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The impact of information provision on public willingness to use recycled water for flushing from the perspective of risk perception

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To solve the current urban water shortage, increasing the willingness of urban residents to use recycled water for flushing is one proposed approach. This study developed a risk perception measurement model of recycled water for toilet flushing to explore which risk triggered people's risk perception of recycled water, and then analyzed the interaction among information provision, trust, risk perception, and willingness to use recycled water. The main results were as follows. First, the risk perception of recycled water for flushing mainly come from four types of risks, which were performance risk, health risk, service risk and financial risk in order of importance. Second, reducing the perceived risk can improve public willingness to use recycled water for flushing, and greater trust in the water authorities and recycled water enterprises reduces the public's perception of the risk of recycled water. A higher level of initial trust is related to higher willingness to use recycled water. Third, information provision can enhance the risk perception of recycled water and enhance trust in the water authorities and recycled water enterprises, but information provision does not directly affect the willingness to use recycled water. This indicates that reducing performance risk and health risk of recycled water, will be the key to controlling the overall risk perception of recycled water and promoting willingness to use. Effective risk communication strategies combine information provision and trust in information providers, which together affect risk perception and thus the willingness to use recycled water.

KEYWORDS

recycled water, risk perception, willingness to use, trust, information provision

1 Introduction

With the intensification of urbanization and the rapid growth of urban population, the demand of water resources in urban area has also increased rapidly, and the water shortage problem has become more and more serious (Wu et al., 2018). As a stable alternative water source, the use of recycled water in cities can not only protect natural water sources, reduce environmental pollution, but also promote sustainable development (Garcia and Pargament, 2015; Fielding et al., 2019). At present, the biggest obstacle to promoting the use of recycled water was not the technical problem, but the psychological acceptance of urban residents (Wester et al., 2016). Many studies have also confirmed that residents' low acceptance of recycled water projects is the biggest obstacle to the use and promotion of

recycled water. Previous studies on the publica acceptance of recycled water have shown that the higher the individuals' risk perception, the lower their acceptance of potable and non-potable recycled water (Gibson and Burton, 2014; Ross et al., 2014; Hurlimann and Dolnicar, 2016).When the perceived risk is low and the level of trust and understanding is high, the acceptance of recycled water increases (Hurlimann et al., 2008; Dolnicar et al., 2011). To improve the willingness of urban residents to use recycled water for toilet flushing, this study measured people's risk perception of recycled water and explored how risk communication strategies composed of information provision and trust in information providers affect the willingness to use recycled water from the perspective of risk perception.

1.1 Risk dimensions

Risk perception refers to the subjective evaluation of the probability and results of negative events such as natural disasters or environmental threats (Slovic, 1987). Risk perception research attempted to explain, predict and influence people's cognition and attitude towards new technologies and related risks (Kasperson et al., 1988). For many technologies, such as mobile communication technology (Siegrist et al., 2005), nuclear technology (Whitfield et al., 2009), nanotechnology (Siegrist et al., 2007), and so on, the risk perception that affects public behavior has been further studied, and has been gradually applied to the field of recycled water use behavior. In recent years, the model of risk perception has been transformed from a two-dimensional structure of uncertainty and negative consequences to a multi-dimensional structure including financial, functional, physical, psychological, social and temporal risks (Bazerman and Moore, 2008).

Risk perception is an important basis for people to make behavioral decision. There is no doubt that the use of recycled water can be regarded as a purposeful behavior, the expected result of the decision to use recycled water is that the water demand is met, if the negative consequences are experienced in the process of use, the expected satisfaction may not be achieved, which is the risk of using recycled water. Some people refused to use recycled water because they doubted its safety, and most people would accept recycled water if its safety performance is guaranteed (Dolnicar et al., 2011). In some studies, stakeholders such as water supply companies, researchers, regulators and ordinary community residents have mentioned a series of risks of recycled water, including the management of recycled water projects, technical reliability, public health and public support (Baggett et al., 2006). Some studies expressed respondents' concerns about the risks posed by technology or system failures and assess possible failures (Dolnicar et al., 2014). Some respondents also expressed concern about the risks caused by human error (Miller and Buys, 2008). Considering that recycled water is produced from sewage as a raw material, it is not surprising that health risks are a major concern for users (Buyukkamaci and Alkan, 2013; Baghapour et al., 2017). Therefore, the previous research of risk perception of recycled water mainly focused on the potential negative consequences of risks.

In the concept of risk, researchers believed that people can take into account a variety of possible consequences of their behavior, but rarely can they consider the consequences with a high degree of certainty (Bauer, 1960). In other words, due to the limitation of cognitive ability, in most cases, participants can only predict a part of the potential consequences and do not know the set of all consequences, which means that it is difficult for participants to assign probabilities to the negative consequences under consideration (Simon, 1976). The literature on risk shows that in the overall risk construction, many different types or dimensions of consequences, although they expressed limited risks, still have an impact on the overall risk (Solomon, 2008). Some researchers have divided five risk dimensions in the overall risk structure, namely, financial risk, performance risk, physical risk, psychological risk and social risk. In the study, respondents were asked to evaluate the risk perception of 12 different products, and it was found that these five dimensions could explain 61.5% of the overall risk perception (Jacoby and Kaplan, 1972). There were also studies on time-effective services that point out that time risk is an important risk dimension (Roselius, 1971). A study has verified that financial risk, performance risk, physical risk, psychological risk, social risk and time risk will explain a large part of the overall risk, in which various risk dimensions affect the overall risk through the intermediary of psychological risk (Stone and Gronhaug, 1993). In view of risk perception was used in different fields, researchers have proposed various specific risk types, such as service risk, privacy risk, opportunity cost risk, and so on (Weinberger et al., 1984). Studies have found that people are more concerned about the functional risks of electronic products than the health risks, or even do not care about the health risks at all (Jacoby and Kaplan, 1972). For online shopping behavior, people attach great importance to privacy risks (Pavlou and Gefen, 2004).

