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LOCAL REGULATIONS ON ALTERNATIVE WATER SOURCES: GREYWATER AND RAINWATER USE IN THE METROPOLITAN REGION OF BARCELONA

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ABSTRACT

Alternative water resources are gaining momentum in Catalonia (north-east Spain) in an effort to promote water conservation and build resilience against drought episodes. Since 2002 more than 50 municipalities (summing up more than 1.3 million people) have approved a water saving ordinance that involves the installation of rainwater harvesting and/or greywater reuse systems in new buildings. These new technologies trigger important transformations in the existing water cycle including institutional and social changes related with water decentralization. Drawing on interviews with local environmental managers and survey data from rainwater harvesters and greywater users, this paper analyses the social and technical learning generated during the implementation of the regulations and the main impediments and barriers that need to be overcome to control health risks and promote social acceptance of these alternative water sources.

Keywords: alternative water sources, greywater reuse, rainwater harvesting, water saving ordinance, Metropolitan Region of Barcelona (MRB).

RESUMEN

Ordenanzas sobre el uso de fuentes alternativas de agua: aguas grises y pluviales en la Región Metropolitana de Barcelona

Las fuentes alternativas de agua están ganando importancia en Cataluña (nordeste de España) como resultado de las nuevas políticas locales que promueven la conservación del agua y una mayor resiliencia frente a episodios de sequía. Desde 2002, más de 50 municipios (incluyendo en total más de 1.3 millones de personas) han aprobado ordenanzas municipales de ahorro de agua, las cuáles exigen la instalación de sistemas de captación de aguas pluviales y reutilización de aguas grises en edificios de nueva construcción. Estas nuevas tecnologías transforman el ciclo hídrico existente e inducen importantes cambios institucionales y sociales relacionados con la descentralización de la gestión del agua. A partir de una serie de entrevistas con técnicos municipales y encuestas con usuarios de sistemas de aguas grises y pluviales, este artículo analiza el aprendizaje socio-técnico generado durante la implementación de las ordenanzas y los principales impedimentos y barreras que deben ser superados para minimizar los riesgos para la salud y promover la aceptación social de estas fuentes de agua alternativas.

Palabras clave: fuentes alternativas de agua, reutilización de aguas grises, captación de aguas pluviales, ordenanza de ahorro de agua, Región Metropolitana de Barcelona (RMB).

