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Personal Involvement in Greywater Reuse: A Study within a French Context

Colin Lemée [1*], Oscar Navarro [1], Gaelle Bulteau [2], Ghozlane Fleury-Bahi [1]

[1] *Laboratoire de Psychologie des Pays de la Loire, Université de Nantes, FRANCE*
[2] *Centre Scientifique et Technique du Batiment, FRANCE*

* CORRESPONDENCE: colin.lemee@univ-nantes.fr

ABSTRACT

Population growth and the unknown consequences of climate change emphasize the need for alternative water sources. Greywater reuse is one of the main options available but such alternatives are poorly accepted by the public. In this research, our aim is to understand how greywater reuse is accepted, with a major emphasis on risk and personal involvement. An online questionnaire was completed by 252 people. The participants lived in the city of Nantes (France). To determine the possible effect of personal involvement and risk perception on greywater acceptance, a Bayesian linear regression was realized in order to determine with certainty the most probable model. Results show that acceptance of greywater reuse is significantly predicted by perceived personal exposure to water shortages and droughts. It also appears that perceived health risks related to greywater reuse work as a brake to greywater reuse acceptance, as well as age and the possession of a rainwater recovery system. Results are discussed in terms of how to inform and involve the population in greywater reuse by reducing risk perception and promoting personal involvement.

Keywords: Greywater reuse, water issues, personal involvement, risk perception, Bayesian multiple regression

THEORETICAL FRAMEWORK

General Context

There is a growing interest in the capacity of people, institutions and communities to manage their water resources more efficiently, in both the academic and professional field (Ivey, Smithers, de Loë, & Kreutzwiser, 2004; Noimunwai, Singhruck, & Sompongchaiyakul, 2018). Indeed, population increase and predictions of fluctuations in rainfall due to climate change have emphasized the need to use existing water resources more efficiently (Dolnicar & Schäfer, 2006). Even if the long-term effects of climate change on the availability of water are not known, we do observe an increasing variability of water resources as well as an increase in the frequency and severity of severe weather events, including drought (Dessai & Sims, 2010; IPCC, 2007). In this context, the development of alternative water sources has gained growing attention from politicians, especially in countries already impacted by water shortage (Dolnicar & Schäfer, 2006). A recent report from the European Union (EU) about water needs in Europe pointed out the increasing demand and expressed climate change concerns (European Commission, 2012), which are driving the EU to rely more on alternative water sources.

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Among these alternatives, wastewater reuse is one of the main ways of reducing potable water requirements in urban areas. In the majority of cases, however, not all domestic wastewater is treated and reused: only greywater (Friedler, 2004) dishwasher water and kitchen sink water are, but the latter are often excluded because they are putrescible.

Before its treatment, greywater may be microbiologically and chemically polluted, with significant concentrations of bacteria, viruses, organic matter and surfactants (Friedler, 2004). Its treatment and disinfection are thus essential prior to reuse. In this paper, the term “treated greywater” will refer only to greywater that has been treated by an individual or a collective treatment system and that can be used for purposes such as toilet flushing or garden watering, which do not require potable water.

Regarding greywater reuse, whilst greywater treatment systems already exist and it is technically possible to reuse greywater, the reliability of these systems is not sufficient to guarantee their acceptance (Nielsen, 1994). Indeed, a review of the literature about greywater reuse highlights the need to gain better understanding of the reasons why people would or would not agree to reuse greywater. In particular, positive public perception of greywater reuse and risk perception appear to be key factors for successful introduction of wastewater reuse projects (Dolnicar & Hurlimann, 2011; Dolnicar, Hurlimann, & Grün, 2011; Dolnicar, Hurlimann, & Nghiem, 2010; Friedler & Lahav, 2006; Nancarrow, Leviston, Po, Porter, & Tucker, 2008).

In conclusion, beyond the theoretical and technical viability of greywater reuse systems, authorities still need proof that on-site greywater recycling technologies are safe, technically practicable and economically viable (Hourlier et al., 2010). The public’s attitudes and perceptions regarding greywater recycling are also of great importance, as negative public perception can be a major barrier to the implementation of recycling technologies and the use of the treated water they produce. Risk perception, perceived vulnerability and positive public perception are key factors for the acceptance of greywater reuse systems.

