Creating an enabling environment for WR&R implementation

P.-M. Stathatou, E. Kampragou, H. Grigoropoulou, D. Assimacopoulos, C. Karavitis and J. Gironás

ABSTRACT

Reclaimed water is receiving growing attention worldwide as an effective solution for alleviating the growing water scarcity in many areas. Despite the various benefits associated with reclaimed water, water recycling and reuse (WR&R) practices are not widely applied around the world. This is mostly due to complex and inadequate local legal and institutional frameworks and socio-economic structures, which pose barriers to wider WR&R implementation. An integrated approach is therefore needed while planning the implementation of WR&R schemes, considering all the potential barriers, and aiming to develop favourable conditions for enhancing reclaimed water use. This paper proposes a comprehensive methodology supporting the development of an enabling environment for WR&R implementation. The political, economic, social, technical, legal and institutional factors that may influence positively (drivers) or negatively (barriers) WR&R implementation in the regional water systems are identified, through the mapping of local stakeholder perceptions. The identified barriers are further analysed, following a Cross-Impact/System analysis, to recognize the most significant barriers inhibiting system transition, and to prioritize the enabling instruments and arrangements that are needed to boost WR&R implementation. The proposed methodology was applied in the Copiapó River Basin in Chile, which faces severe water scarcity. Through the analysis, it was observed that barriers outweigh drivers for the implementation of WR&R schemes in the Copiapó River Basin, while the key barriers which could be useful for policy formulation towards an enabling environment in the area concern the unclear legal framework regarding the ownership of treated wastewater, the lack of environmental policies focusing on pollution control, the limited integration of reclaimed water use in current land use and development policies, the limited public awareness on WR&R, and the limited availability of governmental funding sources for WR&R.

Key words | Copiapó River Basin, enabling environment, implementation drivers and barriers, water recycling and reuse, water scarcity

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INTRODUCTION

Treated wastewater has been shown to be a reliable alternative water resource. The implementation of water recycling and reuse (WR&R) technologies can alleviate adverse water related conditions and reduce the vulnerability of water systems (Friedler 2001; Lazarova *et al.* 2001; Stathatou *et al.* 2016). Despite the various benefits associated with reclaimed water use (e.g. locally controlled and constantly produced water supply, reduced wastewater discharges, decreased water abstractions, environmental protection), WR&R practices are not widely applied around the world; in many places experiencing water scarcity, only isolated or no reuse practices are applied (Miller 2006; Salgot 2008; Garcia & Pargament 2015). This is mostly due to complex and inadequate legal and institutional frameworks and socio-economic structures that hinder the implementation of WR&R schemes. Potential barriers to WR&R implementation may be weak or inadequate governmental policies that discourage WR&R penetration, lack of available funding sources, negative social perceptions, limited capacity of relevant utilities for the reliable and consistent

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production and delivery of reclaimed water, non-existent legal frameworks regulating water resources management, and overlapping jurisdictions among involved institutions (Miller 2006; Asano *et al.* 2007; Hidalgo *et al.* 2007).

A paradigm shift is needed to overcome WR&R implementation barriers and effectively address the water related challenges (Bahri 2009; UNESCO 2013). Wastewater should be considered a valuable asset and not waste, and the traditional linear patterns of water use – wastewater generation – treatment – disposal should be transformed into circular pathways, incorporating wastewater reclamation and reuse for various potable and non-potable purposes (Visvanathan 2015). To achieve this paradigm shift and change patterns in water use, an enabling environment should be created, focusing on several aspects in addition to availability and cost of reclamation technologies, such as government policies and affected people and institutions (Lawrence *et al.* 2002; Miller 2006; Asano *et al.* 2007; Hidalgo *et al.* 2007).

A comprehensive methodology for developing an enabling environment for WR&R implementation is proposed in this paper, aiming to identify implementation drivers and barriers, and recognize the most significant political, economic, social, technical, legal and institutional factors, on which priority should be given by decision-makers in order to enhance wider WR&R penetration. The proposed methodology was applied in the Copiapó River Basin in Chile, which struggles with water scarcity.

METHODS

The study site area

The Copiapó River Basin, which is located in the Atacama Desert of Chile (Figure 1), occupies an area of 18,538 km^2, and holds 200,000 inhabitants (census 2012). The area is characterized by high temporal variation of rainfall and long dry periods, which, combined with the rapid population growth during the last decade and the poor management of the water sector (uncontrolled trade of water rights), place great pressure on available water resources. Water scarcity conditions are apparent in the basin, resulting in intense competition over water supply between the different water use sectors (Porto *et al.* 2012).

