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Determinants of the acceptance of domestic use of recycled water by use type

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Abstract. In the circular economy model, the recycling of water is an alternative option that can reduce the pressure on water resources and guarantee water supply. This water policy measure is currently widespread in agriculture, but thus far few countries have opted for the domestic use of recycled water. In part, this is because it is the source of water with the lowest levels of public acceptance, which poses a threat to the success of the necessary investment. We analyse the degree of acceptance of recycled water for different domestic uses. The main contribution of this study is the analysis of the determinants of acceptance of recycled water by use type. The research was based on data from a questionnaire given to 844 university students in Andalusia, southern Spain. Results are obtained from ordinary least squares regressions that relate the determinants of recycled water acceptance to each of the water use classes. The 'yuck factor'—variously defined as 'disgust' or 'psychological repugnance'—and the perceived risk are found to be the main determinants of the low degree of acceptance of recycled water for ingestion by people and pets. For other uses, such as body washing, laundry and cleaning, environmental awareness stands out as a determining factor. The main conclusion is that if authorities were to opt for measures to promote the use of recycled water, they should take into account the fact that the reluctance to use recycled water and the determinants of acceptance differ according to the intended use.

Keywords: Circular economy; Water reuse; Recycled water; Water sustainability; Spain.

1. INTRODUCTION

According to the United Nations (2015), one of the main challenges facing the world's population is access to water for different uses. An increased risk of water stress is anticipated in many parts of the world in the coming years due to factors such as global population growth and the effects of climate change (Mekonnen and Hoekstra, 2016). Greater efforts are needed to implement measures that make it possible to reconcile access to water with water conservation and sustainability goals (United Nations, 2018).

In the circular economy model, water recycling is an alternative option to reduce the pressure on water resources and guarantee water supply (International Water Association, 2016). The United Nations recently called for wastewater to be considered a valuable resource rather than a problem to be dealt with, and is considering its use for domestic purposes (United Nations, 2017). Although water recycling is widespread in agriculture and for some urban uses—such as cleaning the streets and watering gardens—it is a much less common option for domestic uses (Cotruvo, 2016). However, current techniques enable the production of recycled water fit for human consumption and its widespread adoption is expected in the near future (Ong, 2016; Villarín and Merel, 2020). In many cities, ensuring the availability of urban water will require an increase in the use of recycled water, among other measures (Ananda, 2019).

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Consumer participation is key to the success of investments in circular economy projects (Urbinati et al., 2017; Kuah et al., 2020). Nevertheless, the public is reluctant to use recycled water for domestic purposes. There is evidence of a low degree of acceptance of the use of recycled water compared to alternatives such as water from conventional sources—surface water and groundwater—or other non-conventional sources—rainwater harvesting and desalination—in Australia (Dolnicar and Schäfer, 2009; Dolnicar et al., 2011; Fielding et al., 2015), the United States (Ishii et al., 2015; Hui and Cain, 2018), China (Liu et al., 2018; Zhu et al., 2018) and Spain (López-Ruiz et al., 2020). There is also evidence of a low degree of acceptance of the use of recycled water for irrigation and even consumption of farm products irrigated with recycled water (e.g., Menegaki et al., 2007).

Although recycled water is a genuine alternative within a water policy framework, it is a risky investment. Without public acceptance of recycled water, people may turn to defensive actions such as buying bottled water (González-Gómez et al., 2020). Such consumer behaviour would detract from the economic, social and environmental effectiveness of the investment. Therefore, users' opinions should be taken into account before undertaking such an investment. In fact, some recycled water initiatives have been rejected by citizens. The most widely reported case is that of Toowoomba, Australia, where residents voted in a referendum against the construction of a wastewater reuse system to supply additional water to the area (Hurlimann and Dolnicar, 2010; Price et al., 2012).

In this study, we explore user acceptance of recycled water. The main contribution of this paper is the analysis of the determinants of the level of acceptance of recycled water, distinguishing between different household uses. For the study, a classification of uses is proposed that takes into account the proximity of people’s contact with the recycled water, as well as the function of the water according to the hierarchy of needs proposed by the World Health Organization (WHO) (2013). This research is of evident interest as the results make it possible to predict the risk of investments aimed at making use of recycled water and, where appropriate, will help in designing plans to reduce the rejection of recycled water according to its intended use.

The research uses data from university students in southern Spain, a region facing extremely high water stress (World Resources Institute, 2019). To perform the estimations, we use ordinary least squares (OLS), and we apply a missing data imputation technique, which yields a sample size of 844 observations. Under Spanish law, domestic use of recycled water is currently only permitted in the event of a disaster declaration (Navarro, 2018). As such, it is not standard practice, but it is a measure that the Government of Spain could propose at some point to alleviate the situation of water scarcity affecting three-quarters of the country. As found in research conducted in other regions of the world, the degree of acceptance of recycled water is lower when there is close-to-body contact and the uses are of more vital necessity in people's lives. With respect to the previous literature, the main finding is the difference in the relative importance of the determinants of acceptance of recycled water according to the intended use. For essential uses, the perceived risk to health and the yuck factor are the most relevant factors in the acceptance of recycled water. However, for uses that are not essential, factors such as environmental awareness, political ideology and education are more relevant. The main conclusion, which can be applied to different scenarios, is that diverse policy strategies must be adopted to increase the acceptance of recycled water in the home according to the intended use.

The article is structured as follows. After this introduction, section 2 provides the background. The materials and methods are described in section 3. The main results are presented and discussed in section 4. The final section of article outlines the conclusions and recommendations.

2. LITERATURE REVIEW

2.1. Determinants of the degree of acceptance of recycled water use

For a thorough review of the determinants of recycled water use, readers should consult the recent comprehensive literature review by Fielding et al. (2019). This section sets out a brief theoretical framework conditioned by the design of the research and the hypotheses to be tested. This framework groups the determining factors into the following sets: sociodemographic; environmental awareness and perception; trust in institutions and the perception of risk; the yuck factor; and social justice and ideology. In this section, we follow this conceptualization to present the background.

