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Obstacles to the reuse of treated wastewater: an analysis of the Puy-de-Dôme region using the Q method

Déprés Christophe, Pauline Pedehour, Léa Buffet, Alioune Toure, Christine Lambey Checchin

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Abstract :

The aim of this study is to investigate perceptions of stakeholders about obstacles to the reuse treated wastewater. We conducted a Q-study and interviews with 14¹ stakeholders in the Puy-de-Dôme region where projects of water reuse are on stage. We found out four main perspectives. While for some individual operational financial and non-monetary barriers are important, for some others, health and pollution, psycho-socio obstacles or management and political obstacle can compromise the implementation of these projects. This study also sheds lights on consensus and disagreements between actors and generally contributes to understanding how stakeholders perceive water reuse projects and their potential obstacles.

Introduction: research issues and motivations

Climate change is altering the amount of rainfall and its distribution in time and space. Coupled with the artificialisation of soils and the resulting reduced infiltration, this is tending to lead to a reduction in the underground and surface reserves available for human use. At the same time, human demand for freshwater is growing at a rate of 1% a year. As a result, the pressure on water resources is growing and competition between public and private uses (such as irrigation in agriculture) is significantly increasing.

In this context, the water reuse is frequently presented as one of the solutions to the problem of the increasing scarcity of available resources (Cerema, 2020). While France currently reuses less than 1% of its wastewater, countries such as Israel (80%), Spain and Italy have active policies in this area. In France today, for health safety reasons (decree of 10 March 2022), reuse is restricted to a limited number of uses, such as agricultural irrigation and green spaces. According to Cerema (2020, see Bilan des Assises de l'eau), in France, *'the objective is to significantly increase the use of treated wastewater, the volume of which currently stands at 1.1 billion cubic metres per year, and thus offset water extraction'*. As part of the Water Plan, the French government is aiming to set up 1,000 water reuse projects by 2027.

However, between 2017 and 2022, the number of abandoned water reuse projects increased from 17 to 26, while the number of projects under consideration between 2017 and 2022 continued to rise, from 29 to 136. Data confirm the interest and willingness of stakeholders in

¹ Complementary interviews will be done by the time of the conference.

water reuse projects and the difficulties in carrying them out, although there are disparities between Departments (Lathune, Bruyere 2023).

In this tensed context, our research question concerns the obstacles to the implementation of water reuse projects. Our general hypothesis is that these obstacles are of several kinds: economic, political, socio-technical, regulatory, health-related and psycho-cultural (Morris et al., 2021). The study focuses on stakeholders in the Departement of Puy de Dôme (63) and their perception of the obstacles to set up projects. To answer the research question, we used the Q methodology to analyse the perceptions of stakeholders involved in water reuse projects.

The initial results of this exploratory study highlight four factors associated with obstacles to change and significant differences in the perception of these obstacles between the stakeholders interviewed².

Our paper is organised as follows. The first part deals with the context of water reuse, describing a highly regulated practice involving a multitude of local players that is struggling to get off the ground. The second part sets out the research approach, survey method and data processing. The results are then presented, analysed and put into perspective in a concluding section devoted to discussion.

Research context

Water reuse, an innovative solution to growing tensions?

After initial use, water taken from the natural environment is referred to as 'waste'. This water, used and contaminated by human activities, must be treated before being discharged into the environment or reused. Wastewater can come from a variety of sources, including domestic, industrial, rainwater and agricultural water. Water reuse involves collecting, treating and purifying wastewater so that it can be reused directly before being discharged into the environment. Water reuse is one of the possible solutions for meeting specific regional challenges or adapting to seasonal water shortages, whether in terms of quantity or quality.

² Complementary interviews will be done by the time of the conference.

Water reuse is part of the small water cycle (Figure 1). This cycle includes blue water, which is water taken from the natural environment (rivers, lakes, groundwater), and grey water, which comes from domestic or industrial uses and can be reused after treatment. Water reuse is a regional approach that aims to reuse grey water after appropriate treatment to make it compatible with human uses such as crop irrigation or green spaces. In theory, water reuse avoids drawing further on blue water reserves and can be likened to a circular economy process (Institut National de l'Economie Circulaire, 2017).

The water resource is reused by completing the production and consumption cycles, within certain limits, however, since reuse in irrigation does not offer the possibility of a perfect completion of the cycle (due in particular to evaporation). Seen from this angle, water reuse would encourage sobriety and savings in water resources. In fact, this is what the government's 2023 Water Plan is encouraging, by setting a target of a 10% reduction in water abstraction by 2030, thereby encouraging more reasoned and efficient water management. Water reuse would therefore be part of a sustainable management of water resources, a resource that is becoming increasingly scarce, particularly as a result of climate change, population growth, rapid urbanisation and intensive industrial activities.

But this view is still being debated. While the government's Water Plan explicitly emphasises water reuse as a way of meeting the challenge of dwindling resources, the recent report from the Cour des Comptes disagrees. For the French government, *'the objective is to significantly increase the use of treated wastewater, the volume of which currently stands at 1.1 billion cubic metres per year, and thus offset the extraction of water'*. The Water Plan aims to set up 1,000 water reuse projects by 2027. However, according to the Cour des Comptes (2023), *'the reuse of treated wastewater is costly and comes up against health considerations. This solution*