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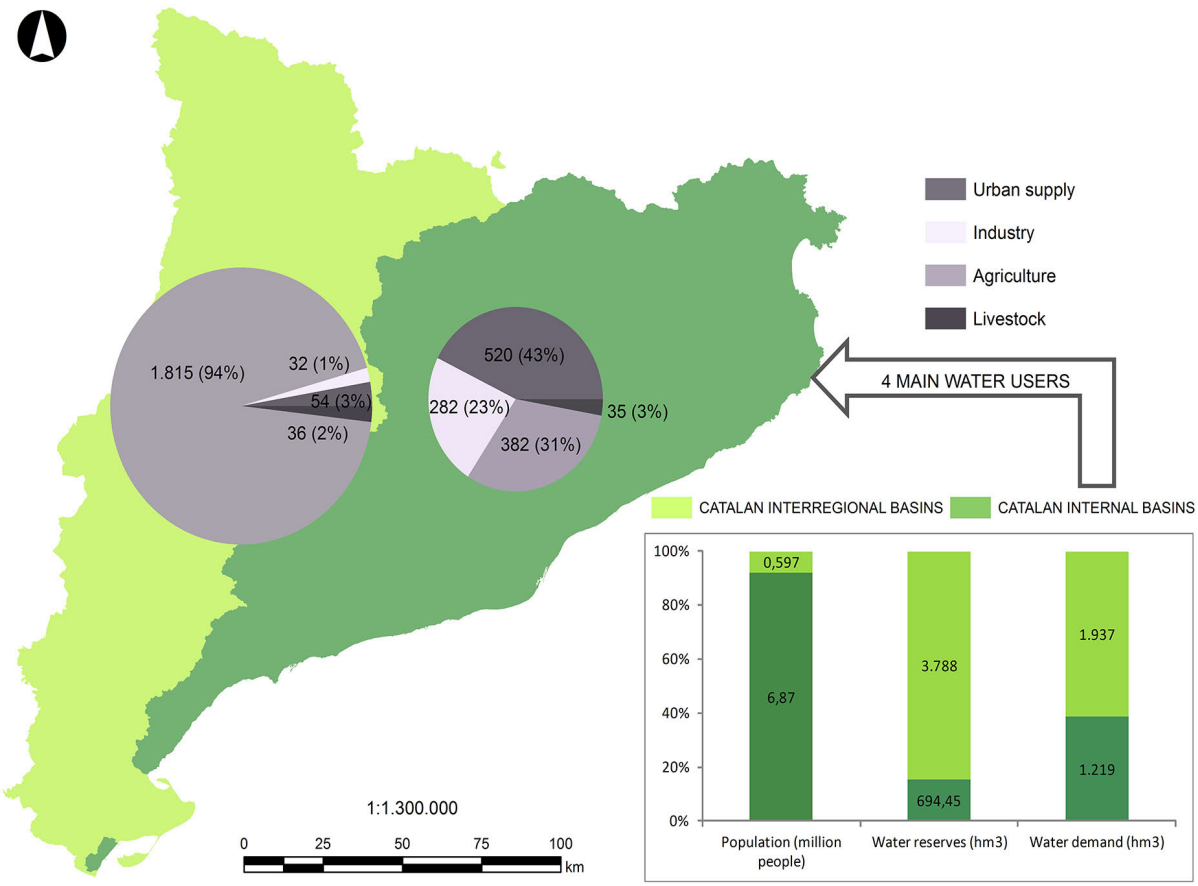
1. INTRODUCTION: THE EMERGENCE OF LOCAL WATER REGULATIONS IN CATALONIA

Urban water management in Catalonia and more importantly in the Metropolitan Region of Barcelona has suffered significant transformations in the last decade. The main drivers of these transformations are environmental and socio-political. On the environmental side, the Barcelona region has suffered important droughts in 1998-2002, 2004-2005 and 2007-08. As Latorre (2008) argues droughts are not only the expression of a weather phenomenon consisting on a lack of rainfall, but also the expression of a social phenomenon defined by the imbalance between available water resources and current demand and demand in the foreseeable future. The 2007-08 drought was the most severe of the last decade. Some outdoor water uses such as garden watering or swimming pool refilling were banned, water tankers had to be used to ship water from Southern Spain and France to Barcelona and the region was just days away of having to enforce domestic cuts (March *et al.*, 2013). Climate change forecasts for the Mediterranean region including Catalonia suggest a reduction in average precipitation and an increase in rainfall variability which will lead to more intense and recurrent droughts in the region (ACA, 2008).

Figure 1. Main features of the Catalan Water Basin Districts



Source: ACA (2008). Own elaboration.