1.2 Risk perception and trust

The higher the risk of recycled water perceived by the public, the lower their willingness to accept recycled water use (Baggett et al., 2006; Ross et al., 2014). Risk perception is a key predictor of the use and promotion of recycled water, which is consistent with previous research in the field of risk perception—that is, there is a clear correlation between risk perception and behavioral intention (Siegrist et al., 2007; Mankad and Tapsuwan, 2011). Risk communication is an important factor that can affect people's perception of risk. In previous studies on risk communication, researchers have generally found that trust in governmental risk management departments is a key factor in perceiving and accepting risks (Lofstedt, 2005; Earle et al., 2012). Trust is a multi-dimensional and complex structure. Here, we adopted a specific description of trust extracted from existing studies: trust is a psychological state, based on positive expectations about the intentions and behaviors of the authorities and enterprises responsible for recycled water programs, which leads to willingness to tolerate the weaknesses of recycled water (Lewicki et al., 2006; Siegrist et al., 2010). An individual's risk perception usually comes from indirect experience, and an individual needs to use his or her relevant professional knowledge to judge whether a certain thing or phenomenon will bring risks. Researchers believe that many people lack the

knowledge, time, and interest to make scientific and technical decisions, so they rely on their trust in authorities or professional bodies to make decisions (Siegrist, 2000).

Looking more specifically at the relationship between trust and risk perception, some studies have suggested that trust is another form of risk perception, as both involve an individual's cognition of possible outcomes. Some studies have also suggested that risk perception plays an intermediary role between trust and behavioral intention and that trust can influence behavioral intention through risk perception. In the context of urban water supply management, some research has suggested that, for water supply plans to succeed, community residents need to trust the relevant government departments to provide them with safe water (Hurlimann and McKay, 2004). Empirical studies in the context of new technologies have been conducted to explore the relationship between trust, risk, and acceptance, and the results showed that trust is related to public acceptance of new technologies (Hurlimann et al., 2008; Nancarrow et al., 2009). Qualitative studies have shown that trust or distrust in science and authority determines whether new technologies are accepted (Miller et al., 2008). In a survey on the acceptance of recycled water, more than half of recycled water users indicated that they felt they could trust suppliers to guarantee the quality of recycled water (Dolnicar et al., 2014). One explanation for this is that the relationship between trust and willingness to use recycled water is regulated by risk perception, and greater trust is associated with lower perceived risk, which in turn is associated with higher willingness to use recycled water (Nancarrow et al., 2008; Ross et al., 2014).

1.3 Information provision and risk communication

Recent studies have explored the impact of different risk communication strategies on risk perception and behavioral intention through questionnaires and found that risk communication can motivate individuals to take measures to reduce risk (Botzen et al., 2013; Haer et al., 2016). Traditional methods of risk communication are often carried out by governments and organizations, which disseminate information in a top-down manner through guidelines, brochures, the media, and the Internet; individuals can choose whether or not to receive this information (Fekete, 2012). Some studies have suggested the adoption of people-oriented risk communication strategies, which can provide customized information about risks and countermeasures based on the needs of individuals or communities. With access to such information, people can assess their own risk situation and take appropriate action (IPCC, 2012; Kellens et al., 2013). Information tailored to meet the specific requirements of individuals has a significant impact on risk perception (de Boer et al., 2014), and this kind of risk communication is critical in reducing people's risk losses. It is also more effective than traditional communication strategies such as only publicizing specific risks.

Studies have explored the effectiveness of providing information specifically on health risks. Testing the mechanisms by which no information or different types of information about recycled water production processes, safety, and so on affect the willingness to use recycled water has revealed that information increases residents' comfort with potable recycled water and increases their acceptance of drinking recycled water compared to those who have not received such information. Those who received the information expressed more positive feelings about drinking recycled water, as well as fewer negative feelings, lower risk perception, and more support compared to those who had not received such information (Fielding and Roiko, 2014). However, if people know more about an issue or topic, they tend have a more positive attitude toward it and accept it more easily (Miller, 2004). Once a recycled water project is in place and running for a long time, the information that recycled water is part of the water supply system may be forgotten. A previous study found that most local respondents were happy with their drinking water, but only a minority knew it came from recycled water projects (Gibson and Burton, 2014).

1.4 The present research

The previous studies on risk perception of recycled water were often limited to a specific risk perceived, ignored the comprehensive investigation of the risk perception of recycled water, especially lacked systematic induction of various risk factors causing the risk perception of recycled water, thus it was impossible to know which types of risks have an impact on the overall risk perception of recycled water. Studies on risk perception mostly focused on the impact mechanism of individual cognition or attitude and external environmental factors on risk perception (Baggett et al., 2006; Ross et al., 2014), but lacked the measurement of various dimensions (types) of risks that trigger the risk perception of recycled water, and the ranking of the importance of various types of risks perceived. Therefore, in order to better evaluate the risk perception of recycled water, this study will classify and evaluate various types of risks that brought the overall risk perception of recycled water based on previous studies on risk dimensions and risk perception of recycled water, and further explore the impact of different types of risks perceived on the overall risk perception.

Existing studies have confirmed the positive impact of information provision on the willingness to use recycled water, but how information provision affects the willingness to use recycled water—whether information provision directly affects people's willingness to use recycled water and then promotes behavior, or whether it indirectly affects people's willingness through other variables—remains an open question. In this study, we attempt to answer this question to clarify the relationship between information provision and willingness to use recycled water. There is currently a lack of research on the impact of risk communication on risk perception and use behavior related to recycled water use behavior, particularly in terms of how people-oriented risk communication strategies that combine information provision and trust in information providers can change perceived risk. Previous studies have focused on the impact of information provision on willingness to use recycled water or the impact of trust and risk perception on willingness to use recycled water, but these studies are isolated and lack empirical analysis that puts information provision, trust, risk perception, and willingness to use recycled water in the same framework. Research in the field of risk communication has shown that people-oriented information

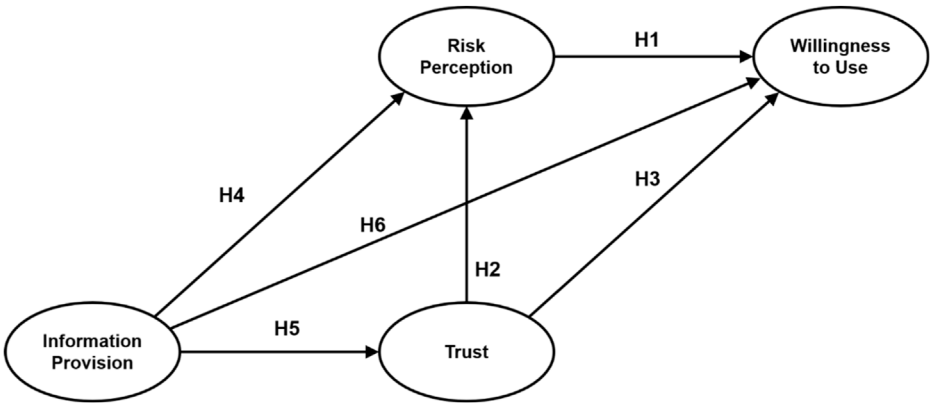

FIGURE 1
Mechanism model of the effects of risk perception, trust, and information provision on public willingness to use recycled water. H1-H6 used in the figure indicate the relationship among variables expressed in the hypothesis.

tailored to individuals or groups can help people better assess their own risk situation and then make appropriate behavioral decisions. People's trust in information providers is also an important prerequisite for perceiving and accepting risks (de Boer et al., 2014). This study therefore suggests that appropriate information provision and basic trust in providers, together, constitute an effective risk communication strategy and influence risk perception and willingness to use.