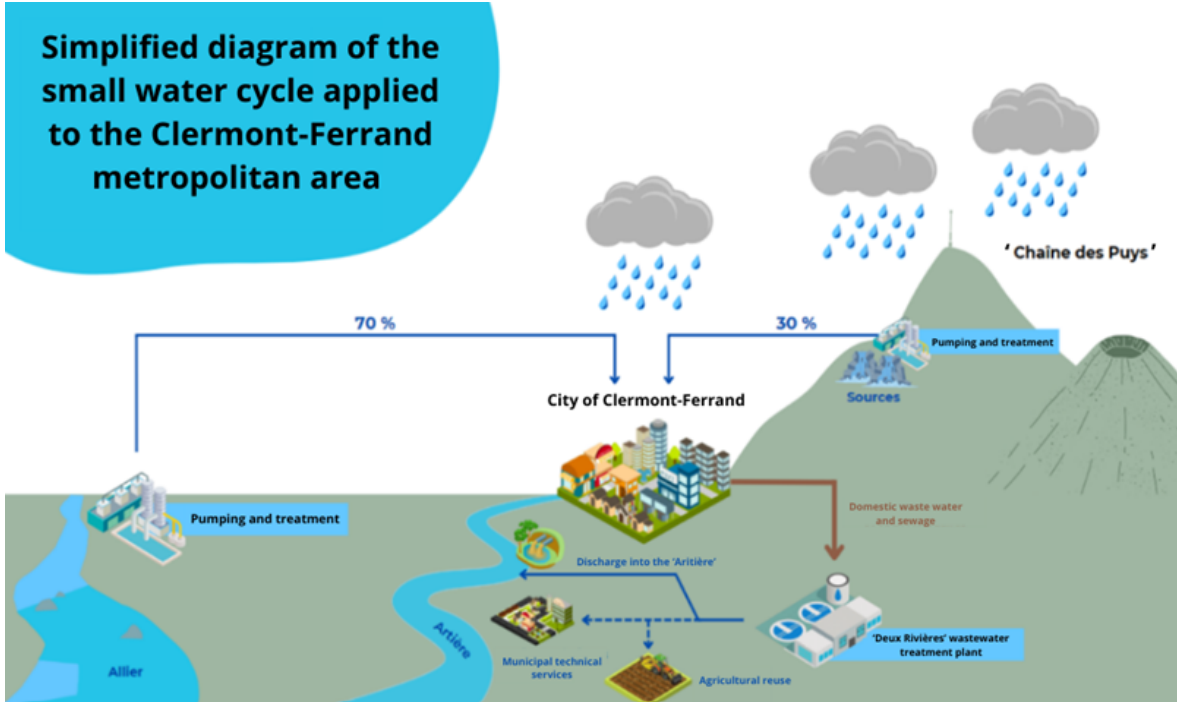


Figure 1: The small water cycle in the Clermont-Ferrand metropolitan area
 Source : Adapted from Bez, M., Erhardt, B., Le Grart, A., Roger, L. VetAgro, 2023

can be developed in coastal areas, where it has less impact on the functioning of watercourses, but has little potential elsewhere’.

Recent developments in the regulatory framework for water reuse

In France, regulations on water reuse started in the early 1990s: circulars dated 22 July 1991 and 3 August 1992, supplemented in 2010 and 2014 by two decrees that set out the conditions for using water from urban wastewater treatment for irrigating crops and green spaces. The 2010 decree classifies treated wastewater according to their sanitary quality (ARS, 2014), with this classification being from A to D. Water of quality A, for example, can be used for all types of irrigation, whereas water of quality D can only be used to irrigate coppice, in short rotation only (see appendix 1).

Since 2020, regulations on water reuse have evolved significantly, driven by Europe and in response to health and environmental challenges. At European level, the practice is governed by Regulation (EU) 2020/7415 of the European Parliament and of the Council of 25 May 2020 on minimum requirements for water reuse (Regulation (EU) 2020/741, 2020). In support of this regulation, decree no. 2022-336 of 10 March 2022 on the uses and conditions for reusing treated wastewater sets out the conditions for implementing reuse of wastewater in France, in line with European requirements. It specifies water quality criteria, monitoring procedures and authorisation procedures for the use of this water, mainly for agricultural irrigation and watering green spaces. The decree aims to ensure the protection of public health and the environment while promoting sustainable management of water resources. It also establishes safety measures to minimise the risks associated with this practice (Decree no. 2022-336, 2022).

The Water Plan, launched in March 2023, is part of the sober, resilient and concerted management of water. The plan includes 53 specific measures designed to meet the challenges of water sobriety and availability. The plan is a response to the growing impact of climate change, such as recurring droughts, increasing scarcity of water resources and more frequent periods of water stress.

In this context, decree no. 2023-835 of 29 August 2023 aims to simplify the authorisation procedure for uses of treated wastewater (Decree no. 2023-835, 2023). According to this decree, water reuse requires an authorisation issued by the prefecture. The use of treated wastewater is prohibited for food, hygiene and amenity purposes (swimming pools, decorative fountains open to the public and watering green areas in buildings) and in residential premises, medical and social establishments, schools and other establishments open to the public (Decree no. 2023-835, 2023). More recently, the orders of 14 and 18 December 2023 set out the requirements applicable to the use of treated wastewater for watering green spaces open to the public and for irrigating agricultural crops. The orders of 21 and 28 December 2023, for their part, aim to simplify the implementation of water reuse projects, by doing away with the conditioning of the quality of mud produced by wastewater treatment plants, while maintaining a rigorous framework of compliance and quality, in order to guarantee the protection of public health and the preservation of natural ecosystems.

All in all, water reuse appears to be a highly regulated activity whose legal framework has recently evolved. The rules with which project leaders must comply impose a number of technical constraints and potentially lengthy and costly administrative procedures. On the other hand, the regulations aim to strengthen controls on health and the ecological/environmental impacts of water reuse, and are likely to increase confidence between stakeholders and reduce the uncertainties relating to health and the risks associated with setting up projects.

Water reuse stakeholders: a diversity of stakeholders to be coordinated

In its 2020 French panorama of water reuse, Cerema Institute shows that one of the factors in the success of projects is the ability to adopt *'a concerted approach with all the stakeholders in the area'*. This so-called integrated approach is based on a forward-looking diagnosis of the challenges facing the territory and knowledge of the diversity of the stakeholders involved (Franck-Neel 2020).

Stakeholders can be distinguished according to their degree of commitment, whether strong or weak (see appendix 2).

Among the stakeholders most involved are the competent local authorities and their delegates, who are responsible for operating the wastewater treatment plants. These are the main stakeholders behind water reuse projects. Their role is to assess water requirements and study the technical and economic feasibility of the project, in compliance with health and environmental standards. They are also responsible for designing water treatment infrastructures, choosing appropriate technologies and establishing distribution networks.

Institutional stakeholders (public) are also heavily involved and play a crucial role. The Water Agencies finance the projects. Decentralised government services, in particular the Departmental Territories Directorate, coordinate the examination of applications for authorisation and the monitoring of facilities. The Regional Health Agencies and the Regional Directorates for the Environment, Planning and Housing provide targeted expertise on health standards and the impact of projects. The Regional Directorates for Agriculture provide information and coordinate services. As for the chambers of agriculture, they play an interface role with the farming profession benefiting from the water reuse service.

Finally, users or beneficiaries (farmers, golf courses, local authority technical services) and other stakeholders, such as environmental associations, businesses, etc., influence the way in which projects are accepted and deployed. They are the main beneficiaries of water reuse projects. This commitment is essential to ensure the social acceptability of projects, and to this end they must be involved in public consultations, express their concerns or suggestions and ensure that projects meet their needs. These same stakeholders can educate and raise awareness to ensure greater acceptance of these practices, and train people on the health, environmental and economic issues involved. Their feedback on the effectiveness of reuse systems and water quality is crucial to continually improving processes.