Risk Perception

Health risks related to wastewater reuse are always subject to uncertainty among the scientific community as they depend on a diversity of situations. The occurrence of human exposure, the nature and concentrations of pollutants, the reliability of treatment processes and the final purpose of the treated water are some of the factors to be considered. Consequently, it is not surprising if the public’s perception of risks does not match expert assessment. Regardless of the strength of scientific evidence, public opposition can cause wastewater reuse projects to fail (Friedler & Lahav, 2006; Uhlmann & Head, 2011) or to be cancelled (Dolnicar & Schäfer, 2006; Ross, Fielding, & Louis, 2014). There are many examples in the USA and Australia (Po, Nancarrow, & Kaercher, 2003; Ross et al., 2014), and Marks, Martin and Zadoroznyj (2006) observe that the scientific-objective way of considering greywater reuse cannot be applied to understanding public acceptance of wastewater recycling. Not only does risk perception play a significant role in shaping mitigation policies when it comes to water resources management, it is also central to take it into account in order to influence public knowledge and opinion, as well as promote alternative water sources (Lujala, Lein, & Rød, 2015).

According to Callaghan, Moloney and Blair (2012), the resistance to recycled water must be considered as psychological rather than technological, as water quality standards are applied in every greywater reuse project. In other words, there are no qualitative differences between regular tap water and treated greywater, except in terms of origin and label (Callaghan et al., 2012): risk perception issues are still largely responsible for community acceptance or rejection of water reuse (Duong & Saphores, 2015). It is commonly accepted in social psychology that risk perception by non-experts is subjective and will differ from experts’ points of view (Slovic, 1987).

In traditional models, risk assessment is considered as a complex process whose aim is to maximize earnings and minimize losses (von Neumann & Morgenstern, 2007), but these models are unable to account for how non-experts perceive complex environmental risks. In addition to these models, the psychometric paradigm seeks to take into account and quantify individuals’ subjective opinions about risks (Slovic, 1987).

These research studies have led to the identification of three higher order factors: the dangerousness or gravity of the risk, knowledge of risk (related to probability of occurrence, novelty and temporality) and perceived risk exposure (number of victims). The extent to which the risks would be assessed on these three characteristics (Fear, Knowledge and Risk Exposure) would explain most of the risk assessment variabilities (Slovic, 1992) according to an individual’s psychological, social, cultural and political determinants (Fischhoff, Slovic, Lichtenstein, Read, & Combs, 1978; Sjöberg, Moen, & Rundmo, 2004; Slovic, 1987).

Personal Involvement

Greywater reuse is not widespread in Europe and hence is poorly understood. In recent years a few projects have been conducted in Great Britain, Germany and Spain (Domènech & Vallès, 2014), but have dealt mostly with public buildings or with people who agreed to move into houses designed to test greywater reuse sustainability. In France, some greywater reuse experimental installations have been authorized. In addition, the practice is tending to develop as part of the construction of certified high quality environmental buildings (ANSES, 2015).

Moreover, Dessai and Sims (2010) observed the existence of several barriers to water behavior change, including a lack of accessible information, a lack of knowledge concerning alternatives and a perceived lack of institutional commitment. In this perspective, we chose to focus on attitudes that would act in favor of adopting greywater reuse systems rather than on attitudes that would act as a brake to adopting them. Thus, we introduced personal involvement towards water management issues and, in particular, towards water shortages and droughts. As theorized by Rouquette (1997), personal involvement can be defined as a predisposition to action and functions as an indicator of the possibility, pertinence and efficacy of action as appraised by the individual (Flament & Rouquette, 2003). It varies according to three independent dimensions: the perceived personal exposure, the value placed on the issue and the perceived capacity to act toward it (Rouquette, 1997).

Thus, with regard to water shortages, personal involvement is highest when an individual feels personally affected by the question (perceived personal exposure), when they consider the matter as important (value placed on the issue) and when they feel able to do something about it (perceived capacity to act) (Ernst-Vintila, Delouvée, & Roland-Lévy, 2011).