To explore how trust, information provision, risk perception, and willingness to use recycled water interact, this study established a mechanism model of willingness to use recycled water based on previous studies and theories, as shown in Figure 1, and put forward the following hypotheses:

H1: Reducing people's perception of the risk of recycled water can improve their willingness to use recycled water.

H2: Increasing people's trust in water authorities and recycled water enterprises reduces their risk perception of recycled water.

H3: More trust is associated with higher levels of willingness to use recycled water.

H4: Providing information can directly reduce people's perception of the risk of recycled water.

H5: Providing information can increase people's trust in water authorities and recycled water enterprises.

H6: Providing information can directly increase people's willingness to use recycled water.

2 Methodology

2.1 Data collection

This study sought to assess the urban residents' risk perception of recycled water for toilet flushing and analyze how information provision, trust, and risk perception affect the willingness to use recycled water and how these factors relate to each other. Data were collected through a questionnaire survey in Xi'an, Shaanxi Province, which is an inland city with low rainfall in northwest China. From April to June 2022, 350 questionnaires were distributed; questionnaires with missing answers and regular answers were deleted, and 306 valid questionnaires were ultimately obtained. The sample size of this study meets the requirements of the principle that the number of questionnaires in the analysis should be more than 10 times the number of questions, as well as the findings of previous studies that have shown it is appropriate to use a sample size greater than 200 for structural equation model (SEM) (Hoogland and Boomsma, 1998). The demographics data for the 306 respondents were as follows: 149 male (48.7%) and 157 female (51.3%); respondents ranged in age from 18 to 72 years, with a mean age of 35.8 years (SD = 12.7); for education level, 11 had completed junior high school (3.6%), 48 had completed senior high school (15.7%), 223 had an undergraduate degree (72.9%), and 24 had a graduate degree (7.8%); there were 12 respondents (3.9%) whose *per capita* monthly income was below 2,000 RMB, 37 respondents (12.1%) had a *per capita* monthly income between 2,000 and 5,000 RMB, 114 respondents (37.3%) had a *per capita* monthly income between 5,000 and 10,000 RMB, 103 respondents (33.7%) had a *per capita* monthly income between 10,000 and 20,000 RMB, and 40 respondents (13.1%) had a monthly income greater than 20,000 RMB. The gender and age of the sample largely reflect the demographic characteristics of China, and the level of education and income ensure the diversity of the sample population.

2.2 Survey design

The questionnaire used in this study consisted of two parts. The first part sought the demographic characteristics of the respondents, including gender, age, education level, and income level. The second part included items related to the respondents' risk perception of recycled water, their trust in the water authorities and recycled water enterprises, their perception of the information provided, and their

TABLE 1 Questionnaire items.

Latent variable	Observed variable	Question	Literature
Financial risk	FR1	It costs more to install recycled water pipes and water meters	Gao and Liu (2019), Fu et al. (2020)
	FR2	Use of recycled water does not really save money on water bills	
	FR3	Related equipment may lead to more spending	
	FR4	It costs more to repair or maintain recycled water systems	
Performance risk	PR1	Pipes and water meters are more susceptible to damage	Mainali et al. (2013), Ding et al. (2022b)
	PR2	Toilets are easily corroded by recycled water	
	PR3	Recycled water system is prone to failure	
	PR4	Recycled water has a peculiar color and odor	
Health risk	HR1	Recycled water affects my health	Chen et al. (2014), Gerrity et al. (2018)
	HR2	Unclean recycled water contains harmful substances such as microbial chemical residue	
	HR3	I feel uncomfortable using recycled water	
	HR4	Using recycled water makes me sick	
Service risk	SR1	The supply of recycled water is unstable	Gu et al. (2015), Wester et al. (2015)
	SR2	The maintenance of recycled water facilities is not timely	
	SR3	Quality supervision of recycled water is not in place	
	SR4	Recycled water and tap water may mix	
Trust	T1	I trust the information provided by the water authorities	Miller et al. (2008), Fragkou and McEvoy (2016)
	T2	I trust the information provided by recycled water enterprises	
	T3	I believe that the water authorities and recycled water enterprises guarantee the quality of recycled water	
	T4	I believe that the water authorities and recycled water enterprises can solve the problem quickly	
Information provision	IP1	I would like more information	Hou et al. (2021), Ding et al. (2022a)
	IP2	Information on recycled water should be more openly available	
	IP3	Timely and effective information should be provided to the public	
Willingness to use	WTU1	Using recycled water for flushing is a wise decision	Fielding et al. (2019), Etale et al. (2020)
	WTU2	Use of recycled water for flushing is worth promoting	
	WTU3	I would recommend the use of recycled water for toilet flushing to others	
	WTU4	Whenever I can, I will use recycled water to flush the toilet.	

willingness to use recycled water for toilet flushing; these items are described, respectively, as the four variables: risk perception, trust, information provision, and willingness to use. Because these variables have been developed theoretically but cannot be directly observed and measured, several observed variables were chosen to estimate the four latent variables, each of which was measured by a question in the questionnaire. Variables and questions were summarized from the relevant previous studies. The formal questionnaire was composed of seven latent variables and 27 observed variables, as shown in Table 1. A seven-point Likert scale was adopted for the questionnaire from 1 (complete disagreement) to 7 (complete agreement). To assess respondents' risk perception of recycled water and express the risk perception variable more concisely in the model, this study summarized the risks of recycled water into four dimensions—financial, performance, health, and service risks. Financial risk (FR) refers to the expenses related to the installation and maintenance of recycled water equipment, as well as the economic losses that may be caused by water bills. Performance risk (PR) refers to the risk that the quality of the recycled water would not meet expectations or that the recycled water supply system would fail. Health risk (HR) refers to the damage that recycled water can cause to physical health. Service risk (SR) refers to the risk of unstable and untimely supply, supervision, maintenance, and other services related to recycled water. Each risk dimension was assessed by four observed variables, with a score of 1–7 indicating perception

TABLE 2 Latent variable reliability test.