2.1.1. Sociodemographic variables

Different sociodemographic variables, such as age, gender and educational level, have been considered as determinants of the acceptance of recycled water use. There is evidence that women (Baghapour, 2017; Dolnicar and Schäfer, 2009), younger people (Dolnicar et al., 2011), those with lower incomes (Garcia-Cuerva et al., 2016; Marsden and Carr, 2014), the unemployed (Dolnicar and Schäfer, 2009) and people with a lower educational level (Baghapour et al., 2017; Wester et al., 2016) are less likely to use recycled water. However, Hartley (2006) and Marks (2004) warn that sociodemographic factors are not good generic predictors of acceptance because demographic associations are not consistent across studies and contexts.

2.1.2. Environmental awareness and perception

Acceptance of the use of recycled water is a form of environmentally responsible behaviour as it reduces the amount of wastewater and increases the amount of freshwater (Dolnicar and Schäfer, 2009). As such, people who are more environmentally aware can be expected to show greater willingness to use recycled water in order to reduce the pressure on conventional sources (Hurlimann, 2007; Ross et al., 2014). Although there are studies (Po et al. 2005; Lease et al., 2014) that have not found a significant relationship between the variables, at least for potable uses, others such as Fu and Liu (2017) have shown a positive relationship between environmental awareness and water recycling. This relationship is conditioned by the perception of the state of the environment, as people who perceive less environmental deterioration will feel less of a need to undertake measures to ensure environmental sustainability. In this vein, Liu et al. (2018) conclude that raising residents' awareness of the environmental crisis and the need to protect the environment increases acceptance of the use of recycled water.

2.1.3. Trust in institutions and the perception of risk

Many people question the safety of recycled water (Hurlimann and Dolnicar, 2010). The perception of risk is usually related to public health problems associated with the safety and quality of recycled water. Since the source of recycled water is wastewater, there is a perception of exposure to contaminants in the water (Rozin et al., 2015). These authors argue that this supposed contagion is resistant to the technological purification of wastewater; therefore, a process of re-naturalization that purifies the water is needed in order to influence public acceptance of water recycling. This would explain why there is greater acceptance of indirect water recycling systems than direct ones, even if the former are unnecessary from a scientific perspective (Schmidt, 2008). Note that indirect Potable Reuse (IPR) involves the advanced treatment of wastewater and then delivering the water indirectly, via environmental buffers, to drinking water treatment facilities that further purify the recycled water before supplying it to consumers as drinking water. Direct Potable Reuse (DPR) involves the introduction of recycled water directly into a drinking water treatment plant, without any environmental buffer (Asano et al., 2007).

Haddad et al. (2009) point out that the perception of the possibility of contagion is negatively associated with willingness to use recycled water. The perception that the use of recycled water can be harmful to health is also a determining factor as it particularly limits levels of acceptance (Po et al., 2003; Fu and Liu, 2017; Callaghan et al., 2012). In this regard, having confidence in the properties of recycled water is a determining factor. According to Ross et al. (2014), community willingness to use recycled water depends on the exchange of information, which improves trust, reducing the perception of risk and increasing acceptance levels. Trust, in both institutions and in science, has therefore been identified as a key factor in the acceptance of non-conventional sources of drinking water, including recycled water (Ross et al., 2014; Fielding et al., 2015). For example, Hurlimann et al. (2008) find a positive relationship between trust in water companies, the quality of the information provided and acceptance of recycled water in Australia. Applying a social-psychological model to the case of Toowoomba, Ross et al. (2014) show that higher levels of public trust led to a lower perception of risk, and the lower perception of risk led to greater public acceptance of the scheme. Furthermore, Massoud et al. (2018) point out that a high level of distrust in the ability of government and institutions to properly manage water recycling plants and provide safe, high-quality water has a negative effect on perceived risk and acceptance levels. Thus, citizens place value on the credibility and information provided by institutions (Po et al., 2005; Russell et al., 2008).

2.1.4. Yuck factor

The emotional distress generated by close contact with certain unpleasant stimuli, known as the ‘yuck factor’ (Russell and Lux, 2009), plays an important role in public opposition to water recycling programmes. Evolutionary psychologists have argued that the emotion of disgust has helped humans to avoid ingesting water and food contaminated by pathogens. Darwin (1872) himself characterized disgust as a feeling that readily arises from anything unusual in the appearance, smell or nature of food and that is offensive to the taste.

Regarding motivations for the possible refusal to use this non-conventional water source, Etale et al. (2020) differentiate between the individual's general tendency to feel disgust (trait disgust) and the particular feeling of disgust that can be caused by recycled water (state disgust). Furthermore, Massoud et al. (2018) point out that in the absence of prior experience, this emotional discomfort is determined by aprioristic beliefs. Along the same lines, Rozin's work on the concept of disgust incorporates three basic principles needed for an emotional response: a sense of oral incorporation, a sense of offensiveness, and contamination potency (Rozin et al., 2008). In the case of recycled water, organoleptic properties—smell, colour and taste—can be predictors of feelings of acceptance or disgust (Amaris et al., 2020; López-Ruiz et al., 2020).

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2.1.5. Social justice and ideology

According to Ansell and Cansunar (2020) and Uslaner and Badesku (2003), citizens who perceive greater income inequality in their country are less likely to accept/positively evaluate government proposals. Greater inequality, as a proxy for social justice, could be linked to greater rejection of any type of public project, including projects aimed at providing recycled water for domestic use.

Ideology is also considered a predictor of water conservation and pro-environmental attitudes and behaviours (Liu et al., 2014). According to these authors, social-liberal politicians, as well as citizens with a stronger social-liberal ideology, tend to care more about the environment. Hui and Cain (2018) also report that, even after accounting for socio-demographic characteristics such as income disparity or education, Americans who identified as Democrats were more willing to use recycled water than Republicans and independents.

2.2. Acceptance of recycled water for different domestic uses

One issue that has not been sufficiently explored in previous research is that there can be varying degrees of acceptance of recycled water depending on the intended use for it in the home. To study this, we propose a two-pronged approach. First, from a functional point of view, we ask whether the consumer considers recycled water to be a good substitute for water from a conventional source; and second, whether the consumer's relationship with recycled water can be affected by the proximity of personal contact.