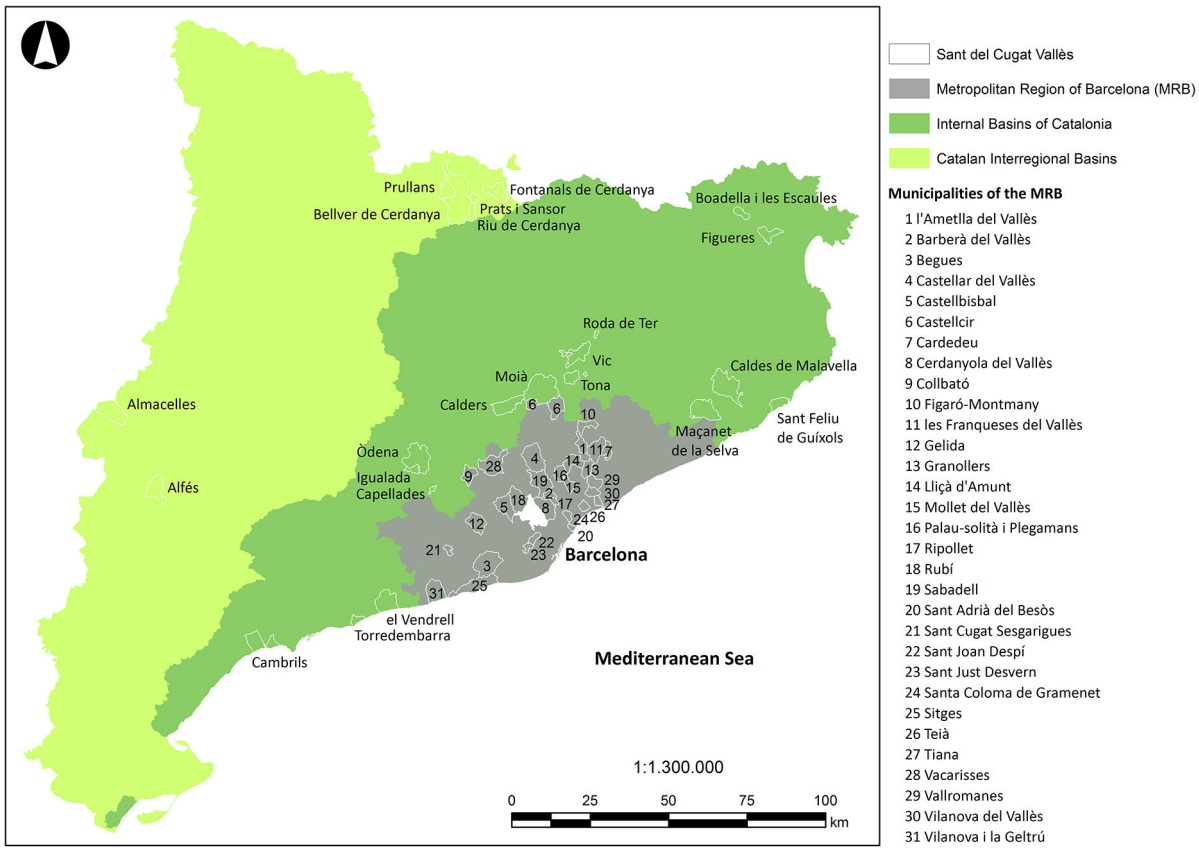
Catalonia is divided into two main administrative areas in terms of water management: the internal hydrographic basins and the interregional hydrographic basins. There is a clear unbalance between population and water reserves in these two areas. Although the surface area of both hydrographic basins is almost the same (52% vs. 48%), only 15% of the water reserves of Catalonia are found in the Catalan internal basins, home on the other hand of 92% of the Catalan population. The interregional basins concentrate 85% of the resource and only 8% of the population. In the Catalan internal basins, most water (65%) is used for urban and industrial purposes while in the interregional basins 90% of the water is used for irrigation (Figure 1) (ACA, 2008).

In an effort to become more resilient against future drought episodes and reduce urban water consumption, many municipalities have approved water saving ordinances to make the most of local water resources and promote water savings in their municipalities. As of October 2013, 55 water saving ordinances had been approved in Catalonia, 49 of them in the Catalan Internal Basins where urban and industrial water consumption is predominant.

Water scarcity has not been the only motivation behind the approval of water saving ordinances. The emergence of a new water management paradigm based on demand-side strategies and a *New Water Culture* have also influenced the policies that some city councils have adopted. In Spain, a *New Water Culture* based on water rationalization and the recognition of the recreational and emotional properties of water started gaining momentum as a response to the 2001 National Water Plan which involved water transfers from the Ebro River to Eastern and Southern Spain. In contrast, the hydraulic paradigm based on the construction of large infrastructures such as water transfers and dams to supply water and meet the growing demand is declining in western countries (Saurí *et al.*, 2001; Kallis and Cocossis, 2003). The reasons behind the decline of the hydraulic paradigm include more restrictive environmental legislation; the opposition from donor basins to water exports; the growing physical scarcity of high quality sources; and the increasing costs and difficulties to finance large infrastructures (Dziegielewski, 1999).