Latent variable	Numbers of observed variable	Cronbach's alpha
Financial risk	4	0.785
Performance risk	4	0.843
Health risk	4	0.879
Service risk	4	0.876
Trust	4	0.828
Information provision	3	0.663
Willingness to use	4	0.842

of risk, from low to high. Four observed variables were used to assess the degree of trust, with a score of 1–7 indicating low to high trust. Three observed variables were used to measure information provision, with a score of 1–7 indicating the perceived information provision, from low to high. The willingness to use was measured by four observed variables, with a score of 1–7 indicating low to high willingness to use recycled water.

2.3 Structural equation model

This study established a risk perception measurement model to analyze the impact of four dimensions (types) of risk on the overall risk perception and a model expressed the effects of trust, risk perception, and information provision on the willingness to use recycled water and their interactions. The model was analyzed using Structural Equation Model (SEM), a multivariate data analysis method used to analyze complex relationships between variables, which is currently widely used in a variety of research fields, such as economics and psychology. We analyzed the measurement model expressing the overall risk perception and the model expressing relationship among the four variables by using IBM SPSS Statistics 25.0 software (SPSS 25.0) and IBM SPSS AMOS 26.0 software (AMOS 26.0). SPSS 25.0 is a statistics software platform, which lets people quickly extract actionable insights from the data. AMOS 26.0 is a structural equation model software that enable people specify, estimate, assess and present the model in an intuitive path diagram to show hypothesized relationships among variables. First, the measurement model that makes up the structural model is analyzed through confirmatory factor analysis, and then the structural model is analyzed.

3 Results and analysis

3.1 Reliability and validity test of the questionnaire

SPSS 25.0 software was used to test the reliability and validity of the data obtained from the questionnaire survey. Reliability refers to the overall consistency, stability, and repeatability of a measurement. The results of the reliability test for the latent variables were represented by Cronbach's alpha coefficient, for which a value greater than 0.6 indicates acceptable reliability, while 0.7 is the recommended value. The analysis results are shown in Table 2. The Cronbach's alpha coefficient for information provision is 0.663, while the Cronbach's alpha coefficient for the other latent variables ranges from 0.785 to 0.879, which indicates that the data of each latent variable are true and reliable.

Validity refers to the degree to which a measure accurately assesses the specific concept, trait, or construct that it claims to be assessing. In the validity test of the observed variables, to simplify the testing process for the risk perception variables, the measured data in the four dimensions were averaged. The four risk dimensions were based on the observed variables FR, PR, HR, and SR for risk perception, and the standard loads obtained were all greater than 0.5. This indicates that it is reliable to measure the overall degree of risk perception with the four dimensions proposed. The KMO (Kaiser-Meyer-Olkin) value was used as the validity test index to determine whether the observed variables within each latent variable are correlated. In this study, a KMO value greater than 0.6 means that the validity is acceptable, and 0.8 is the recommended value. As shown in Table 3, the KMO values of latent variables are all greater than the recommended value of 0.8, except for the value of information provision is 0.635, which indicates that the problems in each latent variable have considerable correlation, and the questions can effectively express the information of the research variables.

By observing whether the standardized factor loading (Std.) of each question is greater than 0.6, the composite reliability (CR) of each latent variable is greater than 0.7, and the average variance extracted (AVE) is greater than 0.5, we can determine whether the consistency between questions is acceptable (Bagozzi et al., 1981). The results showed that the Std. of almost all questions is greater than 0.6, and the rest is less than 0.6, but is greater than the acceptable value (0.5). Except the CR and AVE values of information provision do not meet the conditions, the other latent variables meet CR > 0.7 and AVE>0.5. As shown in Table 4, the results confirmed that the convergent validity of these latent variables is acceptable, which indicates that the problems within one latent variable are consistent, and the measured values among the observed variables are highly correlated, and the reliability is acceptable.

The discriminant validity reflects the low correlation and significant difference among latent variables. As shown in Table 5, the data in bold font on the diagonal in the table is the square root of AVE, which is greater than the absolute value of the correlation coefficient between all latent variables in the column and

TABLE 3 Questionnaire validity test.

Observed variable	Mean	Standard deviation	Standard loads	P	KMO
T1	5.422	1.157	0.768	0.000	0.808
T2	5.075	1.342	0.616	0.000	
T3	5.438	1.256	0.816	0.000	
T4	5.353	1.348	0.798	0.000	
IP1	5.951	0.986	0.705	0.000	0.635
IP2	6.098	0.960	0.790	0.000	
IP3	5.971	0.993	0.698	0.000	
WTU1	5.222	1.250	0.777	0.000	0.806
WTU2	5.441	1.175	0.749	0.000	
WTU3	5.131	1.266	0.809	0.000	
WTU4	5.330	1.283	0.714	0.000	
FR[a]	4.703	1.144	0.819	0.000	0.834
PR[a]	4.221	1.354	0.880	0.000	
HR[a]	4.194	1.420	0.869	0.000	
SR[a]	4.526	1.416	0.838	0.000	

[a]FR, is the average value of observed variables FR1, FR2, FR3, FR4; PR, is the average value of observed variables PR1, PR2, PR3, PR4; HR, is the average value of observed variables HR1, HR2, HR3, HR4; SR, is the average value of observed variables SR1, SR2, SR3, SR4.

other latent variables. This indicates that the discriminant validity of the measurement model in this study is appropriate, and there are significant differences among the latent variables.

3.2 Measurement model of risk perception

Based on the literature on risk perception dimensions and the research on risks of recycled water, this study established a multi-dimensional risk perception measurement model composed of four risk dimensions: financial risk, performance risk, health risk and service risk. Two alternative measurement models were proposed and compared to get a better fit risk perception measurement model: a first-order four-dimensional factor model (named Model 1) and a second-order one-dimensional factor and first-order four-dimensional factor model (named Model 2), As shown in Figure 2. The confirmatory factor analysis was used to determine whether the structure of the measurement models were built properly, and the fitting indexes of the two models were compared to determine the acceptable risk perception measurement model.