Coordination between these various stakeholders relies on mechanisms of dialogue, consultation, and collaboration. Project leaders must regularly engage with institutional stakeholders to obtain the necessary authorisations and ensure compliance with the regulatory framework. At the same time, they need to communicate with users and local populations to ensure that the projects address real needs and are well accepted by the community. Institutional stakeholders, in addition to their regulatory role, can also facilitate these exchanges by organising discussion platforms or providing financial and technical support to project leaders.

In this tensed context, our research question concerns the obstacles to the implementation of water reuse projects. Our general hypothesis is that these obstacles are of several kinds: economic, political, socio-technical, regulatory, health-related and psycho-cultural (Morris et al., 2021). The study focuses on stakeholders in the Departement of Puy de Dôme (63) and their perception of the obstacles to set up projects. To answer the research question, we used the Q methodology to analyse the perceptions of stakeholders involved in water reuse projects.

Methodology and data collection

We use Q methodology to reveal discourses on barriers that may compromise the implementation of water reuse projects. This method, developed by the psychologist William Stephenson (1953), aims to identify distinct points of view on a given topic and areas of consensus and disagreement between various stakeholders in order to elicit their preferences (Durning et al., 1990). The main strength of this method is that it combines qualitative and quantitative approaches. It explores profound subjectivity and beliefs of participants through interviews but also relies on rigorous statistical and mathematical analysis of the data, which sets it apart from other more traditional qualitative surveys. This method has proved its worth in helping to set up new projects and to understand the levers and barriers to their implementation for a wide range of stakeholders (Cuppen et al., 2010; Sneegas et al., 2021). The local aspect of the method also means that local issues and stakeholders' perceptions can be taken into account, which makes it easier to implement such projects (Lévesque et al., 2019; Sneegas et al., 2022).

We follow Brown (1980) and Watts et al. (2008) who recommend several steps to set up of a Q-study: the identification of the theme, the creation of the *concourse* and the Q set, recruitment of participants in the P set, Q sorting process and post-sort interviews, data analysis and factor interpretation. For this article, the general theme was barriers to the acceptance of water reuse projects, and we asked participants the following question: 'In your opinion, what are the main barriers to the acceptance of water reuse projects?' from very important to not important at all.

Concourse and Q set construction

When the theme is defined, the first step is to construct what Stephenson (1953) calls the '*concourse*' which represents a list of all possible responses to the theme. It can be a notion, an idea, a wish and the list should be as exhaustive as possible. Note that in our case we decided to make a list of statements to have more precision in the interpretation of answers, but items can also be pictures, sounds and other media (Zanoli et al., 2015, Naspetti et al., 2016, Lu et al., 2018). This *concourse* can be drawn from literature such as newspaper, research papers, magazines but also from sentences extracted during interviews with stakeholders. In this study, we constructed our *concourse* with a complete literature review on water reuse projects barriers. A total of 82 opinion statements were initially extracted from these sources.

Then, another step is to reduce the statements from the *concourse* to a manageable number of items both for the researcher and participants. This subset of items from the *concourse* is called the Q set and aims to represent all existing opinions on the topic, suppressing less important and redundant statements from the *concourse*. Statements of our Q set were representative of all the six sub-themes (economic and financial barriers, psycho-social and cultural barriers, health barriers, environmental barriers, regulatory and technical barriers, political and governance barriers) that arose during *concourse* selection. This ensures that we represent all possible opinions (Watts and Stenner, 2008). We ended up with a Q set that we pre-tested on 3 pilot respondents to ensure that all statements were perfectly

understandable, and that no main idea has been omitted. Few adaptations, mainly on the wording of statements, were made to obtain the final Q set containing 38 statements presented in Table 1. This is coherent with Barry and Proops (1999) who consider 36 statements are a manageable number to generate meaningful and significant results and Watts and Stenner (2012) who recommend a Q set of around 40 to 80 items.

Economic (costs, markets, etc.) and financial constraints

- 1 The lack of public subsidies for water reuse project
- 2 The amount of investment (infrastructure, equipment, networks)
- 3 The operating expenses associated with water reuse projects (energy and electricity, personal, network)
- 4 Water pricing (price, fees, etc.)
- 5 The financial risk associated with new water reuse projects (distance, volume, profitability, loss income, etc.)
- 6 The abandonment of other development projects
- 7 The need for land to develop water reuse projects (storage spaces, etc.)
- 8 Uncertainty about the savings achieved

Psycho-social and cultural barriers

- 9 Insufficient citizen participation in water reuse projects
- 10 The negative perception associated with wastewater (image of waste, dirt, etc.)
- 11 The necessity to devote time and effort to engage in water reuse projects
- 12 The risk of not receiving support for water reuse projects
- 13 Scepticism about the effectiveness of the water reuse solution
- 14 The lack of information and successful experiences on water reuse projects
- 15 The need to change practices and behaviours to adopt water reuse projects

Health issues and barriers

- 16 Fear and biological or chemical contamination of the soil
- 17 Health risks associated with direct contacts with treated wastewater
- 18 Health risks associated with consuming products from water reuse
- 19 The lack of information and knowledge about health risks
- 20 Health risks (respiratory infection) associated with sprinkler irrigation
- 21 The risks of pollution of drinking water sources (aquifers, etc.) by treated waste water

Environmental barriers

- 22 The degradation of ecological functions provided by the discharge of water treatment plant
- 23 The lack of clear sobriety objectives associated with water reuse projects
- 24 Weather uncertainties and their consequences (available water volume, demand level, etc.)
- 25 The lack of awareness of water scarcity among certain stakeholders
- 26 The absence of general environmental concerns

Regulatory and technical (performance) barriers

- 27 The authorization procedures for water reuse projects (lack of clarity, slowness)
- 28 Usage regulatory constraints (distance to be respected water quality monitoring)
- 29 The absence of specific regulations for certain uses (municipalities, companies) to manage risks
- 30 The regulatory obligation for projects promoters (municipalities, companies) to manage risks
- 31 The complexity of wastewater treatment techniques
- 32 The difficulty of implementing simple techniques for small water treatment plant

Political and governance barriers

- 33 Insufficient involvement of public authorities in water reuse projects
- 34 The complexity of governance and management of water reuse projects
- 35 The lack of commitment and coordination among stakeholders in water reuse projects
- 36 Local opposition to the implementation of water reuse projects (legal actions, administrative disputes, etc.)
- 37 The risk of a change in political direction regarding water reuse projects
- 38 The lack of trust in local public water authorities

Table 1: Q set of the study

P set selection

After the Q set selection comes the P set identification and recruitment of participants for the study. One main objective of this recruitment is to represent all opinions on the studied topic (Barry et al., 1999), given that participants sometimes share common subjective viewpoints.

The number of participants follows recommendation of Watts et al. (2012), staying lower than the number of items to avoid too much statistical noise. Still, with a few participants, the objective is to represent the broadest range of opinions on barriers to water reuse projects implementation. The number of participants does not have to be large contrary to most other survey methods where 'more n is always better'.