The approval of the water saving regulation was also influenced by Local Agenda 21 processes which were initiated in many municipalities after the 1992 Earth Summit. For example, in Sant Cugat del Vallès, the first municipality approving a water saving ordinance in Catalonia, the recommendation to enact municipal legislation regarding water conservation emerged as a result of the Environmental Diagnosis of the Local Agenda 21. This diagnosis detected high water consumption in the municipality and in response the Participatory Action Plan included a proposal to draft an ordinance to reduce water consumption, encourage water savings and promote the use of alternative water resources such as rainwater or greywater.

Figure 2. Municipalities with a water saving ordinance in Catalonia



Source: Vallès, *et al.* (2011). Own elaboration.

With the aim of saving and conserving water, the ordinance of Sant Cugat del Vallès mandates the installation of water saving devices such as water pressure regulators or dual flush toilets and the (re)use of local water sources such as rainwater, greywater and swimming-pool water in new buildings. Sant Cugat del Vallès was the first municipality to approve such regulation in 2002. By 2005, fourteen municipalities had their own water saving regulations. In view of the growing interest, the Diputació de Barcelona (provincial government) approved in 2005 a framework ordinance to help municipalities develop their own legislation. In 2006, State (Spanish) and Regional (Catalan) legal instruments were also approved regarding the installation of water saving devices in toilets, showers and washbasins. As of October 2013, 55 municipalities in Catalonia -totaling more than 1.3 million people- had approved a regulation for saving and conserving water; 32 of them are located in the Metropolitan Region of Barcelona (Figure 2).

The most innovative and salient feature of these local water regulations concerns the installation of small scale water systems to harvest rainwater and reuse grey water on-site. The use of local water flows is based on the principle of fit-for-purpose water use (Brown *et al.*, 2009), or on the assumption that water has many qualities and not all water uses (e.g. toilet flushing, laundry or irrigation) require the same level of quality. Traditionally, most local water sources have been treated as "nuisances" in urban areas but with these regulations, they become valuable resources and promising alternatives to centralized, supply side approaches.

Due to the novelty of these policies and the decentralized nature of the systems, a series of new challenges arise. These systems are not managed by a central water authority and in contrast, water users are the owners of the systems and are responsible for their correct operation. All in all, the use of alternative water resources may trigger important transformations in the existing water cycle including institutional and social changes related with water decentralization.

2. OBJECTIVES AND METHODOLOGY

This paper aims to examine the main barriers to the effective adoption of the water saving ordinance, the socio-technical learning generated since the approval of the first ordinance in 2002 and the prospects for up-scaling the use of alternative water resources in the Barcelona region.

A mixture of methodological tools was used to analyze the implementation of the water saving ordinance and the main impediments associated with the use of rainwater and greywater reuse systems. The text of the fifty five local ordinances approved in Catalonia until October 2013 was systematically assessed. In addition, in 2011 key-informant interviews were conducted in 14 municipalities with the main actors responsible for the development and implementation of the local ordinances. We interviewed the environmental managers of the municipalities that approved the ordinance earlier and therefore had greater experience with this tool. In addition, we conducted an on-line survey with the rest of municipalities that had approved a water ordinance at that time. Ten municipalities responded the on-line survey and therefore, altogether we obtained information of twenty four municipalities (48% of the sample at that time). At the end of the study, we conducted a seminar in the Diputació de Barcelona to discuss the results of the study with local environmental managers. In total, thirteen municipalities participated in the seminar (10 with ordinance and 3 without ordinance).

The results of this study are also complemented with two different surveys conducted in Sant Cugat del Vallès among 134 users of greywater and rainwater systems and with a series of key-informants interviews with the main actors involved in the design, installation and maintenance of these systems. The results of this previous study can be found in Domènech and Saurí (2010) and Domènech and Saurí (2011). Since Sant Cugat del Vallès was the first town that approved a water saving regulation, we have analyzed in more detail the implementation of the regulation in this town.