From a functional perspective, water satisfies human needs in its dual role as a productive resource and a necessity good. In the area of domestic water use, and according to Maslow's hierarchy of human needs (1943, 1954), water is a good that meets first-order needs (drinking and food preparation). However, it is also used for personal hygiene, washing clothes, household cleaning, growing food for domestic consumption, sanitation, and various recreational uses (WHO, 2013). Water is therefore not only able to meet vital physiological needs, but it can also directly or indirectly satisfy needs relating to safety, social relations, self-esteem and self-actualization (WHO, 2013; Prevos, 2018). Figure 1 shows a ranking of water uses according to the hierarchy of needs proposed by the WHO (2013). The question then is whether a person's acceptance of the use of recycled water is the same depending on the function of the water.

Figure 1: Hierarchy of water requirements (after Maslow's hierarchy of needs). Version of the World Health Organization proposal (2013).

Despite the high quality standards to which recycled water is subjected, the literature notes the existence of a 'yuck factor' limiting its acceptance (Furlong et al., 2019, Leong, 2016). The perceived contamination and sense of unease caused by the origin of recycled water triggers rejection in some people. In the absence of previous experiences with recycled water schemes, the organoleptic properties of the water assume more importance. Hurlimann and McKay (2007) point out that the acceptance of recycled water for uses involving some degree of personal contact increases when the water is free from turbidity or odour, but these attributes are irrelevant for non-contact uses, such as water for flushing the toilet or for watering the garden. Thus, according to users, the attributes that would make recycled water suitable for domestic use vary according to what it is used for (Hurlimann and McKay, 2007). In this regard, previous research (e.g., Hui and Cain, 2018; Hurlimann and Dolnicar, 2016; Alhumoud and Madzikanda, 2010; Marks et al., 2006) indicates that when the use of recycled water involves personal contact, such as drinking and cooking, there is a notable drop in the acceptance of the use of recycled water. It can thus be concluded that, regardless of the method used, acceptance of recycled water drops with increasing proximity of personal contact (Fielding et al., 2019).

3. METHODS

3.1. Fieldwork, sample size and demographics

The research was carried out in Andalusia, a region of southern Spain covering an area of 87,268 km^2 and home to almost 8.5 million people. Andalusia suffers from a high level of water stress due to the combined effect of low rainfall and high demand pressure. To alleviate the situation, desalination plants have been built along the coast, but in inland areas some municipalities have to take certain measures during the summer months, such as a ban on specific uses, supply cuts and using tanker trucks to supply water. In these inland areas, recycled water is an option that could reduce pressure on water resources and guarantee the water supply, although under Spanish law the use of recycled water in the home is presently only permitted in disaster situations. Furthermore, the European Union and the Government of Spain, currently seeking to incorporate the principles of the circular economy into their action programmes, are focusing their water policies on water reuse in agriculture and industry, leaving aside the use of recycled water in the home (European Commission, 2020; Ministry for Ecological Transition, 2020). Nevertheless, given the growing pressure on water resources in Mediterranean arid and semi-arid regions and the lower production cost compared to other non-conventional sources of water, recycled water in the urban environment is an emerging solution (Voulvoulis, 2018).

Our questionnaire was given in 2018 to University of Granada students who lived in Andalusia and were aged between 18 and 30 years old (the full questionnaire is available in the Supplementary Information). Questionnaires were delivered to students in the classroom and took around 30 minutes to fill in. Students came from a variety of different areas of study: Business, Sociology, Political Science, Tourism, Marketing, Labour Studies, Nursing, Medicine, Pharmacy and different types of engineering.

This sample of young students was used as a case study because of the importance of the role young people must play in addressing the Sustainable Development Goals: according to United Nations General Assembly Resolution 70/1, this age group should contribute to the implementation of such goals. The sample size appears large enough to be representative of the student population in Andalusia in 2018, when the fieldwork was carried out, which was 244,212 students; with a margin of error of 5% and significance level of 95%, the sample size needed was 384. In the University of Granada (2018), there are 52,881 students, around 60% of whom are women.

Ideally, the study would have been conducted with a representative sample covering different strata of society and the different water realities they face. While using a sample comprised of students may not be the optimal way of addressing the objectives of the research, it does allow us to provide new evidence on an innovative subject. We discuss the limitations of the dataset in more detail in Section 4.3 devoted to the limitations of the study.

3.2. Variables

3.2.1. Dependent variables

The main objective of the study is to evaluate the determinants of the acceptance of recycled water according to different uses. To achieve this objective, the questionnaire included 14 items about water use, as in Hurlimann and Dolnicar (2016). Each item was measured on a seven-point Likert-type scale, where 1 indicates the lowest acceptance of recycled water use and 7 the highest.

To determine the degree of acceptance, some important issues were first raised with the respondents. First, that current regulations do not allow the use of recycled water in the home and, therefore, what is being considered is a hypothetical situation that will not actually happen in the short term. Second, that the authorities could make this option a reality at some point for water security reasons, given the already high and growing water stress in the study area. Third, the option presented was direct potable reuse Note that there are two possibilities for reusing water: IPR and DPR (Brears, 2020). In both cases, the existing technology enables the production of water suitable for use in the home. DPR, an option used in Namibia and Texas, offers a twofold advantage: it is less expensive than IPR and it produces high quality water more quickly (Lahnsteiner et al., 2018; Sgroi et al., 2018). In addition, DPR provides potable water of the same quality as current IPR, or even higher (Hooper et al., 2020). In fact, the environmental barrier that often reassures people can result in high quality water being exposed to potential environmental contaminants (Chaudhry et al., 2017; Burgess et al., 2015; Leverenz et al., 2011)–. Specifically, the following situation was proposed: *"The source of the water is the sewer system, which collects the water previously used in the home (kitchen and bathrooms). The sewage water goes to treatment plants. After intensive treatment, the treated water is transferred to a storage tank where it is blended with water from reservoirs and wells that has previously been treated to make it potable. Finally, the blended water would be delivered to our homes through the supply network.*" In addition, the respondent was informed that the water supplied to his/her home would meet the standards established by the regulations governing the health criteria for the quality of water for human consumption; in other words, it would be fit for human consumption.

