Creating an Enabling Environment for WR&R Implementation

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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 is applied in the Copiapó River Basin in Chile, which faces severe water scarcity.

Keywords
Water recycling & reuse; enabling environment; implementation drivers & barriers; water scarcity; Copiapó River Basin

INTRODUCTION

Treated wastewater has been shown to be a reliable alternative water resource, while 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., 2015). Despite the various benefits associated with reclaimed water use (e.g. locally controlled and constantly produced water supply, reduced wastewater discharges, decreased water abstractions, energy savings, environmental protection), WR&R practices are not widely applied around the world, while, in many places experiencing water scarcity, only isolated or no reuse practices are applied (Garcia & Pargament, 2015; Miller 2006; Salgot, 2008). This is mostly due to complex and inadequate legal and institutional frameworks and socio-economic structures that hinder the implementation of WR&R schemes, such as weak or inadequate governmental policies which discourage WR&R penetration, lack of available funding sources, negative social perceptions, limited capacity of relevant utilities for the reliable and consistent production and delivery of reclaimed water, non-existent legal frameworks regulating water resources management, and overlapping jurisdictions among involved institutions (Asano et al., 2007; Hidalgo et al., 2007; Miller 2006).

A paradigm shift is needed to overcome WR&R implementation barriers and effectively address the water related challenges (UNESCO 2013; Bahri, 2009). 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 more than availability and cost of reclamation technologies, i.e. on government policies and affected people and institutions (Asano et al., 2007; Hidalgo et al., 2007; Lawrence, et al., 2002; Miller, 2006).

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.

MATERIALS & 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), pose 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).

Figure 1. Location of the Copiapó River Basin.

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 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 which 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. 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.

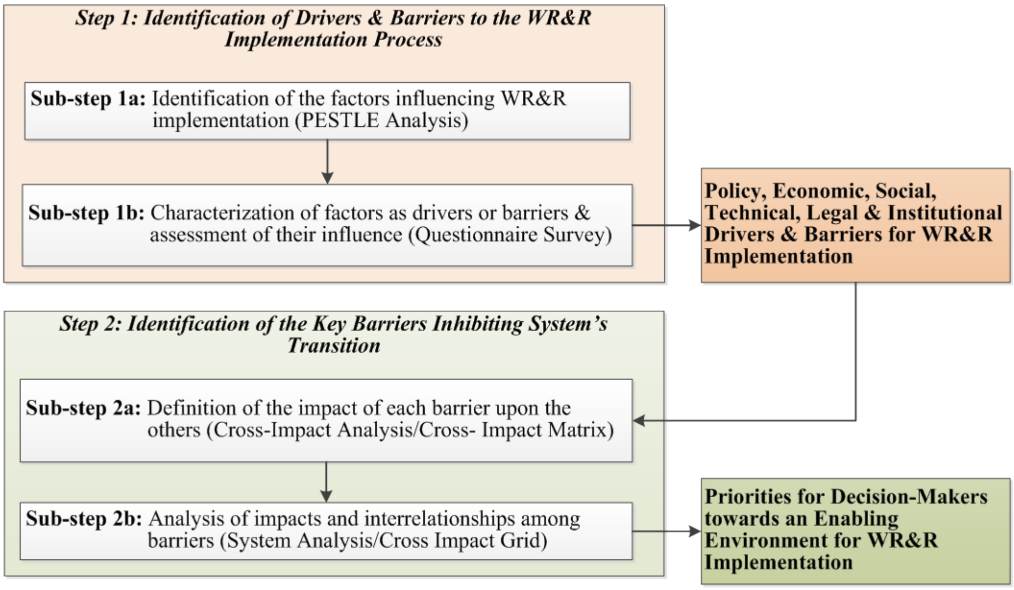

Figure 2. The methodological framework towards an enabling environment for WR&R.

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 PESTLE 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 PESTLE questionnaire was developed for the assessment of the 22 factors. The local stakeholders 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 local stakeholders. Questionnaire respondents covered a wide range of capacities ranging from local government to farmers and civil society members. They have been categorized into different stakeholder groups, to identify different perceptions according to their interests, knowledge and expertise.

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 & agreements
P5. Trade policies (exports of agricultural products)
Economic factors
E1. Availability of governmental & 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 decision-making processes
Technical factors
T1. Technical expertise & know-how of wastewater (WW) reclamation & 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 & 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 & 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

Step 2: Identification of the key barriers inhibiting system's 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 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 experts 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 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).

Impact of ↱ on	B 1	B 2	B 3	B 4	Active sum (AS)
B 1		3	3	1	7
B 2	0		3	2	5
B 3	1	1		2	4
B 4	3	3	1		7
Passive sum (PS)	4	7	7	5	

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

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 Ps and Qs the barriers are classified as follows (Gausemeier et al., 1996; Linss & Fried, 2010; Vester, 1991; 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 strong influence on other barriers, but are not influenced by others much. These barriers can be effective for the system's regulation; changes on 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 on 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 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 the 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, 1996; Wolff et al., 2010). In the present study, the Cross-Impact Grid is divided in five main sections to express the different role of barriers (adopted by Gausemeier et al., 1996) (Figure 4).