3. RAINWATER HARVESTING AND GREY WATER REUSE IN METROPOLITAN BARCELONA: MAIN FEATURES

The use of alternative water resources such as rainwater harvesting and greywater reuse is the most novel feature of the water saving ordinances. Rainwater harvesting may be defined as the collection of

runoff generated from rooftops and its subsequent storage for later use. Almost all municipalities, up to 53 included rainwater harvesting in their water regulations. Rainwater harvesting systems became mandatory in new buildings with a minimum surface of garden. In Metropolitan Barcelona, harvested rainwater is generally used for irrigation purposes which accounts on average for 36% of the daily water demand in a single-family house with garden (Domene *et al.*, 2004). According to Domènech and Saurí (2011) rooftop rainwater can meet more than 60% of the irrigation demand of a standard single or multi-family building of the Metropolitan Region of Barcelona. The same study shows that rainwater harvesting can meet 100% of the toilet flushing and laundry demand in a standard single family house. In spite of the fact that water savings can be significant, home owners rarely feel encouraged to install a rainwater harvesting system because economic benefits are only obtained in the long term after covering for high capital costs. However, most users surveyed did not perceive the cost of their rainwater harvesting system as high, and many even wished they had a larger tank (Domènech and Saurí, 2011).

Table 1. Comparative analysis between rainwater harvesting and greywater reuse systems

	RAINWATER HARVESTING	GREYWATER REUSE
WATER QUALITY	Good	Low-polluted
NUMBER OF ORDINANCES	53 (96%)	35 (64%)
SCOPE	New buildings with a minimum surface of garden	New buildings with a minimum of 8 apartments
WATER TREATMENT	Filter, first flush diversion and/or disinfection	Physicochemical, biological or membranes treatment and disinfection
MAINTENANCE REQUIREMENTS	Relatively low	Depends very much on the type of system
CAPITAL COSTS	Relatively high depending on the size of the tank	Relatively high
PAY-BACK PERIOD	Long	Long
MAIN USES	Garden irrigation	Toilet flushing
ESTIMATED WATER SAVINGS	60% of the garden irrigation and 100% of the toilet flushing and laundry demand in single-family buildings	100% of the toilet flushing demand
PUBLIC ACCEPTANCE	Good	Relatively good
USER SATISFACTION	High	Depends on the type of the system

Greywater systems enable to reuse low-polluted water on-site through a fairly simple treatment process (Eriksson *et al.*, 2002; Warner, 2006). In total, 35 municipalities included greywater reuse in their water regulations as of October 2013. Greywater systems in the Barcelona area are typically installed in new buildings with a minimum of 8 apartments. These systems reuse water from the shower or the bath for toilet flushing purposes and enable to save about 21% of the water consumed in a multifamily building (Domene *et al.*, 2004). Greywater systems also present long pay-back periods and therefore, are not very attractive from a financial point of view. The capital cost of a greywater reuse system was estimated on average at €516 per flat in Domènech and Saurí (2010), which represents less than 0.2% of the total cost of a new flat. In spite of the absence of economic benefits, survey results show again that most users (69%) did not perceive greywater reuse systems as expensive, most probably because the costs associated with the greywater system are not made explicit to users.

At the beginning, the performance of the greywater systems was at times not too satisfactory and numerous complaints for the generation of unpleasant smells were reported in Sant Cugat del Vallès (Domènech and Saurí, 2010). This dissatisfaction was frequently offset by the awareness on the positive impacts of greywater reuse for the environment. Environmental conservation was the most appreciated benefit associated with the new technology. The same study identified the main factors influencing greywater users' acceptance in San Cugat del Vallès. Perceived health risks, operation regime, perceived costs and environmental awareness were found to be the main determinants of public acceptance (Domènech and Saurí, 2010). Among these, the perceived health risk was the most important determinant of public acceptance. Nonetheless, for most greywater users health risks were not a source of great concern. Even

if at the beginning greywater systems raised mixed feelings among users due to operational problems, survey results from Sant Cugat del Vallès show that, in general, public acceptance towards these systems was rather high (Domènech and Saurí, 2010).