The urban sector has the highest reuse potential in the area, as it contributes significantly to water abstractions, and is considered the most appropriate sector to be supplied with reclaimed water by the local stakeholders. In addition, WR&R strategies related to the use of reclaimed water in the

Figure 1 | Location of the Copiapó River Basin.

urban environment are considered the most effective in terms of vulnerability reduction in the Copiapó River Basin, compared to agricultural and industrial WR&R strategies (Assimacopoulos *et al.* 2015).

The proposed methodological framework towards an enabling environment for WR&R

The factors of the external environment that may influence WR&R implementation were identified using PESTL analysis (policy, economic, social, technical, legal and institutional factors), a common variation of the PESTLE analysis (policy, economic, social, technical, legal – institutional, and environmental factors). Environmental factors were not considered here (PESTL analysis instead of PESTLE), as the environmental issues of the Copiapó River Basin have been thoroughly analyzed in Stathatou *et al.* 2016. An on-line PESTL questionnaire was developed to map the views of local stakeholders regarding the influence of these factors (positive/drivers or negative/barriers) on the implementation of WR&R schemes in the Copiapó River Basin. Subsequently, the barriers' dynamics were analysed in terms of mutual sensitivity to determine their functional roles within the system. Specific barriers were identified, the transformation of which into drivers would achieve the greatest positive impact on the residual barriers of the analysed system, to set policy priorities towards an enabling environment. The adopted methodological framework, comprising two complementary steps, is presented in Figure 2.

Step 1: Identification of drivers and barriers to the WR&R implementation process

To identify the drivers and barriers for WR&R implementation, two sub-steps were followed:

Sub-step 1a: Identification of the factors influencing WR&R implementation

Using the PESTL framework (Srdjevic et al. 2012) 22 factors of potential influence on the integration of WR&R options were identified (Table 1). The selection of factors was based on literature review. Some of the factors are related to the use of reclaimed water in specific water use sectors (e.g. use of reclaimed water in crop irrigation, in the urban environment, in industrial processes or for enhancing ecosystem services), while others concern WR&R in general and apply to all possible reclaimed water uses. Of the total 22 factors with potential influence on WR&R implementation, 16 are relevant to urban WR&R schemes: P1, P2, P3, P4, E1, E2, E5, S1, S2, S4, T1 (T1.3, T1.4), T2 (T2.3), L1, L2, L3, L4.

Sub-step 1b: Characterization of factors as drivers or barriers and assessment of their influence

Drivers and barriers were identified through interaction, consultation and active participation of local stakeholders of the Copiapó River Basin. An on-line PESTL questionnaire was developed for the assessment of the 16 factors (comprising 48 questions in total). The questionnaire was filled in by 18 local stakeholders, who completed the questionnaires, providing their views on the type of influence of each factor on implementing WR&R schemes (positive/negative), and on the importance of this influence (low/medium/high). Recommendations on how to overcome factors with negative influence were also suggested by the stakeholders. Questionnaire respondents covered a wide range of capacities ranging from local government to farmers and civil society members (one representative from water supply/sanitation utilities; four representatives from water authorities and government; two farmers; two civil society members; one industry representative; one representative from environmental groups/non-governmental organizations (NGOs); seven scientists, experts and researchers on water resources management). They have been categorized into different stakeholder groups, to identify different perceptions according to their interests, knowledge and expertise.

Step 2: Identification of the key barriers inhibiting system transition

The barriers identified in Step 1 were further analysed to identify the key barriers, i.e. those barriers that obstruct the implementation of WR&R schemes the most. The analysis of barriers was adapted from the bio-cybernetic system approach developed by Vester (1988), which aims to facilitate the understanding of the configurations, rules and feedback mechanisms that characterize the dynamic behavior of complex