The sample surveyed consists of 14 individuals, including a large variety of water field experts. Respondents are described in table 2 Representing various interests about water reuse projects, these respondents can play a crucial role in water reuse projects implementation and have different backgrounds.

Participant n°	Institution	Associated factor
1	SIA de la vallée de l'Auzon	Non-loader
2	Chambre d'Agriculture 63	F1
3	Chambre d'Agriculture 63	F1
4	Agence de l'eau, la Délégation Allier Loire Amont	F3
5	Clermont Auvergne Métropole	F1
6	Direction départementale des territoires du Puy de Dôme	F1
7	Agence Régionale de la Santé 63	F2
8	Centre d'Innovations Sociales Clermont Auvergne	F4
9	Direction Régionale Alimentation Agriculture Forêt	F2
10	SUEZ Puy de Dôme	F2
11	DREAL Auvergne-Rhône-Alpes (Lyon, Rhône)	F3
12	Etablissement public Loire	F1
13	Conseil départemental Puy de Dôme	F3
14	Riom Limagne Volcan	F4

Table 2: Presentation of organisations of participants and their associated factors.

Survey administration: Q-sorting process and exit interviews

Individual face-to-face interviews took place in July and August 2024 and typically lasted around one hour. In this Q study, participants sort the selected statements of the Q set representing barriers to the implementation of water reuse projects from ‘not at all important’ to ‘very important’ in a grid (Table 3). For this study, a 7-point scale was used from -3 to +3 with a forced quasi normal distribution³ which forces respondent to reveal their subjective opinions and to make choices between statements to shed light on the extreme parts of the grid. In Q studies, the number of point scale in the grid vary with nuances and degree of knowledge of respondents on the topic. In this study, we have participants from various backgrounds and with different degrees of knowledge on water reuse projects which enforces our choice to have a 7-point scale grid.

Ranking value	- 3	- 2	- 1	0	+ 1	+ 2	+ 3
Number of statements	3	5	7	8	7	5	3

Table 3: Sorting grid forced distribution

During the Q-sorting process (when participants fill the grid), participants were first asked to read the statements and to divide them into three piles: ‘Important’, ‘Neutral/ do not know’, ‘Not important’. This allows participants to familiarise themselves with the statements for the first time and facilitates the final sorting by reducing the cognitive load. Researchers stayed with interviewees to answer any question or to explain some statements. Statements were printed on small paper cards and participants had to sort one paper in each cell of the grid. Then, participants completed the grid and ranked-order the statements according to their point of view in the grid, introducing more nuances. Each individual's ranking is then known as the ‘Q sort’ of this participant.

After the sorting process, post-sort interviews were conducted with participants to explain their extreme choices in the grid, comment on specific statements and obtain an accurate qualitative interpretation. Interviews were fully recorded and transcribed. It helps to explain the different points of view that will emerge from the analysis.

Data analysis

After data collection we conduct statistical analysis of results. In this study, *Ken Q* (Banasick, 2019) was used. The first step of the analysis is to correlate the Q sorts of respondents with each other in a correlation matrix of dimensions $n \times n$ for n participants. This indicates

³ It is up to the researcher to decide whether to use a forced or an open distribution in the grid, but Brown (1980) has proven that it does not change substantially the results. For an easier statistical analysis and following most other Q study, we opted for a forced distribution.

similarities and divergences between participants' grids of sorting. The average correlation in our sample is 1.846% which shows heterogeneity between opinions of participants on the importance of barriers to water reuse projects implementation. This intercorrelation matrix is then used to conduct factor analysis, in our case based on Principal Components Analysis, to identify main perspectives of thought on the given topic. A point of view in Q studies is called a factor and represents one shared opinion between some participants.

Factors are then rotated using Varimax and/or judgemental rotations. Baker et al. (2006) recommend to do both, but Varimax rotation is recognized as a more objective technique (Watts and Stenner, 2012). We applied Varimax rotation, a standard orthogonal technique which aims to maximise similarities within a factor and to minimise similarities between different factors. This helps to identify clear factors and perspectives on the studied topic.

Best practices in Q methodology suggest triangulating multiple criteria to select the number of factors to extract (Sneegas et al., 2021). We follow this recommendation and select factors on the following criteria: Kaiser-Guttman criterion stating that eigenvalues of factors should be higher than one, Humphrey's rule so that a minimum of two Q sorts significantly load on the factor, variance accounts for over 50% of the variance, scree plot analysis and interpretability of the factors to identify clear perspectives of thought. Based on these criteria, we keep 4 factors, representing a cumulative explained variance of 55%.

On the 14 participants, 13 loaded significantly factors with a p -value < 0.01 ⁴ and five to two were associated to each factor. This choice also follows recommendations of Buckel et al. (2020) who explain that usually, a factor should be representative of at least four or five respondents. Factor information is provided in Table 4. These profiles show that participants do not perceive the same barriers to the implementation of water reuse projects as important. This diversity is interesting to study to accompany these new projects.

Factor	1	2	3	4	5	6	7	8
Eigenvalues	2,6956	1,9158	1,7178	1,399	1,1064	1,0514	0,8786	0,8013
% of Explained Variance	19	14	12	10	8	8	6	6
Cumulative % of explained Variance	19	33	45	55	63	71	77	83
Composite Reliability	0,952	0,923	0,923	0,889				

Table 4: Results of eigenvalues and explained variance, reliability for factors

⁴ Following [Brown \(1980\)](#), at a $P < 0.01$ significance level, a significant factor loading can be calculated by using the equation $2.58(1/\sqrt{N})$ where N equals the number of statements in the Q set. For this particular study a significant factor loading would be equal to or greater than $2.58(1/\sqrt{38}) = \pm 0.42$ ([Brown, 1980](#)).

The factors extracted are associated to composite Q-sorts, representing the sort of statements from a hypothetical respondent with a 100% loading on the factor (Van Excel et al., 2005) around which all the closest Q sorts are gathered. Q-sort composite construction is based on the average score of each statement in the Q-sorts of associated participants for each factor (Brown, 1980) and to the weights of these participants in each factor. These composite Q sorts are provided in the Appendix 3 to 6.

Finally, the last step in Q methodology is the interpretation of the factors extracted by the statistical process. These factors represent the social discourses revealed by the study on barriers to water reuse projects. Data analysis also provides information on consensus and disagreements among participants on the studied topic. These results are presented in the following part.

Results

This part provides empirical results on water reuse projects barriers with different stakeholders' perspectives. We highlight factors obtained associated to perspectives on water reuse barriers, areas of consensus and disagreements between views. These results are based on Table 5 provided and composite Q sorts provided in the appendix which details factor scores and values for each statement.