Although respondents were asked about their acceptance for 14 uses of water, we established a posteriori five water use clusters to facilitate data processing and the interpretation of the results (see Table 1). The classification emphasizes the proximity of the personal contact with recycled water. Furthermore, although the two do not exactly correspond, there is a parallel between this classification according to the proximity of contact with the water and the hierarchy proposed by the WHO (2013) based on the need for the water. Thus, generally speaking, the closer the proximity to the water, the more the water is of vital necessity in people's lives. The main exception to the correspondence between the proposed classification based on personal contact and vital need is swimming in the pool. This action involves bodily contact with water, but does not cover a function that is essential to the person’s life. In addition, feeding pets does not entail people coming into direct contact with recycled water. However, the function at the personal level is not so obvious, as for people living alone, pets can play a vital role.

The first level involves maximum proximity to the water and maximum need for the water, as the individual ingests it for drinking and cooking. At the second level of proximity, there is direct contact with recycled water, but at a surface level. At the third level, the contact with recycled water is indirect, through personal and household items. At the fourth and fifth levels, there is no direct or indirect contact with people, since the water comes into contact only with pets, plants and the car.

Table 1.
Classification of water uses

World Health Organization (2013)	**Proximity (Research proposal)**	**Water uses included in the questionnaire**
Short-term: Survival	Level 1: Ingestion	– Drinking – Cooking
Medium-term: Maintaining	Level 2: Personal contact	– Brushing teeth – Bathing the baby – Showering / taking a bath – Refilling / topping up the swimming pool
	Level 3: House cleaning	– Washing dishes, glasses and cutlery – Washing clothes / doing the laundry – Cleaning the kitchen – Cleaning the bathroom – Cleaning the house (less bathroom / kitchen)
Long-term: Lasting solution	Level 4: Pets	– Feeding my pets
	Level 5: Uses outside the house	– Washing the car – Watering the garden – flowers trees and shrubs

Note: The water uses proposed in the questionnaire do not exactly correspond to those in the World Health Organization (2013) proposal. It should be noted that the research was conducted in a predominantly urban environment. As such, with respect to the World Health Organization proposal (2013), uses such as growing food and business (crops, livestock) have been removed and other options have been added, such as brushing teeth and having pets at home.

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3.2.2. Independent variables

The questionnaire also included questions to identify the relationships between personal characteristics and different degrees of acceptance of recycled water for the various intended uses. Table 2 presents the details of the variables used in the study, their description and main descriptive statistics. The variables are grouped according to the approach set out in Section 2.1. We are aiming to analyse the relationship between the degree of acceptance of recycled water for the five established levels of domestic use (Table 1) and the variables capturing sociodemographic characteristics, environmental awareness and perception, trust in institutions and perception of risk, beliefs about organoleptic properties, and social justice and ideology (Table 2).

Table 2.
Independent variables. Description and descriptive statistics

Variable	Description	Mean/ %	Standard Deviation	Min	Max
Sociodemographic variables					
Gender	1 = Man; 0 = Woman.	47%		0	1
Age	Years old	21.70	3.18	18	30
Residents	Number of residents in the household	3.47	1.04	1	8
Job	1 = In addition to studying, the respondent has a job; 0 = Other case.	37%		0	1
Education	1 = Education in engineering or health sciences; 0 = Other qualification (Social sciences and humanities).	23%		0	1
Environmental awareness and perception					
Environmental_awareness	Importance of environmental conservation and protection. 1 (none) to 7 (very high).	6.12	1.01	1	7
Environmental_Perception	Satisfaction with the state of the environment. 0 (utterly unsatisfied) to 10 (fully satisfied).	4.66	2.06	0	10
NGO	Membership of an environmental conservation NGO. 1 = Yes; 0 = No.	9%		0	1
Trust in institutions and perception of risk					
Health_Hazard	I think that recycled water will not be of good quality and will cause health problems. From 1 (complete disagreement) to 7 (complete agreement).	4.32	1.82	1	7
Control	I would not trust the controls carried out by the authorities, I would never drink recycled water. From 1 (complete disagreement) to 7 (complete agreement)	4.24	1.86	1	7
Technology	I do not trust the existing technology to produce safe recycled water. From 1 (complete disagreement) to 7 (in full agreement)	4.03	1.88	1	7
Inst_Credibility	Credibility of the information provided by the institutions. From 1 (none) to 7 (absolute)	3.71	1.01	1	7
Researchers	Credibility of the information provided by researchers on technological improvements. From 1 (none) to 7 (absolute)	4.83	1.08	1	7
Bottled_water	1 = respondent usually drinks bottled water; 0 = respondent rarely drinks bottled water.	31%		0	1
Beliefs about organoleptic properties (Yuck factor)					

Smell	I don't think I will like the smell of recycled water. From 1 (strongly disagree) to 7 (strongly agree).	4.41	1.75	1	7
Taste	I don't think I will like the taste of recycled water. From 1 (strongly disagree) to 7 (strongly agree).	4.52	1.74	1	7
Turbidity	I think recycled water will have suspended particles. Likert 1 (strongly disagree) to 7 (strongly agree).	4.41	1.73	1	7
Social Justice and Ideology					
Politics	Declared political ideology. From 1 (extreme left) to 7 (extreme right)	3.16	1.47	1	7
Inequality	Opinion about the existence of excessive inequality in income distribution. From 1 (complete disagreement) to 7 (in full agreement)	5.79	1.33	1	7

Although the description of the variables in Table 2 is sufficiently explanatory, it is worth making some clarifications. The block of sociodemographic variables does not include the educational *level* of the respondent. This is because all the respondents are university students. Instead, a dummy has been incorporated to differentiate between students in the field of health sciences and engineering, who will have learned something about issues related to the characteristics and/or quality of water and the technological possibilities for water treatment and purification, and those in the field of social sciences and the humanities, who are not taught anything in this respect.

The variable *Bottled_water* has been included in the block regarding trust in the use of recycled water. The variable captures information about whether the respondent usually drinks bottled water, compared to the possibility of drinking water directly from the tap. Like Graydon et al. (2019), we consider that people drink bottled water because of the perceived health risks and quality of tap water. In a region such as Andalusia, the choice of bottled water can be interpreted as a sign of distrust, since tap water in the study area is potable; it regularly meets the quality criteria stipulated in Royal Decree 140/2003, of 7 February, which establishes the health criteria for the quality of water for human consumption. It seems obvious that if the respondent distrusts tap water from a conventional source, he or she will have at least the same level of distrust of recycled water.

In the block of beliefs about organoleptic properties, we emphasize that the respondent has no experience with recycled water. Therefore, faced with the proposed scenario, the respondent's answers are based on aprioristic opinions or beliefs.