In table 1, we compare the main features of rainwater harvesting and greywater reuse systems in the Metropolitan Region of Barcelona.

4. ALTERNATIVE WATER RESOURCES AND LOCAL GOVERNANCE: MAIN CHALLENGES

At the local level, the elaboration and implementation of the water saving regulation has been and still is a challenging task for the municipalities. Most municipalities, up to 53 included rainwater harvesting in the ordinance while only 35 municipalities included greywater reuse. The lower number of ordinances promoting greywater reuse in comparison with rainwater harvesting is explained by a number of factors. Greywater reuse was not considered in municipalities having a predominantly disperse urban form (greywater systems are less cost-effective in single-family houses than in apartment blocks). Besides that, some local environmental managers and other water actors were reluctant to enforce its use because they had reservations regarding the potential and performance of the technology.

Some municipalities faced difficulties during the elaboration and implementation of the ordinances due to lack of cooperation between the different municipal departments. The ordinances are usually developed by the local environmental department but frequently, the implementation of the ordinance is responsibility of the urban planning department. All the departments of the municipality affected by the ordinance need to understand and agree with the benefits and requirements of the regulation for a successful implementation of the ordinance.

The communication of the water saving regulation to the affected public is also crucial. Citizens become both "producers" and "consumers" of alternative water sources and therefore, need to be aware of system requirements. In this sense, the municipalities have used various strategies to inform citizens about the new regulations and the specificities of decentralized water systems including the publication of the ordinance in the website or local bulletin, the publication of news in the local media, the distribution of water saving devices, the organization of information sessions, the publication of handbooks and leaflets about the ordinance and setup of information booths, etc.

However, results of the survey conducted with the users of the grey water systems point at a limited efficacy of these actions (Domènech and Saurí, 2010). The survey revealed that over 50 per cent of the greywater users ignored basic information about the operation of the system while over 50 per cent of users declared not having received enough information about greywater reuse. In addition, in multi-family buildings, many residents ignored the presence of the rainwater harvesting system in their building (Domènech and Saurí, 2011). Users need to be aware of the restrictions that apply to reused water and accordingly, adjust their behavior in order to minimize risks and reduce potential failures of the system (e.g. chemical products should not be thrown down the bathtub because they can harm the greywater system).

Decentralized water supply systems change the configuration of the urban water cycle. Instead of private or public water companies, citizens are called upon to play a central role in the management of these water systems, as users are the owners of the systems and are responsible for their proper operation and maintenance. In single family houses alternative water systems are individually owned and managed while in multi-story buildings a community form of management is required.

An important concern for local environmental managers is how to make sure that these systems are operating well and do not pose health risks to users. With this intention, the ordinances establish that the developer has to sign a contract with a maintenance professional company for duration of at least two years. However, after that period, the responsibility of maintaining the system falls on the users who should continue hiring someone to undertake such task. The city council supervises and authorizes the startup of the systems when these are new but after that, does not have the capacity to control the adequate operation of the systems on a regular basis. Some environmental managers proposed the creation of a regional entity as a potential solution to ensure the safe operation of greywater systems and more

affordable and viable water quality testing. So far, water quality standards for these types of systems have not been approved by the competent authorities although some guidelines are available in AQUAESPAÑA (2011) and some ordinances also include in an appendix water quality standards for greywater reuse. Unless these standards are set and approved by the competent authorities, new investments and new technological developments could be hard to implement. In this respect, it is very important to bear in mind that any failure of the systems, especially if the failure involves health issues, would be terrible from the perspective of public perception and acceptance would probably fall drastically.