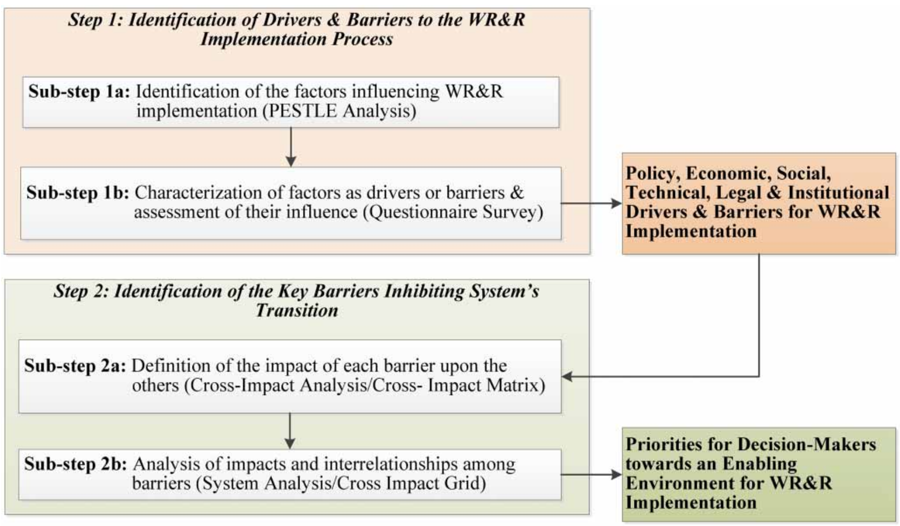

Figure 2 | The methodological framework towards an enabling environment for WR&R.

Table 1 | The identified factors of potential influence on WR&R implementation

Policy factors
- P1. National/regional policies on water resources management (WRM)
- P2. National/regional environmental policies
- P3. Land use policies
- P4. Transnational or transboundary treaties and agreements
- P5. Trade policies (exports of agricultural products)

Economic factors
- E1. Availability of governmental and public funds
- E2. Indirect financial incentives
- E3. Freshwater pricing schemes for crop irrigation
- E4. Freshwater pricing schemes for industrial uses
- E5. Freshwater pricing schemes for urban uses
  - E5.1 Freshwater pricing schemes for municipal urban uses
  - E5.2 Freshwater pricing schemes for residential urban uses
- E6. Farm operating costs

Social factors
- S1. Public awareness on water scarcity problems
- S2. Public awareness on WR&R
- S3. Social perceptions on the consumption of crops irrigated with reclaimed water
- S4. Involvement of different stakeholder groups in the decision-making processes

Technical factors
- T1. Technical expertise and know-how of wastewater (WW) reclamation and supply
  - T1.1 For the irrigation of food crops
  - T1.2 For the irrigation of non-food crops
  - T1.3 For unrestricted urban uses
  - T1.4 For restricted urban uses
  - T1.5 For industrial processes
  - T1.6 For environmental enhancement
- T2. Technical expertise and know-how of using reclaimed water
  - T2.1 For farmers and field workers
  - T2.2 For industries
  - T2.3 For urban citizens
- T3. Irrigation systems used

Legal and institutional factors
- L1. Ownership of treated WW – water rights law
- L2. Regulatory framework on WR&R
- L3. Enforcement of regulations and laws
- L4. Delineation of responsibilities among the institutions involved in water & WW management

systems. This approach does not focus on the components of the examined systems separately, but on their interrelationships, for pattern recognition. The necessary sub-steps to identify the key barriers are described in detail below.

Sub-step 2a: Definition of the impact of each barrier upon the others

Cross impact analysis (CIA) (Gordon & Hayward 1968) was performed to analyze the causal interrelationships and impacts among the set of barriers identified in Step 1. A cross-impact matrix (CIM) was developed, composed of the cause-effect relationships between each pair of the examined barriers (Figure 3). The identified barriers were placed in the same order in the rows and columns of the CIM. To fill up the CIM, the impact of each barrier of the CIM rows (B i) on every barrier of the CIM columns (B j) was considered through the following question: '*If barrier i changes and behaves as a driver for WR&R implementation, what is the impact of this change on barrier j?*'. Answers to this question were quantified and a Cross-Impact score value was assigned, as follows: 0: No improvement/change; 1: Slight/weak improvement; 2: Strong improvement; 3: Very strong improvement (i.e. the barrier becomes a driver). The CIM was completed by a group of local experts (scientists and researchers on water resources management) of the Copiapó River Basin, expressing expected changes considering the local water resources management frameworks and issues.