N° Statement	F1	F2	F3	F4	Ranking value
30 The regulatory obligation for projects promoters (municipalities, companies) to manage risks	0	0	0	0	0,027
19 The lack of information and knowledge about health risks	1	1	1	1	0,044
13 Scepticism about the effectiveness of the water reuse solution	-1	-1	-1	-2	0,058
15 The need to change practices and behaviours to adopt water reuse projects	0	0	1	1	0,124
24 Weather uncertainties and their consequences (available water volume, demand level, etc.)	-2	-2	0	-2	0,137
38 The lack of trust in local public water authorities	0	-2	0	-1	0,163
29 The absence of specific regulations for certain uses (municipalities, companies) to manage risks	0	1	3	0	0,202
34 The complexity of governance and management of water reuse projects	0	0	1	-1	0,235
12 The risk of not receiving support for water reuse projects	1	-1	0	1	0,298

9	Insufficient citizen participation in water reuse projects	0	-1	-1	1	0,308
8	Uncertainty about the savings achieved	-1	-1	0	-2	0,325
26	The absence of general environmental concerns	-2	0	0	0	0,359
14	The lack of information and successful experiences on water reuse projects	2	-1	1	1	0,363
35	The lack of commitment and coordination among stakeholders in water reuse projects	0	2	2	3	0,374
5	The financial risk associated with new water reuse projects (distance, volume, profitability, loss income, etc.)	2	1	2	-1	0,457
28	Usage regulatory constraints (distance to be respected water quality monitoring)	2	-1	1	2	0,466
20	Health risks (respiratory infection) associated with sprinkler irrigation	-1	2	1	-1	0,61
11	The necessity to devote time and effort to engage in water reuse projects	1	0	-2	-3	0,614
32	The difficulty of implementing simple techniques for small WWTPs	1	1	-1	3	0,667
2	The amount of investment (infrastructure, equipment, networks)	2	0	3	0	0,693
31	The complexity of wastewater treatment techniques	-1	-2	-3	-3	0,735
10	The negative perception associated with wastewater (image of waste, dirt, etc.)	-1	1	-1	3	0,749
25	The lack of awareness of water scarcity among certain stakeholders	-3	1	0	1	0,837
3	The operating expenses associated with water reuse projects (energy and electricity, personal, network)	2	0	-1	-2	0,85
17	Health risks associated with direct contacts with treated wastewater	-2	2	1	0	0,856
16	Fear and biological or chemical contamination of the soil	1	3	-2	-1	0,873
33	Insufficient involvement of public authorities in water reuse projects	-1	-3	0	2	0,879
1	The lack of public subsidies for water reuse project	3	1	-2	2	0,93

27	The authorization procedures for water reuse projects (lack of clarity, slowness)	3	2	-1	-1	1,019
4	Water pricing (price, fees, etc.)	0	0	-3	-3	1,024
36	Local opposition to the implementation of water reuse projects (legal actions, administrative disputes, etc.)	-3	-3	2	-2	1,063
37	The risk of a change in political direction regarding water reuse projects	1	-2	-2	2	1,235
6	The abandonment of other development projects	1	-3	-3	1	1,268
23	The lack of clear sobriety objectives associated with water reuse projects	-3	-1	2	0	1,304
7	The need for land to develop water reuse projects (storage spaces, etc.)	3	-2	2	-1	1,348
22	The degradation of ecological functions provided by the discharge of the WWTP	-2	2	3	0	1,475
21	The risks of pollution of drinking water sources (aquifers, etc.) by treated wastewater	-2	3	-1	2	1,604
18	Health risks associated with consuming products from water reuse	-1	3	-2	0	1,743

Table 5: Factor scores and values sorted from more to less consensual statements.

Perspectives on water reuse projects barriers

Factor 1: The operational financial and non-monetary barriers to water reuse projects

Factor 1 explains 19% of the cumulative variance, is a bipolar factor (1 respondent) and is defined by the sorts of 5 participants (cf. table 2).

A commonality of these participants is the importance of operational barriers to the implementation of treated wastewater reuse projects. For this factor, a main barrier to water reuse projects is the financial aspect with “the lack of public subsidies” (S1, +3**) and “the operating expenses associated to reuse projects (S3, +2**). While the cost of the projects is a first problem that could compromise their implementation, other operational barriers are also important according to this factor.

For instance, this factor highlights “the need for land to develop reuse projects” (S7, +3**) and “the necessity to devote time and effort to engage in reuse projects” (S11, +1**) which highlights the importance of time, investment and available area and resources to implement such projects.

However, for this group of perception, environmental concerns are less important barriers or levers to the implementation of water reuse projects. Indeed, for this factor, some statements will not play a crucial role in the implementation of reuse projects as “the lack of awareness of water scarcity among certain stakeholders” (S25, -3**), “the lack of clear sobriety objectives associated with reuse projects” (S23, -3**), “the degradation of ecological functions provided by the discharge of step resources” (S22,-2*) and “the absence of general environmental concerns” (S26, -2**).

Health barriers are also considered less important for this factor. For instance, “health risks associated with direct contacts with treated wastewater (S17,-2**)” and “the risks of pollution of drinking water sources (S21,-2*)” are not important barriers to the implementation of water reuse projects.

Thus, for this factor, water reuse projects will probably face strong barriers associated to operational and financial resources and non-monetary costs (time, land availability). However, environmental concerns and health risks appear less problematic to implement such projects.

Factor 2: The health and pollution barriers to water reuse projects

Factor 2 explains 14% of the cumulative variance and is defined by the sorts of 3 participants.

This factor is characterised by the importance of health barriers. It focuses a lot on the effects of water reuse projects on sanitary and pollution issues and considers health barriers as the most important ones in the implementation of water reuse projects. This factor positions “health risks associated with consuming products from reuse water” (S18, +3**), “the risks of pollution of drinking water sources” (S, +3**), “fear and biological or chemical contamination of the soil” (S16, +3**) and “health risks associated with direct contacts with treated waste water” (S17, +2*) in the extreme positive part of the grid, meaning that health issues are central obstacles to these projects for this factor.

On the contrary, for this factor, some barriers are less important such as the “insufficient involvement of public authorities” (S33,-3*) and “usage regulatory constraints” (S28,-1**) meaning that this will probably not be a problem to implement water reuse projects. For this factor, past experiments are documented enough and “the lack of information and successful experiences of reuse water projects” (S14,-1**) is not a huge barrier to the implementation of these projects.

To conclude, this factor highlights strong health and pollution issues that can compromise the implementation of water reuse projects, but involvement of public authorities and lack of past experiences information are not an important barrier.