Model one is a first-order four-dimensional risk perception model. The numbers on the arc were the correlation coefficients among first-order factors, and the correlation coefficients were all greater than 0.7, indicating that the four first-order factors are significantly correlated. Model two established a second-order one-dimensional factor and first-order four-dimensional factor model. If first-order factors are correlated, then the correlation between first-order factors is statistically caused by a single second-order factor, that is to say, the perception of four related risks of different types in the model belongs to one variable: risk perception. As can be seen from the above figure, model two showed that the factor loads of performance risk and health risk were 0.96 and 0.90 respectively, so they were the two most important risk dimensions of recycled water for flushing. Financial risk (0.82) and service risk (0.85) played less important role in total risk perception. Factor analysis showed that four risk dimensions explained 60.76% of the total variance.

Table 6 shows the fit index of model one and model 2. For the two models, the ratio of chi-square to degree of freedom (CMIN/DF) are less than 3, indicating excellent fitting. The goodness-of-fit index (GFI) are greater than 0.9, the adjusted goodness-of-fit index (AGFI) are less than 0.9 but greater than 0.8, indicating the models are still in the acceptable range. The root mean square error approximation (RMSEA) are less than 0.07. The comparative fit index (CFI) and the non-normed fit index (TLI) are both greater than the recommended value of 0.9. This indicates that both model one and model two have good goodness of fit.

The target coefficient can be used to test whether a higher-order model can substitute for a lower-order model. In this study, the target coefficient = CMIN of model 1/CMIN of model 2 = 231.65/234.45 = 0.988, and the target coefficient is close to 1. Therefore, the second-order model can be used to replace the first-order model for risk perception analysis, that is, both model one and model two preferably explained residents' risk perception of recycled water for toilet flushing. The overall risk perception can be expressed in terms of four types of risks. In summary, the total risk perception of recycled water can be measured by the second-order model of risk perception composed of four dimensions of risks more concisely.

TABLE 4 Convergence validity test.

Latent variable	Observed variable	Estimation of parameter significance				Question reliability		Composite reliability	Convergent validity
		Unstd	S.E.	t-value	P	Std	SMC	CR	AVE
Trust	T1	1.000				0.749	0.561	0.831	0.552
	T2	1.028	0.097	10.607	***	0.664	0.441		
	T3	1.101	0.092	11.985	***	0.760	0.578		
	T4	1.233	0.100	12.331	***	0.793	0.629		
Information provision	IP1	1.000				0.692	0.479	0.622	0.358
	IP2	0.821	0.162	5.082	***	0.583	0.340		
	IP3	0.737	0.145	5.101	***	0.506	0.256		
Willingness to use	WTU1	1.000				0.789	0.623	0.844	0.576
	WTU2	0.859	0.070	12.275	***	0.721	0.520		
	WTU3	1.060	0.077	13.787	***	0.826	0.682		
	WTU4	0.898	0.076	11.740	***	0.691	0.477		
Risk perception	Financial risk	1.000				0.818	0.669	0.935	0.783
	Performance risk	1.666	0.188	8.845	***	0.960	0.922		
	Health risk	1.948	0.206	9.446	***	0.901	0.812		
	Service risk	1.709	0.189	9.050	***	0.855	0.731		
Financial risk	FR1	1.000				0.633	0.401	0.799	0.501
	FR2	1.449	0.156	9.280	***	0.647	0.419		
	FR3	1.456	0.137	10.621	***	0.782	0.612		
	FR4	1.309	0.126	10.406	***	0.757	0.573		
Performance risk	PR1	1.000				0.702	0.493	0.844	0.576
	PR2	1.171	0.095	12.386	***	0.767	0.588		
	PR3	1.137	0.090	12.670	***	0.786	0.618		
	PR4	1.155	0.092	12.541	***	0.777	0.604		
Health risk	HR1	1.000				0.826	0.682	0.880	0.647
	HR2	0.935	0.059	15.820	***	0.796	0.634		
	HR3	0.968	0.062	15.494	***	0.784	0.615		
	HR4	0.937	0.058	16.251	***	0.812	0.659		
Service risk	SR1	1.000				0.794	0.630	0.876	0.639
	SR2	1.089	0.070	15.645	***	0.828	0.686		
	SR3	1.047	0.068	15.308	***	0.813	0.661		
	SR4	0.992	0.070	14.094	***	0.760	0.578		

3.3 Structural model analysis

According to the structural model in Figure 1 and the data related to respondents' risk perception, trust, information provision, and willingness to use from the questionnaire, we analyzed the relationship among the four variables by using AMOS 26.0 software.

3.3.1 Goodness of fit

The commonly used model fit index criterion and the goodness of fit of the structural model are shown in Table 7. The model fit index includes chi-square value (CMIN), degree of freedom (DF), the ratio of chi-square to degree of freedom (CMIN/DF), goodness-of-fit index (GFI), adjusted goodness-of-fit index (AGFI), comparative fit index (CFI), non-normed fit index (TLI), root mean square error

TABLE 5 Discriminant validity analysis.

Latent variable	Convergent validity	Discriminant validity			
	AVE	Information provision	Risk perception	Willingness to use	Trust
Information provision	0.358	**0.599**[a]			
Risk perception	0.783	0.057	**0.885**		
Willingness to use	0.576	0.336	−0.408	**0.759**	
Trust	0.552	0.452	−0.255	0.709	**0.743**

[a]The bold numbers on the diagonal are the square root of the average variance extracted (AVE), and the numbers in the triangle below the bold numbers are the Pearson correlation coefficients between latent variables.

approximation (RMSEA), and standardized root mean square residual (SRMR). After comparison, it can be seen that the model's goodness of fit meets the recommended criteria, which indicates that the model has sufficient adaptability to the collected data.

3.3.2 Structural model results

SEM yielded a good initial test result. However, the effect of recycled water information provision on the willingness to use recycled water was not significant ($\beta = 0.07$, $p = 0.311$)—that is, the hypothesis H6 was not valid, so we deleted this hypothetical path. After adjusting the model, the optimal structural model was obtained, as shown in Figure 3. The model path analysis results are shown in Table 8, and it can be seen that the relationship among the adjusted hypothetical paths is significant.