Sub-step 2b: Analysis of impacts and interrelationships among barriers

For each barrier, the active sum (AS) and the passive sum (PS) were calculated based on the scores of the CIM. The AS (sum of score values across a row) expresses the overall impact of

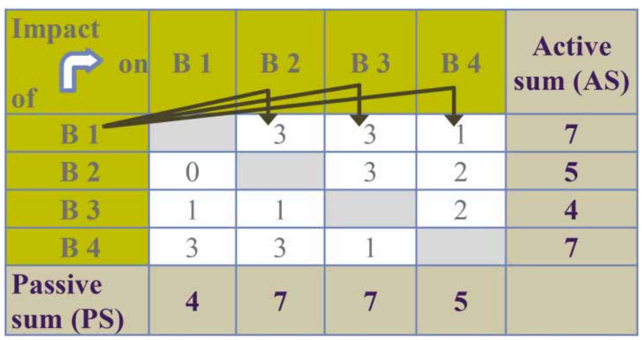

Figure 3 | An example of a CIM, including the calculation of the AS and PS.

the barrier in question upon all other barriers. The PS (sum of score values across a column) expresses the overall impact of all other barriers on the barrier in question (Figure 3).

The AS and PS are then used to identify the systemic role of the barriers. For each barrier the product P (P = AS x PS) and the quotient Q (Q = AS/PS) are calculated. Based on the corresponding P and Q values, the barriers are classified as follows (Vester 1991; Gausemeier *et al.* 1996; Linss & Fried 2010; Wolff *et al.* 2010):

- *Active barriers (barriers with high Q values)*: The higher the Q (i.e. the AS is much higher than the PS), the more regulative the barrier can be. Such barriers have a strong influence on other barriers, but are not influenced by others much. These barriers can be effective for the system's regulation; changes to these barriers can have a leverage effect on the system.
- *Reactive barriers (barriers with low Q values)*: These barriers have little influence on other barriers, but are strongly influenced by others. They are commonly used as indicators for the observation of the system's condition.
- *Critical barriers (barriers with high P values)*: The higher the P, the more integrated the barrier into the system. The barrier has strong influence on the other barriers and is also strongly influenced by them. These barriers are not easily controllable because they are highly embedded in the system's interrelationships; hence, changes to these barriers can have destabilizing effects on the system.
- *Buffering barriers (barriers with low P values)*: They are the opposite of critical barriers. These barriers have a low level of integration into the system, and are neither influencing other barriers nor influenced by others. They are inert to system change, and should be examined separately.

Based on the AS, PS, Q and P, the Cross-Impact Grid is developed for visualization of the systemic role of the barriers. The Cross-Impact Grid is a two-dimensional diagram (axes: AS & PS), made up of straight lines and hyperbolas, and divided into different color fields/areas. Each area expresses a different level of influence and integration respectively. The role of each barrier within the system is revealed according to its position in the diagram (Vester 1991; Gausemeier *et al.* 1996; Wolff *et al.* 2010). In the present study, the Cross-Impact Grid is divided into five main sections to express the different role of barriers (adopted by Gausemeier *et al.* 1996) (Figure 4). The sectioning is made using the horizontal line y = average AS, the vertical line x = average PS, the straight lines y/x = 1.3 and y/x = 0.75 and the hyperbolas x*y = 1.3 * (average AS)^2 and x*y = 0.75 * (average PS)^2. Section 1 contains the

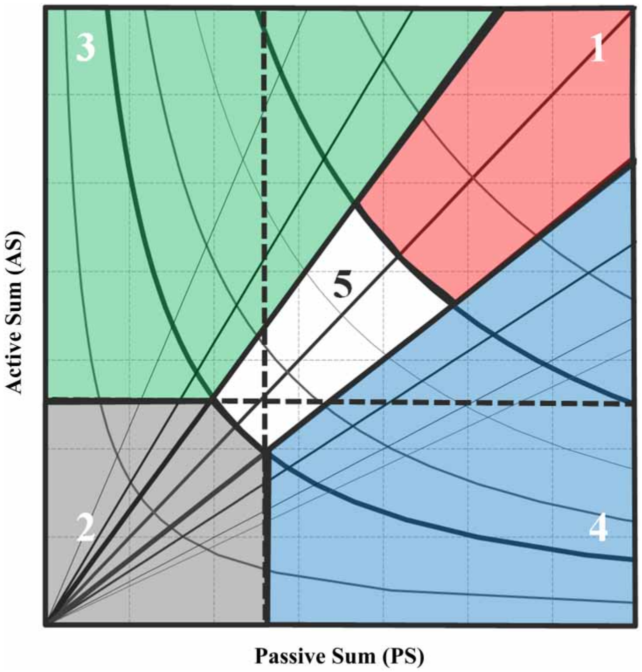

Figure 4 | The five sections of the Cross-Impact Grid: 1: Critical barriers; 2: Buffering barriers; 3: Active barriers; 4: Reactive barriers; 5: Transition zone/neutral barriers. Dotted lines correspond to the average values of AS and PS (Adapted by Gausemeier *et al.* 1996).