The pertinence of personal involvement in the field of environmental psychology has already been demonstrated (Ernst-Vintila et al., 2011; Gruev-Vintila & Rouquette, 2007; Lemée, 2017; Michel-Guillou & Moser, 2006). According to Kalali (2017), even though water management issues are perceived as interesting and important, it is necessary to help people build a more relevant relationship to the environment, both socially and personally, to help them change their habits. In this way, personal involvement can play a decisive role in the adoption of pro-environmental behaviors (Michel-Guillou & Moser, 2006) and especially, it can help people to accept greywater reuse as a solution to water issues.

Indeed, personal involvement may act as a mediator between the perception of an object and the adoption of pro-environmental behaviors (Michel-Guillou & Moser, 2006). Applied to greywater reuse acceptance, high personal involvement in water management issues, and in particular regarding water shortages and droughts, could act as a driving-force for greywater reuse acceptance. One can wonder if it is true that the more an individual places value or feels personally exposed to water shortages and droughts, the more they would accept greywater reuse as a solution.

Objectives

In a context of uncertainty concerning the future of water resources, we chose to focus on people's perceptions of water management issues and droughts, which is likely to be a significant factor for acceptance of alternative water sources and could help to overcome the barriers to behavioral change, especially in Europe where there appears to be a lack of studies on this subject (Duong & Saphores, 2015). In particular, we focused on greywater reuse as it appears to be one of the main solutions to water shortages and droughts.

Our aim was to establish how risk perception and personal involvement may play a role in greywater reuse acceptance. Regarding risk perception, the focus was placed on the two principal dimensions of gravity and perception of occurrence according to the psychometric paradigm (Slovic, 1992). We expected that risk perception would act as a brake to greywater reuse acceptance and that personal involvement in risk management issues and droughts could act as a possible driving-force for greywater reuse acceptance.

METHOD

Participants

A quantitative survey was conducted among a French convenience sample of inhabitants of a western French metropolitan area. The study took place in Nantes, France's sixth largest city, located in mainland France and comprising a metropolitan area of about 900,000 inhabitants (INSEE, 2012). The sample was composed of 252 participants aged 19 to 78 years (M = 39, SD = 14) with 138 women (M = 38.8, SD = 14) and 114 men (M = 39, SD = 14), which is representative of Nantes's population. Details of the sample are presented in **Table 1**.

Procedure

The data were gathered via an online questionnaire, using Limesurvey. Participants were introduced briefly to the survey and were given a definition of the technical terms used in the research (e.g. greywater, treated greywater). The questionnaire remained online throughout September and October 2014. As our aim was to establish as broad a panorama as possible of opinions about greywater reuse, participants in rural and urban areas were recruited.

To ensure maximum research visibility, the link to the questionnaire was sent to local associations, except for environmental associations which were discarded because of possible bias in the results. It was also published on the homepage of Nantes Métropole's website.

Materials

The online questionnaire was composed of three different parts: greywater acceptance, personal involvement and perceived risk and vulnerability.

Part 1 – Greywater acceptance: Greywater reuse acceptance was assessed by a seven-item scale that took into account every possible domestic purpose: garden watering, vegetable garden watering, vehicle washing, toilet flushing, house cleaning, clothes washing and personal care. For each use, participants were asked to rate on a 5-point scale whether they were absolutely ready or not at all ready to use greywater for these purposes. A mean score of acceptance was calculated ranging from 1 to 5: the higher the score, the higher the level of acceptance. Internal consistency was good (Cronbach's alpha = 0.83).

Part 2 – Personal involvement in water shortages and droughts: In order to measure the participants' personal involvement, we developed a three-dimensional scale, inspired by the previous works of Demarque, Lo Monaco, Apostolidis and Guimelli (2011), Lheureux, Lo Monaco and Guimelli (2011) and Navarro et al. (2016) in the field of environmental psychology. Two mean scores were calculated, ranging from 1 to 5, for the following two dimensions: "perceived personal exposure" (two items: *I feel seriously concerned about water shortages*; *For me, water shortages are a major topic*) and "value placed on the issue" (two items: *Water shortages are a real problem*; *Water shortages are irreversible*). Perceived possibility of action was measured with one single item (*At my level, I can take action to reduce the problems related to water shortages*).