3.3. Imputation of data

A total of 896 questionnaires were given out and 844 valid questionnaires were returned. Of those, 791 contained complete responses and 53 were incomplete. In other words, 53 of the 844 valid questionnaires returned contained at least one missing value (item non-response). Missing data is a common problem in analyses based on survey data and is commonly caused by respondents not answering some questions (Little and Rubin, 2019; Fuller, 2011). Removal of incomplete cases is fairly standard practice but this solution may be unsatisfactory because it decreases the sample size and, as a consequence, reduces the power of statistical tests. In our case, the application of this method reduces the sample size by approximately 6.3%. Other common techniques used in the treatment of missing data include data imputation methods, which consist in replacing missing values with plausible values. The main advantage of data imputation methods is that they allow the use of the complete sample.

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Even though our sample is representative enough for the population under study, a bigger sample is always better for our estimation purposes, because it increases the power of statistical tests. In order to solve the problem of missing values, we apply a data imputation method; specifically, the kNNI (k-Nearest Neighbour Imputation) method, which has used in numerous surveys carried out by Canada's national statistical agency and various national agencies of the United States (Chen and Shao, 2000), as well as in other contexts, such as hydrologic time series (Lall and Sharma, 1996). This method consists in assigning the median value of the variable taken from the nearest k cases with respect to the rest of the variables. In other words, consider an incomplete case with a missing value in one of the variables. To impute the value, the nearest k cases with respect to the rest of the variables are selected and used to calculate the median of the observations of the variable with the missing value in the incomplete case. A widely discussed issue is how to determine the value of k. We define k=29 following the method proposed by some researchers such as Jonsson and Wohlin (2004), who propose the optimal value of k as the odd integer closest to the square root of the number of complete cases.

The method has been applied for the imputation of missing items in our questionnaires, using R software (Kowarik and Templ, 2016). The treatment of missing items through data imputation allows us to use the total number of observations in the sample for the application of the rest of the statistical techniques. Once the missing observations had been imputed, the dependent variables were obtained as the arithmetic mean of the corresponding water use items. That is, the first step entailed imputing the missing observations from the 14 questionnaire items on the use of water; and in a second step, the values of the dependent variables were calculated as the arithmetic mean of the scores of the corresponding items. In the case of independent variables, the values were obtained directly from the questionnaire item. Table 3 shows a count of the imputed observations for each variable.

Table 3.
Number of imputed values per variable

Variable[+]	Number of imputed observations	*Variable*	Number of imputed observations	*Variable*	Number of imputed observations
Level 1	3	*Gender*	0	*Technology*	7
Level 2	3	*Age*	0	*Inst_Credibility*	2
Level 3	2	*Residents*	7	*Researchers*	0
Level 4	2	*Job*	1	*Bottled_water*	0
Level 5	2	*Education*	0	*Smell*	7
		Environmental_ awareness	0	*Taste*	7
		Environmental_Perception	35	*Turbidity*	7
		NGO	0	*Politics*	6
		Health_ Hazard	7	*Inequality*	0
		Control	7		

[+]Level 1: Ingestion; Level 2: Personal contact; Level 3: House cleaning; Level 4: Pets; Level 5: Uses outside the house

3.4. Data Analysis

The analysis of the data has been conducted in two stages. In the first stage, we present descriptive information on the acceptance of recycled water according to different uses. In a second step, we analyse which variables in Table 2 are related to the acceptance of direct potable reuse for each of the five clusters of domestic use. We use OLS to relate each variable of different recycled water use with the independent variables described in the previous subsection. An advantage of this method with respect to others, and the main reason why it is used, is the simple interpretation of the regression coefficients.

The estimated model can be summarized as follows:

$$Acceptance\_Rec\_Water_{ji} = \alpha + \beta_1\ Sociodemographics_i + \beta_2\ Environmental\ awareness\ and\ perception_i + \beta_3 Trust\ in\ institutions\ and\ perception\ of\ risk_i + \beta_4\ Beliefs\ about\ organoleptic\ properties_i + \beta_5\ Social\ Justice\ and\ Ideology_i + \varepsilon_i$$

Where $Acceptance\_Rec\_Water_{ji}$ is the dependent variable that expresses the willingness to use recycled water in every level of water use in the household (j=1,..., 5) by individual *i* (i = 1,..., 844). It takes values between 1 (lowest acceptance) and 7 (highest acceptance). ε_i is the error term. The model was estimated for each of the five levels of recycled water use (see Table 1).

Referring to the review of Fielding et al. (2019), we can make different predictions about the expected results. With regard to sociodemographic variables, we can expect to see greater acceptance of the use of recycled water among men, older people and people educated in the fields of engineering and health sciences. On the other hand, it is not clear what results to expect for the variables *Residents* and *Job*.

People who are more environmentally aware are expected to show a greater willingness to use recycled water to reduce the pressure on existing water resources. We also hypothesize that a stronger perception of the health risk associated with the consumption of recycled water—whether motivated by personal beliefs or a low level of trust in institutions, scientists, and technological capacity—will be related to a lower degree of acceptance of its use. Additionally, the belief that this water has worse organoleptic properties is expected to be negatively related to acceptance of the use of recycled water.

In the case of political ideology and social justice, there is no conclusive prior evidence regarding its relation to the acceptance of the use of recycled water.

4. RESULTS AND DISCUSSION

4.1. Acceptance of the use of recycled water by intended use

Table 4 shows the main descriptive statistics of acceptance for each level of recycled water use. According to the arithmetic mean, the lowest degree of acceptance of use corresponds to Level 1, which involves the closest personal contact with recycled water and greater vital need, while the highest acceptance is that of Level 5, which involves the least proximity and least vital need. Out of a maximum value of 7, the mean degree of acceptance of recycled water use ranges from a minimum of 2.68 for uses such as drinking and cooking to a maximum value of 5.01 for uses outside the house. Levels 2, 3 and 4 show mean acceptance values lying between the extreme values obtained for Level 1 and Level 5.

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Table 4.
Descriptive statistics for the acceptance of recycled water use according to the degree of proximity.