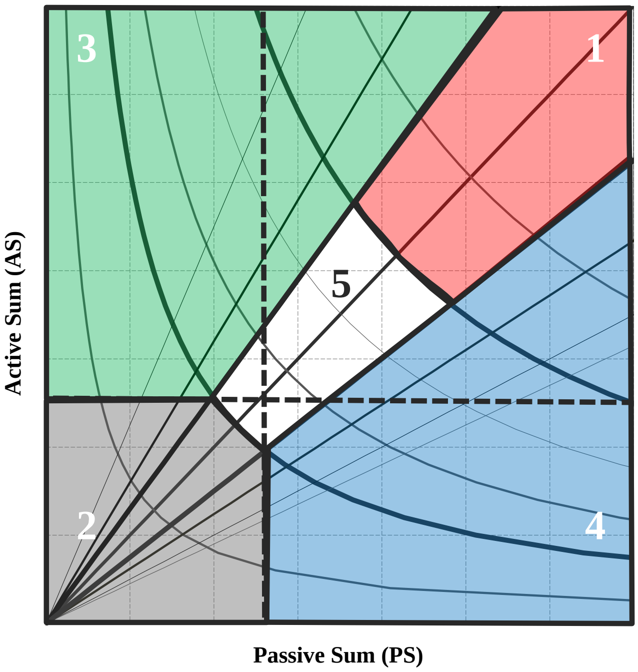

Figure 4. The five sections of the Cross-Impact Grid: 1: Critical barriers; 2: Buffering barriers; 3: Active barriers; 4: Reactive barriers; 5: Transition zone / neutral barriers. Dotted lines correspond to the average values of AS and PS (Adapted by Gausemeier et al., 1996).

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 & DISCUSSION

Barriers & 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, 5 drivers). The 10 identified implementation barriers are presented in Figure 5.

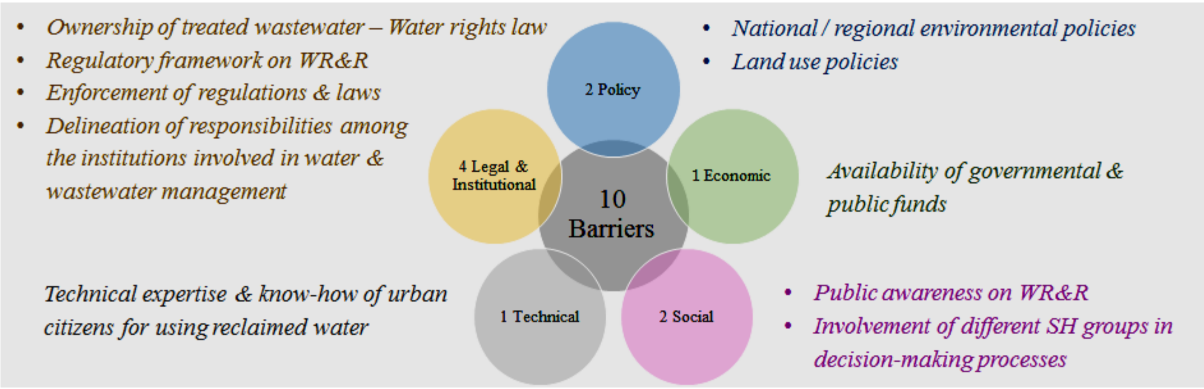

Figure 5. The identified barriers for WR&R implementation in the Copiapó River Basin.

Key barriers inhibiting system's 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).

Table 2. The Cross-Impact Matrix of the Copiapó River Basin*

	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**	

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

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).

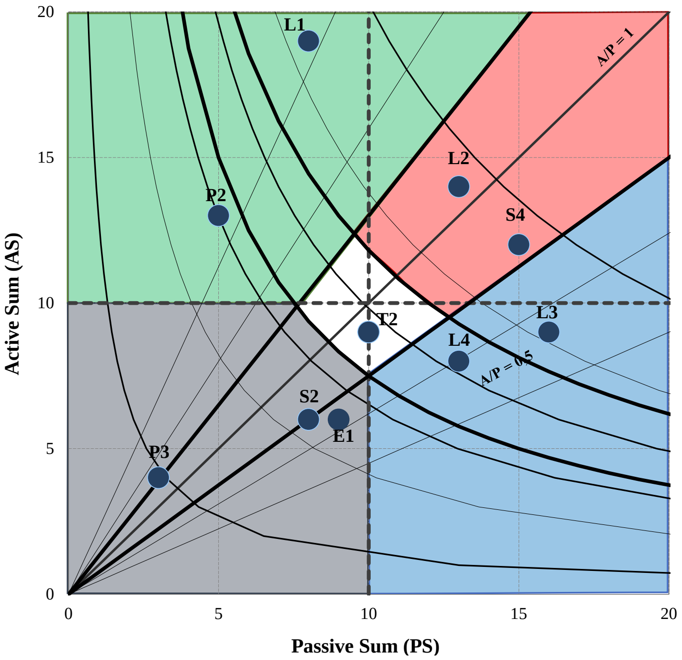

Figure 6. The Cross-Impact Grid of the Copiapó River Basin.

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 in the Copiapó River Basin for implementing urban WR&R schemes, are: the unclear legal framework regarding the ownership of treated wastewater (L1), the lack of environmental policies focusing on pollution control (P2), the limited integration of reclaimed water use in the current land use and development policies (P3), the limited public awareness on WR&R (S2), and the limited availability of governmental funding sources for WR&R (E1).

The lack of clarity on ownership and management of the treated wastewater is one of the most significant legal barriers for wider WR&R implementation in the area. A water rights system which 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. The limited integration of reclaimed water use in the current land use and development policies inhibits the 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 on WR&R could reduce public opposition and enhance acceptance of reclaimed water use, while financial incentives, 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

This study proposes a versatile and effective approach for the in-depth understanding of the local water systems, providing an exhaustive list with the factors that may influence WR&R schemes. It proposes a novel and systematic method to recognize the most significant implementation barriers, and prioritize the enabling instruments and arrangements that are needed for the wider WR&R penetration, combining and adapting methodological approaches used in different fields. In addition, the adopted methodological framework enhances the participatory decision-making processes, as it engages the local stakeholders and incorporates their views and standpoints.

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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