Part 3 – Perceived risk: gravity and probability of occurrence: In order to measure perceived risk gravity, the participants had to assess the risk related to greywater reuse on a five-point scale for themselves, their relatives, vulnerable people (with an item associated to each kind of vulnerable individual: children, elderly and sick people) and for the environment. An overall perceived gravity score was calculated for this five-item scale, ranging from 1 to 5. Internal consistency was good (Cronbach's alpha = 0.90).

To measure perceived probability of occurrence, a list of five potential risks was established, based on the study carried out by ANSES (French National Agency for Sanitary Safety, 2015). These threats covered every possible disease related to greywater (by ingestion, inhalation and physical contact). One item related to soil pollution and one item related to interconnection between treated greywater and drinking water networks were also included. The participants were asked to rate these potential threats on a 5-point scale (5 = very high probability of occurrence). An overall perceived probability of occurrence score was calculated and internal consistency was verified (Cronbach's alpha = 0.73).

Questions were finally asked regarding participants' current domestic experience of alternative sources of water (rainwater recovery system or the use of well water).

Data Analysis

In order to attain our main objective and to determine the possible effect of personal involvement and risk perception on greywater acceptance, a Bayesian linear regression was realized in order to determine with certainty the most probable model. The outcome variable is the score of greywater acceptance, and eight independent variables were included in the model: perceived risk gravity, perceived probability of occurrence, perceived personal exposure, value placed on the issue, perceived capacity to act, age, gender, rainwater recovery system, the use of well water.

Table 1. Demographic characteristics of the sample and descriptive statistics

			Perceived Risk Gravity		Perceived Probability of Occurrence		Greywater Acceptance		Capacity of Action		Perceived Personal Exposure		Value Placed on the Issue	
	n	**%**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**
Men	114	45.2	2.87	*0.60*	2.63	*0.77*	3.75	*0.70*	3.31	1.3	3.55	0.94	3.44	0.76
Women	138	54.8	3.08	*0.78*	2.61	*0.83*	3.72	*0.71*	3.71	1.0	3.73	0.8	3.68	0.72
[20;30[	84	33.3	3.07	*0.60*	2.55	*0.75*	3.69	*0.69*	3.04	1.4	3.19	0.96	3.5	0.69
[30;40[	57	22.6	3.03	*0.80*	2.57	*0.88*	3.84	*0.54*	3.86	1.2	3.45	0.99	3.43	1.09
[40;50[	53	21	2.97	*0.60*	2.65	*0.75*	3.76	*0.71*	3.74	1.0	3.85	0.91	3.76	0.72
[50;60[	36	14.3	3.14	*0.78*	2.96	*0.85*	3.59	*1.03*	2.38	1.0	3.46	0.85	3.44	0.48
[60;+	22	8.7	2.32	*0.58*	2.37	*0.68*	3.75	*0.43*	3.58	1.0	4.17	0.91	3.67	0.65
Total	**252**		2.96	*0.70*	2.64	*0.78*	3.72	*0.71*	3.53	1.2	3.65	0.87	3.57	0.75

The Bayesian linear regression takes into account two aspects in the evaluation of the quality of a regression: its quality of adjustment to the data (measured by the likelihood) and its complexity (measured by its number of unknown parameters). The Bayesian linear regression leads to retaining the solution that achieves the best compromise between quality of fit and parsimony of the model. Indeed, it introduces a penalty term for the number of parameters in the model. Every combination was tested using this method and all combinations were compared to a null model on the basis of the thresholds determined by Lee and Wagenmakers (2014) for the estimated Bayes factor.

All analyses were performed using the software JASP.

RESULTS

The mean scores for all the different measures are presented in **Table 1**.