					Response frequency (in percentage)						
Variable+	**Mean**	**Standard Deviation**	**Min**	**Max**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Level 1	2.68	2.02	1	7	41.47	16.35	12.32	9.00	4.86	5.81	10.19
Level 2	3.31	2.03	1	7	25.83	16.00	15.76	12.91	7.70	10.31	11.49
Level 3	4.22	2.14	1	7	16.59	10.43	12.44	12.80	11.26	14.69	21.80
Level 4	3.17	2.18	1	7	34.36	16.00	9.95	11.49	8.29	5.33	14.57
Level 5	5.01	2.05	1	7	10.31	4.74	6.52	11.61	13.27	12.91	40.64

*Level 1: Ingestion; Level 2: Personal contact; Level 3: House cleaning; Level 4: Pets; Level 5: Uses outside the house

In the order established, the most striking result is associated with Level 4. Going from lower to higher degrees of acceptance, recycled water use for pets comes immediately after acceptance of recycled water use involving ingestion by people. This result indicates that even if there is no direct personal contact respondents would not be very willing to give their pets recycled water. This result is not surprising considering that, for many people, their pet is a member of the family and may even hold a central place in the lives of many people (Redmalm, 2020).

The distribution of responses reinforces the above comments. The greatest rejection of recycled water use is found for the case of ingestion by people (Level 1) and domestic animals (Level 4). It should be noted that the standard deviations are similar for each level. Regarding personal ingestion, 57.82% of respondents stated that they would never or only exceptionally consume recycled water. This percentage drops slightly, to 50.36%, for ingestion by domestic animals. At the other extreme, the highest acceptance of recycled water use is found at Level 5 and Level 3: 53.55% of respondents said they would accept recycled water always or almost always for uses outside the house, and 36.49% for cleaning the house.

These results are in line with those reported in previous research (e.g., López-Ruiz et al., 2020; Hui and Cain, 2018; Hurlimann and Dolnicar, 2016; Ormerod and Scott, 2013; Alhumoud and Madzikanda 2010). In general, willingness to use recycled water increases as physical contact decreases. In terms of the function fulfilled, the more vital the function of the water in respondents' lives, the less willing they are to use recycled water.

4.2. Determinants of acceptance of recycled water use for different use types

Table 5 shows the results for the OLS estimations that relate the determinants of recycled water acceptance to each of the water use classes in Table 1. The F-test of the overall significance of the model indicates that the five fitted models are significant (p-value < 0.001). The model fitted with the dependent variable Level 1 has a higher adjusted R-squared than the rest, which indicates that the independent variables explain the acceptance of the use of recycled water slightly better in this case. An interpretation of this finding is that the individual observable factors in Level 1 make more difference to the use of recycled water than those in the other levels.

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Table 5.
Ordinary least squares estimations for the analysis of determinants of acceptance of recycled water use for each proximity level.

	Levels+				
Variables	**1**	**2**	**3**	**4**	**5**
(Intercept)	5.8614***	4.5428***	4.5255***	4.8165***	4.0684***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Sociodemographic variables					
Gender	0.2107.	0.1964	0.3189*	0.3900**	0.2073
	(0.0906)	(0.1225)	(0.0234)	(0.0061)	(0.1341)
Age	0.0068	0.0579**	0.0524*	0.0449.	0.0748**
	(0.7453)	(0.007)	(0.0271)	(0.0608)	(0.0014)
Residents	-0.0041	0.0211	0.061	0.0260	0.1567*
	(0.9453)	(0.7264)	(0.3605)	(0.6992)	(0.0172)
Job	-0.0389	0.0159	0.1014	0.1039	0.0967
	(0.7562)	(0.9012)	(0.4743)	(0.4679)	(0.4882)
Formation	0.0366	0.4083**	0.4353*	0.2327	0.7509***
	(0.8104)	(0.009)	(0.0118)	(0.182)	(0.0000)
Environmental awareness and perception					
Environmental_ awareness	0.1061	0.1902**	0.2305**	0.1022	0.1366.
	(0.1001)	(0.004)	(0.0016)	(0.1652)	(0.057)
Environmental_Perception	-0.0106	-0.0117	-0.0323	-0.0118	-0.0438
	(0.7396)	(0.7192)	(0.3704)	(0.7454)	(0.2178)
NGO	0.2218	0.0347	0.1017	-0.101	-0.0233
	(0.3194)	(0.8789)	(0.6858)	(0.6909)	(0.925)
Trust in institutions and perception of risk					
Health_Hazard	-0.2394***	-0.2145***	-0.1603*	-0.1417*	-0.0583
	(0.0000)	(0.0002)	(0.0106)	(0.0252)	(0.3438)
Control	-0.0312	-0.0869.	-0.061	-0.0063	0.0097
	(0.5185)	(0.0787)	(0.2641)	(0.9092)	(0.8561)
Technology	0.0262	0.0631	0.0451	-0.0002	-0.0297
	(0.5897)	(0.2036)	(0.411)	(0.9978)	(0.5827)
Inst_Credibility	-0.049	-0.0694	-0.0137	-0.0548	-0.0323
	(0.4405)	(0.285)	(0.8485)	(0.4498)	(0.6474)
Researchers	-0.0418	-0.0563	-0.0683	0.0504	-0.0542
	(0.4785)	(0.3503)	(0.3055)	(0.4543)	(0.4084)
Bottled_water	-0.3682**	-0.1482	-0.0433	-0.3625*	-0.1749
	(0.0055)	(0.2732)	(0.7718)	(0.0165)	(0.2346)
Beliefs about organoleptic properties (Yuck factor)					
Smell	-0.3303***	-0.259***	-0.1819**	-0.2465***	-0.0776
	(0.0000)	(0.0000)	(0.0036)	(0.0001)	(0.2064)
Turbidity	-0.0109	-0.0216	-0.0374	-0.0861	-0.072
	(0.8288)	(0.6742)	(0.5098)	(0.1334)	(0.1977)
Social justice and ideology					
Politics	-0.0453	-0.0991*	-0.1841***	-0.0722	-0.1636**
	(0.3246)	(0.0352)	(0.0004)	(0.1689)	(0.0014)
Inequality	-0.1416**	-0.1219*	-0.0858	-0.1962***	-0.0379
	(0.0042)	(0.0155)	(0.1232)	(0.0005)	(0.4888)
F-test (p-value)	17 (0.000)	14.8 (0.000)	9.446 (0.000)	10.58 (0.000)	6.792 (0.000)
Adj. R2	0.2547	0.2275	0.1528	0.1697	0.1101

RMSE	1.744	1.7181	1.97	1.989	1.939
N	844	844	844	844	844

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, . p<0.1

[+]Level 1: Ingestion; Level 2: Personal contact; Level 3: House cleaning; Level 4: Pets; Level 5: Uses outside the house.