The results of path analysis showed that risk perception had a negative impact on the willingness to use recycled water (H1: $\beta = -0.240$, $p < 0.001$); for every unit increase in perceived risk, the willingness to use recycled water decreased by 0.24 units. Trust had a negative effect on risk perception (H2: $\beta = -0.357$, $p < 0.001$)—that is, when trust increased by one-unit, perceived risk decreased by 0.357 units. Trust had a positive effect on the willingness to use (H3: $\beta = 0.653$, $p < 0.001$); for every unit increase in trust, the willingness to use recycled water increased by 0.653 units. Information provision had a positive effect on risk perception (H4: $\beta = 0.220$, $p < 0.05$)—that is, when information provision increased by one-unit, perceived risk increased by 0.22 units. Information provision also had a positive effect on trust (H5: $\beta = 0.462$, $p < 0.001$), and for every one unit increase in information provision, trust increased by 0.462 units. Hypotheses H1, H2, H3, and H5 are valid, while H4 is contrary to the original hypothesis—that is, information provision does not directly reduce risk perception, but rather increases it; H4 is thus not valid. However, information provision indirectly reduces risk perception through increasing trust. In general, information provision increases people's perception of the risk of recycled water for flushing, and it also increases their trust in the water authorities and recycled water enterprises. Trust in the water authorities and enterprises, however, reduces people's perception of risk and directly increases people's willingness to use recycled water, while risk perception directly reduces their willingness to use recycled water.

4 Discussion

4.1 Risk perception of recycled water

This study developed a risk perception measurement model for urban residents' risk perception of recycled water for toilet flushing. Previous studies on risk perception have shown that the importance of different risk dimensions will vary according to different fields (Stone and Gronhaug, 1993). In this study, performance risk and health risk are the most important risk dimensions of recycled water for flushing, while financial risk and service risk are the less important risks. In other words, the participants had a higher perception of the quality of recycled water or related equipment falling short of expectations and the damage of recycled water to health, and a lower perception of possible monetary losses and subsequent maintenance and repair. It can be explained that recycled water for toilet flushing as a kind of recycled water use that may often appear in residents' daily life, because of the high frequency of use, people pay more attention to the quality and efficacy of recycled water itself and recycled water facilities. If there is a failure in water quality or recycled water equipment, it will bring greater inconvenience to people's daily life. Because of the spatial distance between human body and recycled water for toilet flushing is closer than that for other uses such as gardening and road cleaning, people are also very concerned about the harm that recycled water may bring to their own health and that of their families. Previous studies have shown that possible harmful microorganisms and chemical residues in recycled water pose a potential threat to human health, which has raised concerns about the safety of recycled water use (Gerrity et al., 2018). As a result, the public was reluctant to use recycled water due to health risks (Chen et al., 2014). Meanwhile, the loss of money and the inconvenience of subsequent maintenance receive less attention. This may be because the promotion of recycled water often focused on the lower price of recycled water than tap water, leading to a higher expectation that the use of recycled water could save money, thereby reducing the perception of financial risk. In addition, due to the past experience of using tap water for flushing, although people are aware of the seriousness of the inconvenience caused by equipment failure, people are less aware that equipment failure caused by recycled water may require additional follow-up maintenance services. Therefore, the risk perception of recycled water is more reflected in the perception of performance risk and health risk, and the perception of performance risk and health risk is also an important reason for people's reluctance to use recycled water. Reducing the perception of these two types of risks can more effectively promote the use of recycled water by urban residents.

4.2 Impact of information provision on willingness to use

The SEM results showed the relationships among trust, risk perception, and willingness to use recycled water. Previous studies

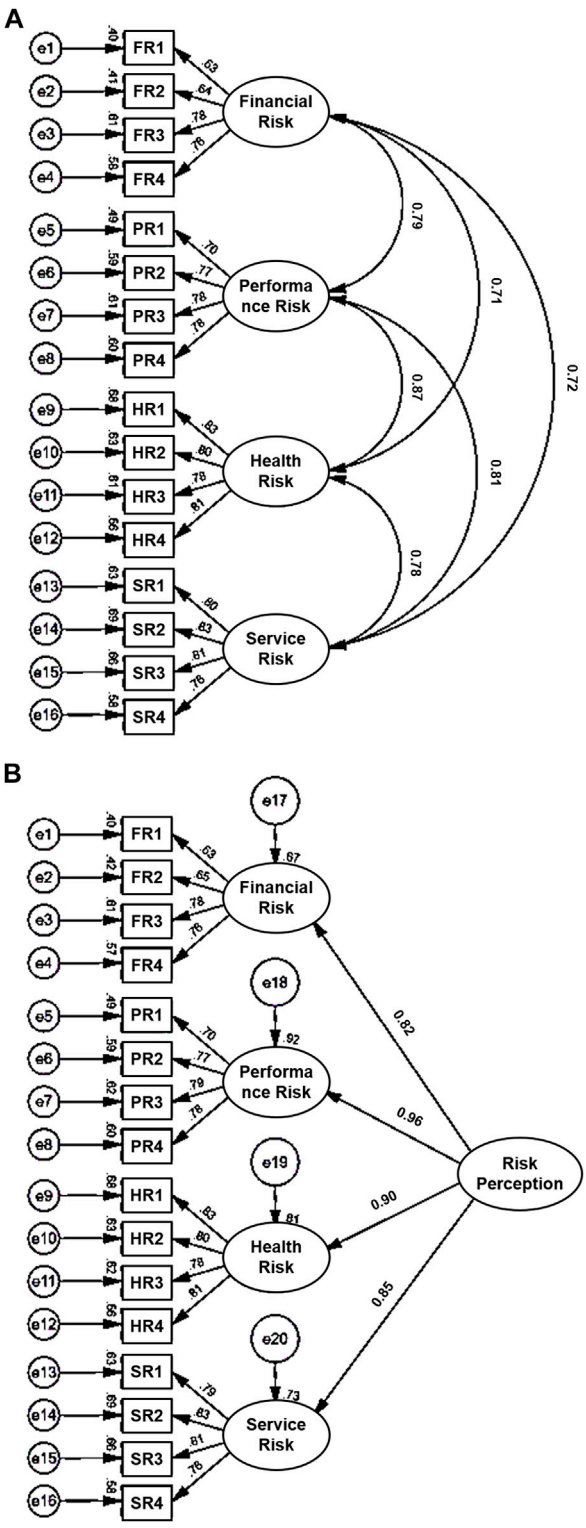

FIGURE 2
Confirmatory factor analysis of risk perception measurement models. **(A)** Model one is a first-order four-dimensional model, which represents the relationship among the four variables of financial risk, performance risk, health risk and service risk, and the numbers on the arc are correlation coefficients. **(B)** Model two is a second-order one-dimensional factor and first-order four-dimensional factor model. The numbers on the line between the four types of risk and the risk perception indicated the importance of this risk in the overall risk perception.

