanitation is indicated as an important factor in recent studies (Eggimann et al., 2016; Schoen et al., 2017). Therefore, it would be interesting to quantify what the general public is willing to pay for new sanitation, and under what circumstances (cf. Ishii and Boyer, 2016). In addition, it would be interesting to look at the general public's actual adoption of new sanitation in real estate projects and underlying motivations for choosing new sanitation – or not. In that regard, it should be mentioned that a potential caveat lies in the currently used method of convenience sampling. Therefore, another avenue for research would be to replicate this study with a stratified sample of the general public.

5. Conclusion

The Dutch general public's perception of new sanitation can be best explained by the proposed extended VBN model, including risk and benefit perceptions. The majority of participants had a positive perception of new sanitation: 64% indicated they would (likely) use new sanitation in their own home.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.watres.2017.12.032.

Appendix A. Factor loadings of the risk perception items on five different factors. Only values > .40 are displayed, item loadings in bold indicate grouping in factors. Eigenvalues, explained variance and reliabilities (Cronbach's alpha) of the identified factors are displayed in the lower rows.

Item	Factor 1: risk health	Factor 2: risk technology	Factor 3: risk household	Factor 4: risk housing market	Factor 5: risk environment
My own health	**.836**				
Safety of wastewater treatment regarding public health	**.784**				
Hygiene (during the use of the vacuum toilet and the kitchen grinder)	**.773**				
Safety of wastewater treatment regarding environmental pollution	.687				**.490**
Water quality of the water I use	**.672**				
Bad hygiene due to wrong application or use		**.788**			
Missing knowledge on the system (own knowledge/other people's knowledge)		**.785**			
Technical defects		**.632**	.546		
Costs of discharge and treatment of wastewater		**.519**			
Time loss during cleaning		.517	**.408**		
Comfort			**.819**		

(continued on next page)

(*continued*)

Item	Factor 1: risk health	Factor 2: risk technology	Factor 3: risk household	Factor 4: risk housing market	Factor 5: risk environment
Adjusting my (toilet and kitchen) habits			**.769**		
Attractiveness of your house to the housing market				**.885**	
The value of your house to the housing market				**.867**	
Reuse of resources from wastewater (e.g. in agriculture)					**.660**
Environmental pollution due to wrong application or use		.543			**.656**
Eigenvalues	7.50	1.60	1.12	0.95	0.88
Percentage of variance	46.89	10.03	7.01	5.95	5.52
Cronbach's alpha	.86	.82	.77	.91	.69

Appendix B. Factor loadings of the benefit perception items on five different factors. Only values > .40 are displayed, item loadings in bold indicate grouping in factors. Eigenvalues, explained variance and reliabilities (Cronbach's alpha) of the identified factors are displayed in the lower rows.

Item	Factor 1: benefit household	Factor 2: benefit environment	Factor 3: benefit housing market	Factor 4: Benefit safety	Factor 5: benefit costs
Adjusting my (toilet and kitchen) habits	**.844**				
Time saving during cleaning	**.838**				
Hygiene (during the use of the vacuum toilet and the kitchen grinder)	**.807**				
Comfort	**.803**				
My own health	**.666**				
Water quality of the water I use	**.540**			.515	
Decrease depletion of natural resources		**.871**			
Decrease environmental pollution		**.862**			
Living environmentally friendly		**.834**			
Reuse of resources from wastewater (e.g. in agriculture)		**.770**			
Increased biodiversity	.403	**.661**			
Attractiveness of your house to the housing market			**.859**		
The value of your house to the housing market			**.826**		
Contribution to innovation		.428	**.561**		
Safety of wastewater treatment regarding environmental pollution				**.823**	
Safety of wastewater treatment regarding public health				**.818**	
Costs of discharge and treatment of wastewater	.485				**.716**
Eigenvalues	7.78	2.38	1.20	1.04	0.74
Percentage of variance	45.77	14.02	7.07	6.14	4.37
Cronbach's alpha	.89	.89	.85	.77	–

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