Factor 3: Psycho-socio barriers and local oppositions to water reuse projects

Factor 3 explains 12% of the cumulative variance and is defined by the sorts of 3 participants.

For this factor the main barriers to water reuse projects are associated to local acceptance of these projects, both about the “the need for land to develop reuse projects” (S7, +2**) and “local opposition to the implementation of reuse water projects” (S36,+2**).

Contrary to all other factors which consider uncertainty as a very not important barrier to water reuse projects, this factor positions it in the neutral area, in a higher position than all other factors. Thus, for this factor, “weather uncertainties and their consequences” (S24,0*, higher than in all other factors) and “uncertainty about the savings achieved” (S8,0**, higher than in all other factors) are more important barriers than in the other perspectives.

However, this factor considers as not important “the lack of public subsidies for reuse projects” (S1,-2**) and “Water pricing” (S4,-3) because the barriers to implementation of water reuse projects are not financial or this factor. Additionally, this factor also consider “health risks associated with consuming reuse water products” (S18, -2**) as not important to brake reuse projects implementation.

To resume this factor highlights local oppositions and psycho-socio barriers associated to uncertainties more than the other factors but financial aspects do not appear as a main barrier to water reuse projects implementation.

Factor 4: Change management and political barriers to water reuse projects

Factor 2 explains 11% of the cumulative variance, is a bipolar factor and is defined by the sorts of 2 participants.

For this factor, change management and political barriers are very important for the implementation of water reuse projects. Thus, “the difficulty of implementing simple techniques for small WWTP (Waste Water Treatment Plant)” (S32, +3**) is considered as a very important barrier and shows the complexity of these kind of projects than can be controversial. Political barriers are also central for this factor with “the risk of a change in political direction regarding water reuse (S37,+2**) and “insufficient involvement of public authorities in water reuse projects” (S33,+2*) that can compromise the implementation of these projects.

Conversely, financial aspects and some technical aspects as “the financial risks associated to new water reuse projects” (S5, -1**) and “health risks associated with sprinklers” (S20,-1*) are not very important obstacles to these projects.

To conclude, this factor highlights strong political and change management barriers to the implementation of water reuse projects.

Areas of consensus and disagreements

Despite the differences highlighted in the perspectives above, there are also interesting similarities across all factors, as revealed by the six so-called “consensus statements” in the composite Q sorts (Appendix 3 to 6). We first highlight positive consensus that represent

important barriers for all factors. For instance, all factors consider “the lack of information and knowledge about health risks” (S19) and the need to change practices and behaviours to adopt water reuse projects (S15) as important barriers. A neutral consensus also emerges on the regulatory obligation for projects promoters to manage risks.

On the contrary, some negative consensuses arise, meaning that these points are not important barriers. For instance, all factors consider as non-important barrier the “scepticism about the effectiveness of the water reuse solution” (S13), “weather uncertainties and their consequences” (S24) and “the lack of trust in local public water authorities” (S38).

On the contrary, factors strongly disagree on some interesting points. First about ecological concerns, factors do not share a common vision on the lack of clear sobriety objectives associated with water reuse projects (S23) and the degradation of ecological functions provided by the discharge of the Plant (S22). Factors also disagree on the need for land to develop reuse projects (S7). Lastly health and pollution risks are very controversial, and factors do not agree on the importance of barriers associated with the risks of pollution of drinking water sources (S21) and “health risks associated with consuming products from reuse projects” (S18).

Discussion and Conclusion

Perception profiles

Various lessons and research perspectives emerge from our findings.

The first concerns the emergence of the two main barriers (factors 1 and 2⁵) related to the financial and non-monetary resources of the stakeholders (time, knowledge, access to land, etc.), as well as perceived risks. These results align with several reports and studies that have also highlighted these obstacles to the commitment of project leaders in water reuse projects. Similar to the "homo economicus" model (according to neoclassical theory), they assess the constraints and limits of their resources when implementing this innovative solution. To complement the analysis of this "rational" behaviour of optimising choices, researchers could examine the trade-offs or benefits derived from this solution through the value creation approach (Yuen et al., 2018).

However, this research highlights the presence of psychological costs and social barriers (via factors 3 and 4). Implementing such projects requires the acceptance of stakeholders who hold controversial (even conflicting) positions on water management. Water issues and its uses within a territory (tourism and leisure, agriculture, industry) remain a source of tension and uncertainty. The role of water agencies and local authorities (Regional Department for

⁵ For factor 1: Chamber of Agriculture 63; Departmental Directorate of the territories of Puy-de-Dôme; Clermont Auvergne Métropole; Public establishment Loire

For factor 2: SUEZ Puy-de-Dôme; Regional Health Agency 63; Regional Directorate Food Agriculture Forest

the Environment, Planning and Housing, Puy-de-Dôme Departmental Council, municipal communities), which raise these obstacles, is crucial in reducing social unacceptability. The implementation of water resource evaluation indicators can reduce uncertainty about the benefits and success of TWR. But beyond objective measures, it is also necessary to ensure stability in political and public decisions. The analysis of relationships and power dynamics between structures (institutional framework and other organisations) would benefit from further exploration.

Finally, the study of barriers to water reuse through the Q method highlights the perceived complexity due to the diversity of stakeholders, latent tensions, and points of disagreement. It is also important to address the elements that create consensus and those more neutral aspects that help build a common foundation of knowledge and values. A better understanding of trust and engagement among stakeholders, based on evidence, offers a promising research path to guide public action.

Methodological implications (Q methodology practices)

The exploratory project in progress leads to a discussion of the Q method applied to the water reuse in the context of the Puy-de-Dôme on four points:

The first extension of these results would be to analyze the responses on extreme positions and the complementary questionnaires of the interviews in order to better understand the diversity of perceptions.

A second work envisaged is related to the correlation of factors 3 and 4, which is in the order of 30%. If the Q method does not require a large P set, additional interviews to our sample (14 respondents) could be conducted in order to reach "saturation" and ensure its replicability (Sneegas et al., 2021). The inclusion of other stakeholders would help to confirm or not the perspectives found, namely the distinction between factors 3 and 4.

Third, the choice not to include non-expert stakeholders (environmental protection associations, farmers not yet engaged in the sobriety schemes, consumer clients) in the Q Set is justified by the bias generated by their responses when applying the method to the unacceptability of the water reuse. However, if ignored, the views of these stakeholders would be an obstacle to the adoption of circular economy practices in water management (Al-Saidi, 2021). A research perspective would be to conduct an additional qualitative survey on the perception of the project in the territory to ensure local social acceptability.

Finally, we chose a rather urban context with only one water reuse project in operation and another under consideration. Considering other territories (rural/ medium mountain) is an issue to better identify the constraints related to the exploitation of the water reuse (technical) and its uses (acceptability and conflict).