have suggested that trust affects the willingness to use recycled water through risk perception and that risk perception plays a mediator role between trust and the willingness to use recycled water (Ross et al., 2014). As can be seen from the structural model, the effect of trust on the willingness to use recycled water (β = 0.653) is higher than that of risk perception (β = −0.240). In other words, trust in the water authorities and recycled water enterprises is the main determinant of urban residents' willingness to use recycled water for flushing. However, if the risk perception increases or if trust is breached, the willingness to use decreases. Research on risk perception has pointed out that people try to take action to avoid harm when they feel there is a risk (Slovic et al., 2004). It has also been pointed out that the success of a recycled water project is closely related to the cognition, awareness, and behavioral choices of the stakeholders, and public willingness to use recycled water is greatly influenced by their perception of its risks (Baggett et al., 2006). In this case, the perceived threat of using recycled water for flushing prompted residents to take protective actions—i.e., refusing to use recycled water—which was intended to directly reduce their willingness to use recycled water. Risk perception is, however, also negatively affected by trust, and the reduction of trust also leads to increased risk perception and thus a reduction in willingness to use recycled water. Previous studies have noted that trust is easily destroyed, and it is difficult to restore to its initial state; in some cases, lost trust may never be restored (Slovic, 1993). Maintaining a high level of public trust in the water authorities and recycled water enterprises is thus essential to ensure a high level of willingness to use recycled water. Initial trust weakens people's perception of the risk of recycled water and directly brings about greater willingness to use it, which is also conducive to the promotion and publicity of using recycled water for flushing.

SEM also analyzed the relationship among information provision, trust, and risk perception. Because the subjective evaluation of information provision was explored from the perspective of information receivers, objective indicators such as the comprehensiveness and timeliness of information from the perspective of information providers were not adopted. Providing comprehensive and open information is a factor that creates trust, so the role of information provision should not be underestimated, but it also should not be regarded as the purpose (Kellens et al., 2013). Information provision does not appear, from the results of this study, to affect the willingness to use recycled water directly, and there is no significant correlation between the two. The willingness to use recycled water is indirectly affected through risk perception and trust, which is inconsistent with the findings of some previous studies (Hou et al., 2020). A possible explanation for this is that the key to effective risk communication lies in the provision of specific information and trust in the information provider (Haer et al., 2016). Here, the specific information provided and trust in the information provider functioned together as a whole, but trust in the information provider is a prerequisite, and this whole was often considered to be a risk communication. Researchers have suggested that behavioral intention is the result of the interaction between perception and information provision, which are affected by surrounding environmental factors; information provision has a good regulating effect on individuals' environmental perception and behavior (Guagnano et al., 1995). Information from different

TABLE 6 The goodness of fit index of risk perception alternative models.

Model	CMIN	DF	CMIN/DF	GFI	AGFI	RASEA	CFI	TLI
Model 1	231.65	98	2.364	0.913	0.880	0.067	0.954	0.943
Model 2	234.45	100	2.346	0.912	0.880	0.066	0.953	0.944

TABLE 7 Model's goodness of fit.

Indicators	Value of this study	Evaluation criteria	Conclusion
CMIN	672.765	Lower is better	
DF	315	Lower is better	
CMIN/DF	2.136	<3 was regarded as good	Good fit
		<5 acceptable fit	
GFI	0.858	>0.9 was regarded as good	Acceptable fit
		>0.8 acceptable fit	
AGFI	0.830	>0.9 was regarded as good	Acceptable fit
		>0.8 acceptable fit	
CFI	0.918	>0.9 was regarded as good	Good fit
TLI	0.908	>0.9 was regarded as good	Good fit
RMSEA	0.061	<0.08 was regarded as good	Good fit
		<0.1 acceptable fit	
SRMR	0.0558	<0.08 was regarded as good	Good fit

sources can lead to different levels of trust, which can influence the behavioral decisions of individuals or groups (Sutherland et al., 2013). In this study, information provision strengthened people's trust and risk perception simultaneously but had a stronger effect on trust enhancement compare to risk perception, while trust and risk perception were negatively correlated. In general, information provision thus seems to reduce the risk perception through the moderating effect of trust. One possible explanation for this is that the accurate and unbiased information provided by water authorities and recycled water enterprises creates more trust from the public, but the knowledge about the risks and safety of recycled water from the information provided may also reinforce people's perception of its risk. As previous studies have shown, information about recycled water technology can have a positive impact, but some caution should be taken with such information, because the process of removing pollutants from sewage demonstrated by the technical information may enhance people's perception of risk (Goodwin et al., 2018), which also explains why hypothesis H4 was not supported. If a risk communication takes trust and information provision as a whole, it has a negative impact on risk perception, which is consistent with the results of previous studies on risk communication. Without understanding the risks, individuals expand their perception of risk for their own safety, and effective risk communication can significantly prevent such expansion and reduce perceived risk (Fekete, 2012; Ross et al., 2014). However, risk communication research has shown that providing information to the public is a highly sensitive issue. Poorly designed communications may even trigger a negative emotional response, either due to the risk itself or due to specific elements of the communication expression, such as scary images (Jones, 2015). Strengthening trust in recycled water technologies and products may be another effective way to communicate.

Based on the above analysis, the model composed of the four factors of information provision, trust, risk perception, and willingness to use recycled water developed in this study can also express the influence of risk communication on risk perception and willingness to use recycled water—that is, the risk communication–risk perception–willingness to use model. Here, the water authorities and recycled water enterprises provide the information that people want to know, which developed into an effective risk communication strategy and increased public willingness to use recycled water by reducing perceived risk.