critical barriers, which have AS and PS above average, Q between 0.75 and 1.30, and P above 1.3 * (average AS)^2. In Section 2 the buffering barriers are found, which have AS and PS below the average values and P below 0.75 * (average PS)^2. In Section 3 the active barriers are placed, which have AS above average AS and Q $\geq$ 1.30. Section 4 contains the reactive barriers, which have PS above average PS and Q $\leq$ 0.75. Section 5 is a transition zone, which comprises the neutral barriers that can be used neither for regulation nor for observation of the system.

The key barriers which could be useful for policy formulation towards an enabling environment, and to which priority should be given by the decision-makers for the implementation of WR&R, are the active barriers, which will have the greatest positive impact on the system, and the buffering barriers, which otherwise cannot be changed to drivers.

RESULTS AND DISCUSSION

Barriers and drivers for WR&R implementation

Of the 16 factors with potential influence on the implementation of urban WR&R schemes, 15 were considered relevant to the Copiapó River Basin by the questionnaire respondents, as no transnational or transboundary treaties and agreements concerning water resources use exist in the area (factor P4).

Barriers outweigh drivers for the implementation of urban WR&R schemes in the area (10 barriers, five drivers). The 10 identified implementation barriers are presented in Figure 5.

Key barriers inhibiting system transition

Cross-impact analysis of the identified barriers

The CIM of the 10 examined barriers was developed. For each barrier, the AS and PS were calculated based on the scores of the CIM (Table 2).

System analysis of the identified barriers

Based on the AS, PS, Q and P, the Cross-Impact Grid was developed for the visualization of the systemic role of the examined barriers. The identified barriers were classified as follows: Active: L1, P2; Reactive: L3, L4; Critical: L2, S4; Buffering: P3, S2, E1; Neutral: T2 (Figure 6).

As mentioned in the Methods section, the key barriers that could be useful for policy formulation towards an enabling environment are the active and the buffering barriers. In the Copiapó River Basin, two active and three buffering factors were identified, as shown in Figure 6.

The lack of clarity on ownership and management of the treated wastewater (L1) is one of the most significant legal barriers for wider WR&R implementation in the area. A water rights system that would clearly define the ownership of treated wastewater according to its origin (e.g. municipal wastewater, grey water, industrial wastewater) and determine who has the right to use and sell it, is needed to facilitate the launch of new schemes. Incentives for using reclaimed water and minimizing wastewater discharges are necessary and could be provided by relevant environmental policies aiming to control pollution, improve water quality, and protect water ecosystems (P2). The limited integration of reclaimed water use in the current land use and development policies (P3) inhibits wider WR&R penetration, which could be significantly enhanced through supplying with reclaimed water parks and recreation areas for the redevelopment of abandoned urban zones. Furthermore, increased awareness of local society about WR&R (S2) could reduce public opposition and enhance acceptance of reclaimed water use, while financial incentives (E1), such as special programs, grants, subsidies, and loans, could motivate investments in WR&R. Along with the introduction of funding mechanisms, financial arrangements should be made to facilitate fund mobilization, and the capacity of potential investors to search for and access locally controlled funds should be fostered.

CONCLUSIONS AND DISCUSSION

The proposed methodology considers all the enabling environment aspects, as suggested by Lüthi et al. (2011), i.e. the political, economic, social, technical, legal and institutional aspects, proposing a holistic/versatile approach for the in-depth understanding of the local water systems. It provides an exhaustive list with the factors that may influence WR&R schemes, identified after an extensive literature review (sources: Baumann 1983; Blumenthal et al. 2000; Lawrence et al. 2002; Abu Madi et al. 2003; EPA Victoria 2003; Abu Madi 2004; US EPA 2004, 2012; Bixio et al. 2005; UNEP 2005a, 2005b; Bixio et al. 2006a, 2006b; Miller 2006;