Managerial implications

This exploratory research work allows us to identify some managerial implications.

First, raising awareness of the reuse project among stakeholders (knowledge of health risks, information on quality level, etc.) is an issue for all the stakeholders interviewed who consider decision making based on information asymmetry and cognitive biases as a risk or a significant barrier.

Another practice already common in the implementation of controversial projects on a territory is to facilitate exchanges, organize consultation and coordinate stakeholders. Identifying the perception profiles of stakeholders and their participation in the co-creation process is an asset to reduce cognitive and psychosocial barriers.

Finally, these measures related to changing perceptions and attitudes require resources and time. More direct action through the use of regulatory levers and the implementation of monetary/ financial compensations (prices, project financing) as provided for in the Water Plan is to be continued or even strengthened on agricultural activities whose stakes are the most risky.

Appendix

Appendix 1

Regulations	Objectives
Regulation of the European Parliament and of the Council of 25/05/2020	This regulation, which concerns minimum requirements for water reuse, aims to ensure that recycled water used for irrigation is safe for human health and the environment. The regulation lays down water quality criteria, monitoring and risk management obligations, as well as transparency and public information requirements. Its main objective is to promote the sustainable use of water resources, particularly in times of water stress.
Decree no. 2022-336	Sets out the conditions for implementing water reuse in France, in line with European requirements. It specifies water quality criteria, monitoring procedures and authorisation procedures for the use of this water, mainly for agricultural irrigation and watering green spaces. The decree aims to ensure the protection of public health and the environment while promoting sustainable management of water resources. It also establishes safety measures to minimise the risks associated with this practice.
Water Plan of March 2023	Aims to meet the growing challenges of managing water resources in the context of climate change. The objective is to reduce water consumption by 10% by 2030. This involves measures to encourage water savings in the domestic, agricultural and industrial sectors. The Water Plan places particular emphasis on increasing water reuse for agricultural irrigation and other non-potable uses, in order to better preserve drinking water resources. Investment and aid are planned to support certain stakeholders, such as farmers, and to modernise drinking water and wastewater networks in order to reduce leakage and improve the efficiency of water distribution.
Decree no. 2023-835	Specify the conditions under which wastewater from treatment plants can be used for certain purposes, such as agricultural irrigation, watering green spaces, or in certain industrial applications. It defines water quality requirements, the sanitary conditions to be met, as well as authorisation procedures for operators. This is part of an approach aimed at promoting sustainable water resource management in response to increasing water stress, while ensuring public health safety and environmental protection.
Orders of 14 and 18 December 2023	Set the requirements applicable to the use of treated wastewater for watering green spaces open to the public, as well as the requirements applicable to the use of treated wastewater for the irrigation of agricultural crops.
Orders of 21 et 28 December 2023	They outline the specific procedures related to the irrigation of crops and the watering of green spaces. The aim is to simplify the processes for project leaders while maintaining a rigorous framework of compliance and quality, in order to ensure the protection of public health and the preservation of natural ecosystems.

Appendix 2

Stakeholders	Skills and roles	Level of action
Government and ministries	Define national water policies, decree and oversee major plans (Water Plan, Water development and management master plan), supervise the sustainable management of water resources and ensure compliance with European directives.	National
Regional Department for the Environment, Planning and Housing	Oversee the application of public policies relating to the environment and water at regional level, participate in the control of classified installations and monitor water quality.	Regional
Regional Health Agencies	Control the quality of water intended for human consumption and the hygiene of installations, monitor health and manage risks to public health.	
Regional Directorates for Agriculture, Food and Forestry	Manage regional agricultural policies, ensuring sustainable water management in farming practices, particularly in terms of irrigation and environmental impact.	
French water agencies	Fund water management projects (wastewater treatment, protection of aquatic environments), and manage the Schémas Directeurs d'Aménagement et de Gestion des Eaux (SDAGE).	
Departmental Territorial Directorates (<i>DDT</i>)	Implement the State's water management policies at local level, enforce water policing, control water use authorisations and participate in the prevention	

	of natural hazards (floods, droughts).	
Users (agriculture, industry, domestic users, local authorities, etc.)	Consume water (households, farmers, industry) and are directly involved in its sustainable management through their use, their compliance with regulations and their financial contribution (water charges). They can also take part in local consultation bodies (local water commissions).	Local
Environmental associations	Defend the protection of aquatic environments and the sustainable use of water. They play a role in raising awareness and educating the public, and take part in public debates, consultations and the monitoring of water management policies.	
Scientific experts and prescriber	Validate the technologies and practices for the reuse of treated wastewater. Their expertise spans various fields, including environmental engineering, microbiology, hydrology, and public health. They are primarily involved in assessing environmental impact, ensuring sanitary safety, and recommending innovative technologies tailored to each specific use case.	Regional / Local

Appendix 3

Composite Q Sort for Factor 1

-3	-2	-1	0	1	2	3
Local opposition to the implementation of REUT	Weather uncertainties and their consequences (available)	* ► The complexity of wastewater treatment techniques	The absence of specific regulations for certain uses (municipalities,	The risk of not receiving support for REUT projects	The amount of investment infrastructure, equipment, networks)	** ► The lack of public subsidies for REUT project
** ◀ The lack of awareness of water scarcity among certain stakeholders	* ◀ The dégradation of ecological functions provided by the discharge of	Health risks associated with consuming products from REUT	The complexity of governance and management of REUT projects	* ► The necessity to devote time and effort to engage in REUT projects	Usage regulatory constraints (distance to be respected water	** ► The need for land to develop REUT projects (storage spaces, etc.)
** ◀ The lack of clear sobriety objectives associated with REUT projects	** ◀ The absence of general environmental concerns	* Health risks (respiratory infection) associated with sprinkler	Insufficient citizen participation in REUT projects	** Fear and biological or chemical contamination of the soil	** ► The operating expenses associated with REUT projects (energy and	The authorization procedures for REUT projects (lack of clarity,
	** ◀ Health risks associated with direct contacts with treated wastewater	Insufficient involvement of public authorities in REUT projects	* ◀ The lack of commitment and coordination among stakeholders in	** The risk of a change in political direction regarding REUT	The financial risk associated with new REUT projects (distance,	
	* ◀ The risks of pollution of drinking water sources (aquifers,	The negative perception associated with wastewater (image of	Water pricing (price, fees, etc.)	The lack of information and knowledge about health risks	The lack of information and successful experiences on REUT projects	
		Skepticism about the effectiveness of the REUT solution	The need to change practices and behaviors to adopt REUT	The abandonment of other development projects		
		Uncertainty about the savings achieved	The regulatory obligation for projects promoters municipalities,	The difficulty of implementing simple techniques for small STEPS		
			The lack of trust in local public water authorities			