In the block of sociodemographic variables, the variable *Age* is the most statistically significant in explaining differences in acceptance of use. In general, the degree of acceptance of recycled water use increases with age (Dolnicar et al., 2011). This result has been influenced by the fact that there are few students between the ages of 25 and 30. Moreover, at a younger age just a few years can make a noticeable difference in terms of personal maturity. *Gender* is also a determining factor. Although the relationship is less robust, men are more willing than women to use recycled water, in line with the findings of Hui and Cain (2018) and Gibson and Burton (2014), among others. Additionally, Fielding et al. (2015) confirm that this trend holds for all non-conventional sources. This may be because women are more risk averse than men (Kim et al., 2018). As Miller and Buys (2008) point out, women report having less trust in the technology involved in the recycling process. On the other hand, it should be noted that the *Education* variable is positively related to the acceptance of the use of recycled water. People who are taking engineering or health sciences at university are more willing to use recycled water. Studying for these degrees provides students with a better understanding of how technology can be used to produce quality water through the treatment and purification of raw and recycled water. This finding is in line with the results of Price et al. (2015) and Fielding and Roiko (2014), showing that information and knowledge influence attitudinal responses to recycled water schemes.

In the set of variables reflecting environmental awareness and environmentally conscious behaviour, we also find some relationships to be significant. As reported by Hui and Cain (2018), people who claim to be more aware of environmental issues also show a greater willingness to use recycled water, provided it does not involve ingestion by people or pets. For uses involving ingestion, the psychological “disgust” factor has been identified in many previous studies and has proven to be the hardest to overcome (Dolnicar and Schafer 2009; Wester et al. 2016). Therefore, in the situation presented to respondents, people who self-identified as more environmentally aware would be more willing to use recycled water in order to help reduce water stress in the region and avoid putting more pressure on natural resources, as reported in the studies by Hurlimann (2007) and Ross et al. (2014). Although the variable representing environmental awareness shows the expected sign, no relationship is found to be statistically significant.

In the trust block, the risk perceived by the respondent is the most significant determinant explaining the lower acceptance of recycled water use. Different studies agree that the higher the perceived risk, the lower the acceptance of recycled water (see Dolnicar and Hurlimann, 2010; Gibson and Burton, 2014; Ross et al, 2014; Hurlimann and Dolnicar, 2016). The lack of significance for Level 5 may be due precisely to the fact that the absence of bodily contact reduces the perceived risk. In this vein, Hurlimann and Dolnicar (2010) show that providing information counteracts the perceived risk for moderate contact uses, but the effect is very limited for ingestion. The non-significance of other variables in this block may well be due to the fact that the perceived risk variable is capturing the effect of all these variables. In tests carried out to check for imperfect collinearity some correlations were high but they did not exceed the limit of 0.7. In addition, the variance inflation factor (VIF) test was implemented, yielding a maximum value below 2.82. Both tests indicate that there are no serious collinearity problems among the variables. The lack of previous experience with water recycling schemes may also have a limiting effect on the other variables. Moreover, it can be seen that the perceived risk variable has greater explanatory power when the water is intended for drinking and cooking and when there is direct contact, such as brushing teeth or showering. The variable indicating frequent purchases of bottled water for drinking at home, a proxy for respondents' degree of distrust of the safety and quality of water supplied to the home, is also negatively related to the use of recycled water. In this case, it is only significant for ingestion, both for people (Level 1) and for pets (Level 4). Therefore, those who already distrust the current source of water and opt instead to buy bottled water make up the group of people who are most averse to ingesting recycled water.

As for the variables that capture the yuck factor through the organoleptic properties of the water, odour is significant with the expected sign. As in Dolnicar and Hurlimann (2010), respondents who expect recycled water to smell show less acceptance for uses involving ingestion and direct or indirect personal contact. In line with what Hurlimann and McKay (2007) and Amaris et al. (2020) report, the importance assigned to this characteristic becomes greater the closer the personal contact. The reason for this could be a distrust of water quality and a greater perceived health risk. As noted in point 2.1.4, the sense of disgust arises from a defence mechanism against risks of contagion. This may explain why it becomes more intense the closer the personal contact. We note that the correlation between *Smell* and *Taste* was 0.893 and the VIF value was above 5 (max. 5.734), indicating that there may be a multicollinearity problem. That is why Taste does not appear in the estimates presented. The estimates with *Taste* instead of *Smell* are available in the Supplementary Information.

Ideology is also a predictor of the acceptance of recycled water use. People who claim to have a more right-leaning ideology show less acceptance of the use of recycled water. However, significant differences are only found when the intended use is something other than ingestion, whether by people or by pets. The result aligns with the hypothesis that people with a right-wing ideology are less environmentally aware (Liu et al., 2014). Finally, people who have a greater sense of social injustice are also less inclined to use recycled water. The rejection is greater when it involves ingestion by people or pets.

When we review the results considering the degree of proximity, we see similarities between Level 1 and Level 4, and between Level 2 and Level 3, while Level 5 seems to be an independent case. In situations where the ingestion of recycled water is intended, either by people or by pets, the variables representing the Health Hazard, the Yuck Factor and Social Justice are the most significant. So for ingestion, people who anticipate a greater health risk show more aversion to the use of recycled water, and those who have a greater sense that they are living in a situation of social injustice have a lower acceptance of using recycled water. In Levels 2 and 3, although Health Hazard and the Yuck Factor are determinants of the acceptance of recycled water use, other factors play a comparatively greater role in this regard, such as environmental awareness, political ideology and education.