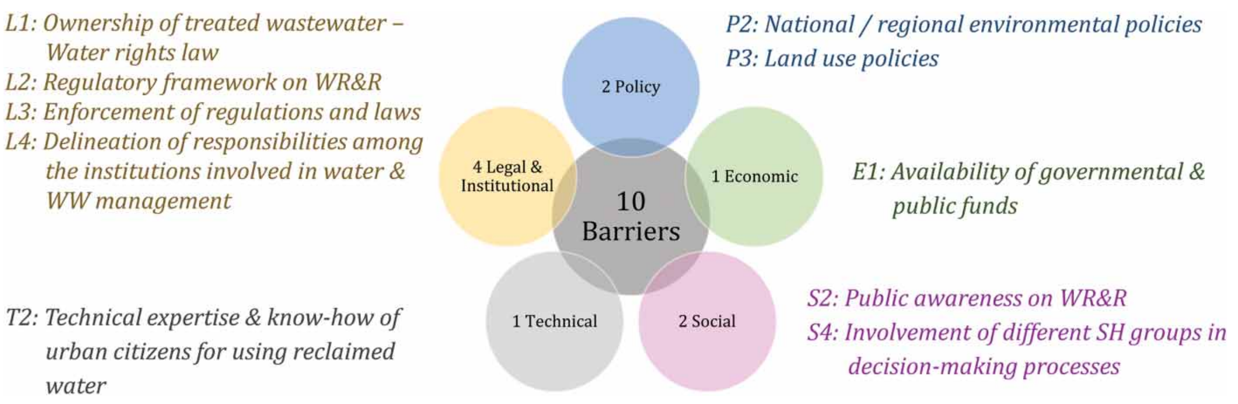

Figure 5 | The identified barriers for WR&R implementation in the Copiapó River Basin.

Table 2 | The CIM of the Copiapó River Basin[a]

	P2	P3	E1	S2	S4	T2	L1	L2	L3	L4	AS
P2		3	2	0	3	0	1	1	2	1	**13**
P3	1		1	0	1	0	0	0	1	0	**4**
E1	0	0		1	1	2	0	0	1	1	**6**
S2	0	0	1		1	1	0	2	1	0	**6**
S4	1	0	1	0		1	2	2	2	3	**12**
T2	1	0	1	2	0		2	2	1	0	**9**
L1	1	0	2	2	3	2		3	3	3	**19**
L2	0	0	1	2	2	2	1		3	3	**14**
L3	0	0	0	1	2	2	1	1		2	**9**
L4	1	0	0	0	2	0	1	2	2		**8**
PS	**5**	**3**	**9**	**8**	**15**	**10**	**8**	**13**	**16**	**13**	

[a]0: no improvement/change; 1: slight/weak improvement; 2: strong improvement; 3: very strong improvement (the barrier becomes a driver).

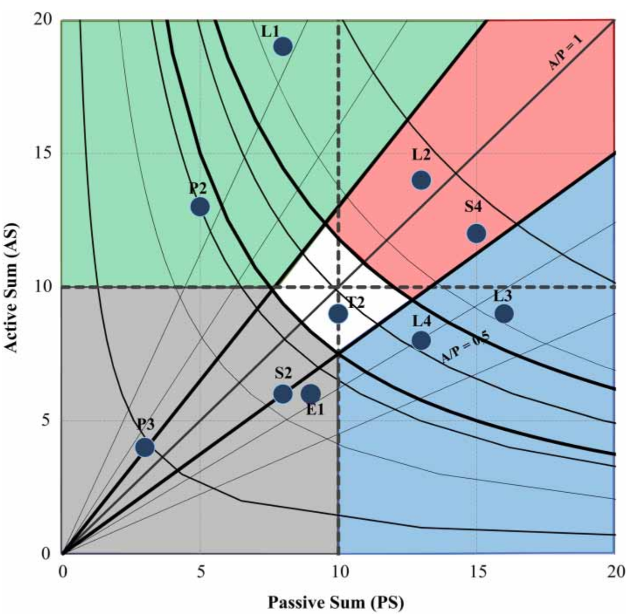

Figure 6 | The Cross-Impact Grid of the Copiapó River Basin. Red section: Critical barriers; Grey section: Buffering barriers; Green section: Active barriers; Blue section: Reactive barriers; White section: Transition zone/neutral barriers. Dotted lines correspond to the average values of AS and PS. The full color version of this figure is available in the online version of this paper, at http://dx.doi.org/10.2166/wst.2017.353.