Legend
* Distinguishing statement at P< 0.05
** Distinguishing statement at P< 0.01
► Z-score for the statement is higher than in all other factors
◀ Z-score for the statement is lower than in all other factors
□ Consensus Statements

Composite Q Sort for Factor 2

-3	-2	-1	0	1	2	3
Local opposition to the implementation of REUT	The lack of trust in local public water authorities	Skepticism about the effectiveness of the REUT solution	Water pricing (price, fess, etc.)	The financial risk associated with new REUT projects (distance, etc.)	The dégradation of ecological functions provided by the discharge of	**▶ Health risks associated with consuming products from REUT
*◀ Insufficient involvement of public authorities in REUT projects	The complexity of wastewater treatment techniques	**◀ Usage regulatory constraints (distance to be respected water)	The regulatory obligation for projects promoters municipalities,	The negative perception associated with wastewater (image of)	*▶ Health risks associated with direct contacts with treated wastewater	**▶ The risks of pollution of drinking water sources (aquifers,
The abandonment of other development projects	The need for land to develop REUT projects (storage spaces, etc.)	The risk of not receiving support for REUT projects	The amount of investment infrastructure, equipment, networks)	The absence of specific regulations for certain uses (municipalities,	The authorization procedures for REUT projects (lack of clarity,	**▶ Fear and biological or chemical contamination of the soil
	Weather uncertainties and their consequences (available)	Insufficient citizen participation in REUT projects	The need to change practices and behaviors to adopt REUT	The lack of public subsidies for REUT projet	Health risks (respiratory infection) associated with sprinkler	
	The risk of a change in political direction regarding REUT	**◀ The lack of information and successful experiences on REUT projects	The absence of general environmental concerns	The lack of awareness of water scarcity among certain stakeholders	The lack of commitment and coordination among stakeholders in	
		Uncertainty about the savings achieved	The complexity of governance and management of REUT projects	The difficulty of implementing simple techniques for small STEPS		
		** The lack of clear sobriety objectives associated with REUT projects	The necessity to devote time and effort to engage in REUT projects	The lack of information and knowledge about health risks		
			The operating expensens associated with REUT projects (ennerg and			

Legend

- * Distinguishing statement at P < 0.05
- ** Distinguishing statement at P < 0.01
- ▶ Z-score for the statement is higher than in all other factors
- ◀ Z-score for the statement is lower than in all other factors
- Consensus Statements

Composite Q Sort for Factor 3

-3	-2	-1	0	1	2	3
The abandonment of other development projects	Fear and biological or chemical contamination of the soil	The negative perception associated with wastewater (image of	** ► Uncertainty about the savings achieved	The need to change practices and behaviors to adopt REUT	The lack of clear sobriety objectives associated with REUT projects	The amount of investment infrastructure, equipment, networks)
Water pricing (price, fess, etc.)	** ◀ The lack of public subsidies for REUT projet	The difficulty of implementing simple techniques for small STEPS	The regulatory obligation for projects promoters municipalities,	The lack of information and knowledge about health risks	** ► Local opposition to the implementation of REUT	The dégradation of ecological functions provided by the discharge of
The complexity of wastewater treatment techniques	The necessity to devote time and effort to engage in REUT projects	Insufficient citizen participation in REUT projects	The lack of awareness of water scarcity among certain stakeholders	Health risks (respiratory infection) associated with sprinkler	The lack of commitment and coordination among stakeholders in	The absence of specific regulations for certain uses (municipalities,
	The risk of a change in political direction regarding REUT	** The risks of pollution of drinking water sources (aquifers,	The lack of trust in local public water authorities	Usage regulatory constraints (distance to be respected water	** The need for land to develop REUT projects (storage spaces, etc.)	
	** ◀ Health risks asociated with consuming products from REUT	The auorization procdures for REUT projects (lack of clarity,	The absence of general environmental concerns	The complexity of governance and management of REUT projects	The finacial risk associated with new REUT projects (distance,	
		The operating expensens associated with REUT projects (ennerg and	Insufficient involvement of public authorities in REUT projects	The lack of information and succesful experiences on REUT projects		
		Skepticism about the effectiveness of the REUT solution	The risk of nor receiving support for REUT projects	Health risks associated with direct contacts with treated wastewater		
			* ► Weather uncertainties and their consequences (available			

Legend

- * Distinguishing statement at P< 0.05
- ** Distinguishing statement at P< 0.01
- Z-score for the statement is higher than in all other factors
- ◀ Z-score for the statement is lower than in all other factors
- Consensus Statements

Appendix 6

Composite Q Sort for Factor 4

-3	-2	-1	0	1	2	3
The necessity to devote time and effort to engage in REUT projects	Skepticism about the effectiveness of the REUT solution	The lack of trust in local public water authorities	The absence of general environmental concerns	The lack of information and knowledge about health risks	** ► The risk of a change in political direction regarding REUT	** ► The difficulty of implementing simple techniques for small STEPS
The complexity of wastewater treatment techniques	Uncertainty about the savings achieved	Fear and biological or chemical contamination of the soil	The regulatory obligation for projects promoters municipalities,	The abandonment of other development projects	* ► Insufficient involvement of public authorities in REUT projects	The lack of commitment and coordination among stakeholders in
Water pricing (price, fess, etc.)	The operating expensens associated with REUT projects (ennerg and	The need for land to develop REUT projects (storage spaces, etc.)	The lack of clear sobriety objectives assoicated with REUT projects	The risk of nor receiving support for REUT projects	** The risks of pollution of drinking water sources (aquifers,	The negative perception associated with wastewater (image of
	Weather uncertainties and their consequences (available	** ◀ The finacial risk associated with new REUT projects (distance,	The amount of investment infrastructure, equipment, networks)	Insufficient citizen participation in REUT projects	The lack of public subsidies for REUT projet	
	Local opposition to the implementation of REUT	The auorization procdures for REUT projects (lack of clarity,	Health risks associated with consuming products from REUT	The need to change practices and behaviors to adopt REUT	Usage regulatory constraints (distance to be respected water	
		The complexity of governance and management of REUT projects	Health risks associated with direct contacts with treated wastewater	The lack of information and succesful experiences on REUT projects		
		* ◀ Health risks (respiratory infection) associated with sprinkler	The absence of specific regulations for certain uses (municipalies,	The lack of awareness of water scarcity among certain stakeholders		
			* The dégradation of ecological functions provided by the discharge of			

Legend

- * Distinguishing statement at P< 0.05
- ** Distinguishing statement at P< 0.01
- Z-score for the statement is higher than in all other factors
- ◀ Z-score for the statement is lower than in all other factors
- Consensus Statements

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