A Bayesian multiple regression was performed in order to determine the best model among all the possible models that would predict the willingness to reuse greywater on the basis of personal involvement, perceived risk, age, gender and the possession of a rainwater recovery system or of a well. The best possible option considers that the acceptance of greywater reuse is partly explained by the "perceived personal exposure" dimension of personal involvement, the different dimensions of perceived risk (i.e. probability of occurrence and gravity) as well as age and rainwater recovery system possession (BF10 = 56000.10). Such Bayes factor indicates that this solution is 56,000 times more probable than the null model. According to Lee and Wagenmakers (2014), a Bayes higher than 150 suggests decisive evidence for the alternative hypothesis rather than the null hypothesis.

A linear multiple regression was conducted to predict greywater reuse acceptance, considering that the best possible model had already been identified using Bayes factor. This model predicts greywater reuse acceptance based on age, perceived personal exposure to water shortages, perceived gravity, perceived risk probability of occurrence and possession of a rainwater recovery system.

The results of the regression indicated that these five predictors explained 15% of the variance (R^2 =.15, F(6.245) = 8.66, $p < .001$). Our predictions are partly confirmed. As we expected, greywater reuse acceptance is significantly predicted by perceived personal exposure to water shortages and droughts (β = .26, $p < .001$). It also appears that the perceived risk gravity for oneself, others and the environment is a brake to greywater reuse acceptance (β = -.18, $p < .05$), as is perceived risk probability of occurrence, for which we observe a tendency (β = -14, p = .09). Age also appears to be a brake to greywater reuse acceptance (β = -.15, $p < .05$) as well as the possession of a "rainwater recovery system" (β = -.15, $p < .05$).

Value placed on the issue and perceived capacity to act, which are two dimensions of personal involvement, did not appear to have a significant impact on greywater reuse acceptance. This is also the case for gender and well water usage. The detailed results are presented in **Table 2**.

Table 2. Means, standard deviation and regression analysis summary of greywater acceptance reuse predictors

Independent variables	M	SD	β	t	*p*
Perceived personal exposure to water shortages	3.65	0.87	0.26	3.91	***
Perceived risk gravity	2.64	0.78	-0.18	-2.42	*
Age	39	14	-0.15	-1.57	*
Rainwater recovery system possession			-0.15	-1.84	*
Perceived probability of occurrence	2.96	0.7	-0.14	-1.69	.09
Value placed on the issue	3.57	0.75	0.001	-0.17	*0.87*
Perceived capacity to act	3.53	1.2	-0.023	-0.6	*.55*
Gender			-0.05	-0.86	*.39*
Possession of a well			-0.1	-1.52	*.11*
F	8.66				
R^2	0.15				
N	252				

Note. 1. Dependent variable: Grey water acceptance reuse. 2. The entries are standardized regression coefficients. 3. : * significant at .05. ** significant at .01. *** significant at .001

DISCUSSION

The aim of the study was to identify how perceived health risk related to greywater reuse and personal involvement might play a role in greywater reuse acceptance in a French context.

Indeed, an important personal involvement in water management issues, and in particular water shortages and droughts, could promote greywater reuse acceptance. Results show that acceptance of greywater reuse is strongly and positively related to perceived personal exposure to water shortages and droughts. The more an individual feels personally exposed to water shortages and droughts and involved in the issue, the more it appears they accept greywater reuse as a solution. Although, it appears that perceived personal exposure is the only dimension of personal involvement that predicts greywater acceptance. Value placed on the issue and perceived possibility to act were not identified as predictors of greywater acceptance. It is a surprising result. Indeed, this would mean that greywater acceptance does not vary with the perceived importance of water issues neither with perceived possibility to act.

It is therefore possible that the participants did not make the connection between water issues and greywater reuse behaviors. The link between water issues and the reuse of greywater is not necessarily known and clear. Based on these results, it seems necessary to provide more accurate information about greywater reuse in order to introduce it as a possible solution to water management issues, and to emphasize its importance as a solution at a local level.