Toze 2006; World Bank 2006; UNDP 2006; Angelakis *et al.* 2007; Asano *et al.* 2007; MED WWR WG 2007; Qadir *et al.* 2007; Bakopoulou *et al.* 2008; General Electric Water & Process Technologies 2008, 2011; Bahri 2009, 2012; UN-Habitat 2009; Condarin *et al.* 2010; Parsons *et al.* 2010; US Department of Agriculture Economic Research Service 2010; Krpan 2011; Lüthi *et al.* 2011; Condom *et al.* 2012; NRDC 2012; Chellaney 2013; UNW-DPC 2013; Sanz & Gawlik 2014; BIO By Delloitte 2015; Freedman & Enssle 2015).

The adopted methodological framework enhances the participatory decision-making processes, as it engages the local stakeholders and incorporates their views and standpoints. In addition, it proposes a novel, effective and systematic approach to recognize the most significant implementation barriers, and prioritize the enabling instruments and arrangements that are needed for wider WR&R penetration, adapted from Frederic Vester (Vester 1988). Vester's method is widely applied for the analysis of various systems (e.g. Chan & Huang 2004; Lang *et al.* 2006; Cole *et al.* 2007; Huang *et al.* 2009; Wolff *et al.* 2010; Kalema *et al.* 2014; Ribeiro 2016). Despite its wide application, this method is used for the first time for the identification of the significant factors affecting the implementation of WR&R schemes. The adoption of this method has the advantage of considering the interrelationships and the systemic role of factors (each factor is not considered in isolation from the rest of the system); an advantage lost in cases where the identification of the factors affecting systems' performance is solely based on expert judgement and stakeholder views (e.g. Abu Madi 2004; Eadie *et al.* 2010; Ghazilla *et al.* 2015; Craig *et al.* 2017) or on literature sources (e.g. Mainali *et al.* 2011). However, the proposed method considers only the direct interrelationships of the examined factors and does not take into account the indirect interrelationships among them and the relevant feedback loops. This may lead to a questionable ranking of the considered factors (Linss & Fried 2009). Therefore, it would be interesting to assess and examine the impact of indirect interrelationships among the identified barriers by applying methods which take them into account, such as the MICMAC method (Duperrin & Godet 1973), the ADVanced Impact Analysis – ADVIAN method (Linss & Fried 2009), and the Decision Making Trial and Evaluation Laboratory – DEMATEL method (Li *et al.* 2014).

An additional constraint of the proposed methodology that needs to be examined further is the subjective scoring of impacts among the identified barriers. The completion of the CIM is based on expert judgement, and relies on the degree of understanding and knowledge/perceptions of the involved stakeholders. Unlike statistical methods, this method introduces subjectivity in the final results. Slight changes in the score after a re-evaluation of the impacts can lead to different results (Linss & Fried 2010). For this reason, it is important to ensure full understanding of the issues that participants are asked to judge.

Application of the proposed approach in the Copiapó River Basin in Chile revealed the most crucial factors inhibiting the wider WR&R penetration in the area and identified the policy priorities towards an enabling environment. A coherent water rights system should be introduced in the area, regulating the allocation of water rights to different users, and the duration of these rights, to allow for efficient discussions among stakeholders and estimation of the economic benefits for different actors. In addition, the current regional environmental policies do not aim to control pollution or regulate the quality of wastewater, and hence they do not encourage WR&R. The institution of policies aiming to protect the aquatic ecosystems and adapt to climate change through the improvement of water quality (e.g. regulations regarding the quality and quantity of effluent discharge, minimum thresholds in environmental flows, and penalties for the untreated wastewater discharge) would provide an incentive for the urban reuse of treated effluents, and minimize wastewater discharges. Likewise, the consideration of reclaimed water use in land use and spatial development policies could enhance the redevelopment of abandoned urban areas through the provision of alternative water resources for the irrigation of parks and the development of recreation areas. Moreover, more governmental and public funding sources should be available to support WR&R schemes and provide direct financial incentives for investments. People in the Copiapó River Basin are still reluctant to accept reclaimed water. Raising public awareness on WR&R and improving the access of local society to relevant information can help overcome concerns related to health and environmental risks and encourage the implementation of urban WR&R schemes.

The assessment results can provide useful input to decision-making and planning processes concerning WR&R implementation. The proposed framework can be applied in different areas to enable the implementation of suitable interventions, and can be further reviewed and adjusted to support the wider penetration of other innovative technologies and practices in cases where similar paradigm shifts are needed.

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