4.3 Research significance and limitations

The risk perception measurement model established in this study extended the study of risk dimensions to the field of recycled water. Understanding the secondary determinants of risk perception is extremely valuable because it can provide a more detailed understanding of why people feel threatened by a technology. Although the basis of risk perception evaluation in this study is not based on objective scientific evidence, the subjective risk perception level of new technologies or new products is an

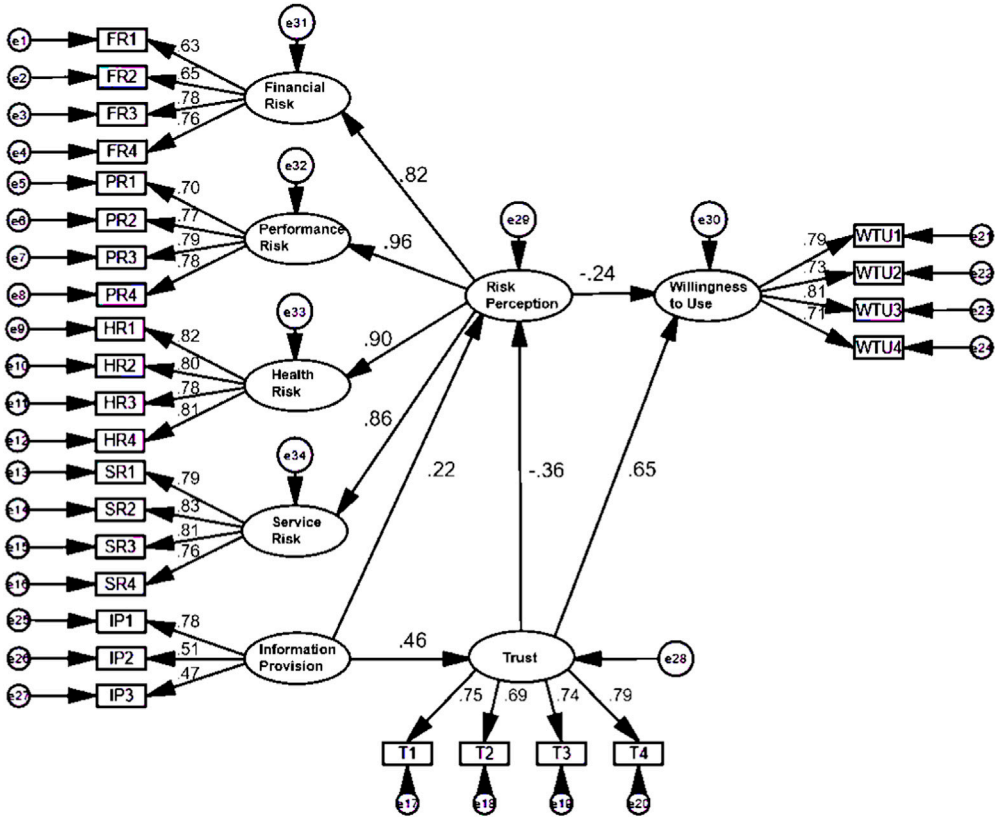

FIGURE 3
Model path of factors influencing people's willingness to use recycled water showing the interaction among risk perception, trust, information provision, and willingness to use recycled water.

TABLE 8 Model path analysis.

Hypothesis	Hypothetical path	Unstd	S.E.	t-value	P	Std.(β)	Results
H1	Risk Perception → Willingness to Use	−0.281	0.067	−4.225	***	−0.240	Valid
H2	Trust → Risk Perception	−0.344	0.082	−4.214	***	−0.357	Valid
H3	Trust → Willingness to Use	0.734	0.079	9.244	***	0.653	Valid
H4	Information Provision → Risk Perception	0.240	0.096	2.502	0.012	0.220	Invalid
H5	Information Provision → Trust	0.522	0.102	5.100	***	0.462	Valid

***$p < 0.001$.

important indicator of people's alertness to their potential hazards. This will help government departments and recycled water companies to reduce the specific risks of recycled water that the public is most concerned about, in order to remove obstacles to the use of recycled water. The combination of information provision and trust can, together, be defined as risk communication, which is an important means to regulate risk perception. An effective risk communication includes not only targeted information provision but also promoting trust in the information providers. The establishment of risk communication–risk perception–willingness to use model in this study expands our understanding of urban residents' willingness to use recycled water from the perspective of risk perception, provides a theoretical basis for policymakers to understand the public's cognition of and attitude toward recycled water, and contributes to the formulation of recycled water promotion policies. This model can also be applied to studies on other pro-environmental behaviors, and the risk of implementing or not implementing the pro-environmental behavior can be analyzed to develop targeted risk communication strategies.

The limitations of this study include two aspects. First of all, as for the variable of information provision, this study mainly focuses on the information receivers' subjective cognition of the timeliness, openness and detail of the information, but does not distinguish the type of information provided. Past studies have shown that providing detailed information or images about the wastewater treatment process increases people's risk perception of recycled

water. Other studies have shown that providing environmental information about water scarcity increases people's willingness to use recycled water. This study lacks data to support which type of information changes risk perception and which type of information changes trust when providing information has an impact on risk perception and trust. The next step is to extend the model of this study by dividing the types of information. Secondly, although existing studies have shown that it is difficult for trust to be rebuilt to the previous level after being destroyed, the model in this study can only express the positive impact of information provision on trust, and cannot express how the connection between trust and information provision is destroyed when trust is lower than a threshold, resulting in trust no longer being positively affected by information provision. The measurement of this threshold is to be explored in future studies.

5 Conclusion

This study established a measurement model of urban residents' risk perception of recycled water for toilet flushing, and used SEM to assess the relationship among information provision, trust, risk perception, and willingness to use recycled water. There are three main conclusions. First, the risk perception of recycled water for flushing mainly came from four dimensions of risks, which were performance risk, health risk, service risk and financial risk in order of importance. Therefore, effectively reducing the performance risk and health risk, the two most concerned risks, will be the key to control the overall risk perception of recycled water. Second, greater trust in the water authorities and recycled water enterprises reduces the public's perception of the risk of recycled water. Reducing the risk perception can improve the willingness to use recycled water for toilet flushing. A higher initial level of trust is related to greater willingness to use recycled water. Third, providing information can enhance the public's perception of the risk of recycled water and enhance trust in the water authorities and recycled water enterprises, but information provision alone does not directly affect the public's willingness to use recycled water. In other words, effective risk communication strategies that combine information provision and trust in the information providers can influence people's willingness to use recycled water by regulating risk perception. The premise of the effect of information provision on willingness to use recycled water is people's trust in the information provider. This provides a theoretical basis for the government to formulate a risk communication strategy to promote the use of recycled water for toilet flushing.

Data availability statement

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

Author contributions

YD: Writing–original draft, Writing–review and editing. XL: Project administration, Supervision, Writing–review and editing.

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Conflict of interest

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

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