We also identified several brakes to greywater reuse acceptance. First, individuals who possess a rainwater recovery system appear to be less likely to use greywater. Two different aspects should be considered regarding this particular result. Indeed, it is possible that the rainwater recovery system is seen as a competing system. Why use greywater and spend money on another installation if the solution lies in the use of rainwater? Although, these two different kinds of systems answer two different kinds of needs (Dixon, Butler, & Fewkes, 1999; Li, Boyle, & Reynolds, 2010). In particular, in the case of apartments or individual housing without gardens, rainwater recovery can be especially difficult and limited. Also, it is certain that rainwater recovery can reduce water consumption, in particular for certain uses, mainly watering gardens or crops, but it is not a solution in the case of long periods of water distress. The reuse of greywater makes it possible to reduce water consumption in any period and to cover more diversified uses. The observed results for rainwater recovery could be seen here as a consequence of a lack of information about these different systems and their benefits.

However, the principal brakes to greywater reuse are related to the health risks associated with this water management solution. This confirms the main results observed in the literature (Duong & Saphores, 2015; Lujala et al., 2015). The higher the perceived probability of occurrence of some threats and diseases, the less positively an individual will consider engaging in greywater reuse as a solution. Besides the technical side of the question, greywater reuse constitutes a major environmental health issue. Indeed, as identified in this study, its acceptance by the population is closely linked with the perception of greywater as a potential vector of diseases and soil pollution.

Greywater contains particulates and organic matter, and is contaminated by micro-organisms including pathogens and physicochemical contaminants (ANSES, 2015). To date, scientific data are insufficient to characterize in a rigorous and exhaustive manner the hazards associated with the different physicochemical and microbiological contaminants of greywater, and the levels of exposure related to different uses and situations. Furthermore, the use of greywater at home requires the installation of a separate water distribution network, and many tests highlight the fact that the presence of a non-potable water system within the habitat could be a major source of risk (ANSES, 2015). Thus, under these conditions, a regulatory framework of the conditions of collection, storage and treatment of greywater is necessary to reduce the health risks of exposed people.

These conditions must be guaranteed and the population must be informed and trained to minimize the risks associated with the use of greywater and the presence of a non-potable water system in the building. In this way, information should reduce the level of perceived risk and anxiety by increasing the level of perceived control (Domènech & Sauri, 2010; Po et al., 2003).

Moreover, our results show a negative effect of age on greywater acceptance. Such results are sometimes observed in the literature but they remain ambiguous. As spotted by Dolnicar et al. (2011), there is no consensus between greywater acceptance and demographic variables, especially for age.

In conclusion, to facilitate and promote greywater reuse acceptance, the first step is to increase the feeling of concern related to water shortages and droughts by providing information related to the effects of climate change on water resources locally and globally, for example. This type of information seems necessary to increase people interest for water issues (and therefore, the value they placed on these issues), and to give them a higher perceived possibility to act towards water issues at a first time. Though, it seems necessary to introduce greywater reuse systems as a possible solution to these water issues, as this solution does not seem to be clearly known and understood.

However, in parallel, it is necessary to reduce the perception of health risks by guaranteeing good conditions of collection, storage and treatment and by highlighting the fact that these conditions minimize the risks. These actions should increase the personal involvement of people regarding water issues, and facilitate their acceptance of greywater reuse as an alternative water source, and diminish their rejection of greywater reuse systems.

This study presents a limit regarding the fact that, while our sample is representative of Nantes' population, the participants lived in areas and buildings which were not involved in greywater reuse projects, because our objective was to identify the perceptions of potential users. Future research should consider actual users of experimental projects and installations in order to analyze their varying appropriation and acceptance of this potential solution for water management. However, these results should complete the present ones by contributing to identifying brakes and facilitators in the appropriation of greywater reuse solutions.

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Disclosure statement

No potential conflict of interest was reported by the authors.

Notes on contributors

Colin Lemée – Laboratoire de Psychologie des Pays de la Loire, Université de Nantes, France.

Oscar Navarro – Laboratoire de Psychologie des Pays de la Loire, Université de Nantes, France.

Gaelle Bulteau – Centre Scientifique et Technique du Batiment, France.

Ghozlane Fleury-Bahi – Laboratoire de Psychologie des Pays de la Loire, Université de Nantes, France.

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