The importance and impact of the results obtained extend beyond the area on which this research is focused. Like the area under analysis, there are currently many regions of the world that are in a situation of severe water stress (World Resources Institute, 2019; Munia et al., 2020). Moreover, this situation is expected to worsen as a result of climate change, so it is increasingly necessary to plan for the use of unconventional sources, such as reclaimed water (United Nations, 2020). Previous research warns of the low level of acceptance of recycled water for residential uses and, consequently, the need to implement strategies to reduce resistance to using reused water (see recent review by Fielding et al., 2019). While our findings are in line of those of previous research, we obtain more detailed results, which offer valuable information for the design of public policies. The determining factors of the degree of acceptance of reclaimed water differ according to the intended end use. Therefore, the design of public policies aimed at promoting reclaimed water will be shaped by the different residential uses, an issue that we address in the next section, where we set out the conclusions and recommendations of the research.

4.3. Study limitations and future research directions

Concerning limitations, it should be highlighted that the fieldwork was limited to university students aged between 18 and 30 years old. Ideally, the study would have been conducted with a representative sample covering different strata of society and water stress realities. The focus on a particular age cohort does not provide a full picture of society, as previous studies have found mixed evidence on the relationship between acceptance of recycled water and age (Fielding et al., 2019). In addition to the limitation regarding age, the study does not analyse all the areas facing water stress. Therefore, our research can be taken as a case study.

These limitations are important, but should be considered in tandem with the strengths of the research. Looking at the added value of the research points to avenues for future research. Having found that the determinants of acceptance differ according to the use made of recycled water in the home, it is our view that future research on the use of recycled water in the home in other regions of the world should take this fact into account. Moreover, it should be incorporated into feasibility studies for new investments and awareness-raising campaigns on the use of recycled water in the home. The situation under study here, focused on a water basin facing high levels of water stress, may serve as inspiration for other regions experiencing similar problems with water or anticipating such problems in the future (see World Resources Institute 2019; Munia et al., 2020). Finally, the age range of the sample reflects the calls made in United Nations General Assembly Resolution 70/1 for this age group to contribute to the implementation of the Sustainable Development Goals. Nevertheless, the fact that the results of this study refer to a certain age range in a particular area opens the door to future research. Subsequent research efforts should thus be aimed at exploring different situations of water stress in order to gain a fuller picture of how policy can be designed to tackle this issue.

5. CONCLUSIONS

As in other sectors, the circular economy model puts forward viable solutions for the water sector to relieve the pressure on the available resources and guarantee supply. These proposals are of particular interest in regions of the world facing ever more severe problems of water stress. Among other water policy measures, one possibility is direct potable reuse for the domestic water supply. However, while current technology makes this option possible, few countries have implemented it to date. The biggest obstacle to this measure is the low level of user acceptance. As with any circular economy proposal, consumer acceptance is needed for the measure to be successful.

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In this research, we analyse the degree of acceptance of the use of recycled water in households in southern Spain, as well as the determinants of said acceptance. This is a hypothetical scenario as under Spanish law the use of recycled water in the home is currently only allowed in case of a disaster declaration, but it could become a reality in the coming years. The main contribution this paper makes to the literature is that it distinguishes between different uses when analysing the determinants of acceptance of recycled water use.

In line with previous research, we found a low level of acceptance of recycled water use. In general, the level of acceptance decreases as the proximity of people's contact with recycled water increases, and the use of the water becomes more vital for people's lives. Another key contribution is the finding that the determinants of the acceptance of recycled water differ according to the intended use. With respect to ingestion by people and domestic animals, the main determining factors are the perceived risk to health and the yuck factor. For other uses that entail direct or indirect contact with water, environmental awareness, political ideology and education are more important.

A first conclusion is that, if permitted by law, investments in this area would not be very successful in ensuring the use of recycled water in the home. In light of the low level of acceptance reported here, the public may well protest if there were no prior awareness-raising and educational initiatives. We could also expect to see the adoption of defensive measures, such as the purchase of bottled water for drinking and cooking. A second conclusion is that if authorities were to opt for measures to promote the use of recycled water, they should take into account the fact that the reluctance to use recycled water and the determinants of acceptance differ according to the intended use. Two recommendations emerge that can be applied to contexts other than the one under study here. First, before investing in water recycling infrastructure, the degree of consumer acceptance of recycled water use must be assessed. This is not new; it has already been done in other parts of the world. Secondly, the main finding points to the advisability of measures to promote recycled water use that account for the different uses and determinants of acceptance of recycled water. General measures will not be enough. As an example of the importance of our takeaway message, note that the results obtained suggest that environmental awareness campaigns warning of the scarcity of water resources would have no effect on the level of acceptance of the use of recycled water for drinking or cooking.

At least for the case analysed here, in order to help overcome people's aversion to consuming recycled water for essential uses, such as drinking and cooking, measures should first be taken to mitigate the perceived risk to health and also the yuck factor. In these cases, a mix of information campaigns accompanied by practical demonstrations could be useful. The message should be conveyed to the public that there is no risk involved in consuming recycled water, as we have the necessary means and know-how to obtain quality water from recycling. Therefore, the fact that there is a reluctance to consume recycled water and that some people decide to pay for bottled water is illogical. In addition, programmes could be proposed to allow people to gain first-hand experience of the organoleptic qualities of recycled water; that is, activities in which people can see, smell and taste recycled water. Such measures could prevent people from taking the defensive measure of buying bottled water for drinking and cooking.

Second, to reduce resistance to using recycled water for uses not involving ingestion, such as personal hygiene or household cleaning, there should be an appeal to environmental values with educational programmes for non-expert audiences. Shining a light on the issue of water stress and the environmental problems associated with the overexploitation of aquifers or the failure to respect the ecological flow of rivers could foster a greater sense of the need for sustainable water use. In turn, it could reduce the resistance to consuming recycled water for uses where the yuck factor and perceived health risk are less relevant determinants. Educational programmes should seek to explain as simply as possible the technology that can be used to produce recycled water and share experiences from other places in the world where recycled water is used in the home.

Further research on the subject is called for. First, there is a need for research similar to this proposal focusing on other areas of the world suffering from high levels of water stress. Cultural differences can lead to divergent results and conclusions. Second, research based on in-depth interviews could be conducted. While quantitative analyses provide a broad overview of the subject, qualitative studies would allow a deeper exploration of particular aspects that could help in the design of specific measures to reduce resistance to the use of recycled water in the home. Finally, it is necessary to test in different contexts the effectiveness of measures aimed at promoting the consumption of recycled water for domestic uses.

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