5. SCALING-UP ALTERNATIVE WATER RESOURCES IN METROPOLITAN BARCELONA: SOCIO-TECHNICAL LEARNING AND THE WAY AHEAD

The emergence and establishment of decentralized technologies in the Barcelona area provides a good example of a transition process in which much learning has been generated by trial and error. Fourteen municipalities have modified the initial ordinance approved to incorporate the experience gained during the last years. For instance, the 2008 modification of the Sant Cugat del Vallès ordinance establishes a minimum tank capacity of 5 m^3 and reduces the minimum garden area required to install a rainwater harvesting system from 1.000 m^2 to 300 m^2 in order to increase the number of households affected by the regulation. Another change involves the modification of the formula used to calculate the size of the greywater recycling system. Instead of calculating the size of the accumulation tank based on the volume of the greywater generated in the showers and baths, the new ordinance states that it should be calculated based on the toilet flushing demand with the objective of minimizing the time that greywater stays in the tank.

Greywater reuse technologies have also substantially evolved in this period. More sophisticated and efficient technologies have displaced less sophisticated ones. In Sant Cugat del Vallès, the first greywater systems installed were quite simple and usually involved a basic filtration device to capture coarse elements and a tank for the chlorine treatment. Maintenance requirements included the removal of refuse from the filtration devices and the periodic replacement of the chlorine pill (usually once a week). As we mentioned in section 3, greywater systems raised mixed feelings in flat owners and tenants because performance was at times not completely satisfactory and complaints for the generation of unpleasant smells were common (Domènech and Saurí, 2010). A rather usual scenario was one of satisfaction at the beginning (in part related to the more pro-environmental attitudes of dwellers) that turned into dissatisfaction when the first problems in maintenance appeared. The use of chlorine, in particular, has proven to be very problematic because of lack of knowledge in proper doses and the need for a continuous maintenance. While the first maintenance services sometimes performed a deficient job, the behavior of contractors and builders did not help much either. During the first years of operation of these systems the environmental department of Sant Cugat city council had to argue and sometimes fight hard with contractors in order to have the systems properly installed and operational.

However, recent greywater systems appear to have left behind many of the problems of the first installations. As in other parts of the water cycle, a major breakthrough has been the proliferation of systems using extremely fine filtration procedures in the form of membranes. The most advanced systems installed in Sant Cugat in 2010 and 2011 use a much more sophisticated and reliable technology with biological and ultra-filtration procedures. For instance, in one of the systems currently used in new housing developments water coming from showers is subject to a double process. First, a biological cleaning using bacterium allows for the destruction of all organic matter. Second, the resulting water is subject to a process of ultra-filtration with a pore size of 0.05 µm. In this way no further chemical treatments are needed. Instead of the weekly or more frequent maintenance tasks, these newer systems can operate for months, and maintenance is performed by a specialized company. Hence, many of the problems associated with the early greywater systems pointed above have disappeared, especially those related to odors and the management of chemicals. Furthermore, maintenance costs have also decreased. For a system serving some 20 apartments, maintenance costs are about 800 euro/year; that is, below the 1,500 euros or more of other systems. However, membrane technologies imply higher energy costs. The energy consumption of a system treating 4,000 liters/day is calculated in 1.7 kWh/m^3 of water. For

comparison purposes, the desalination plant of Barcelona consumes approximately 4 kWh/m^3 (see Domènech *et al.*, 2013).

Public acceptance towards these new technologies is also critical to ensure their widespread adoption. This is even more critical for the case of greywater reuse due to its initial lower quality in comparison to rainwater. A survey comparing assessments of four water supply alternatives (desalinated water, reclaimed water, greywater and rainwater) by different water management stakeholders in Catalonia revealed that water supply companies did not appear to support the implementation of decentralized water systems which may be explained by the fact that decentralized systems may reduce the scope of action of large public and private supply companies (Domènech *et al.*, 2013). The same study reveals that rainwater was preferred to greywater in all cases, and that, for some stakeholders (e.g. the main water regulator in Catalonia) greywater reuse was the least preferred alternative (Domènech *et al.*, 2013).

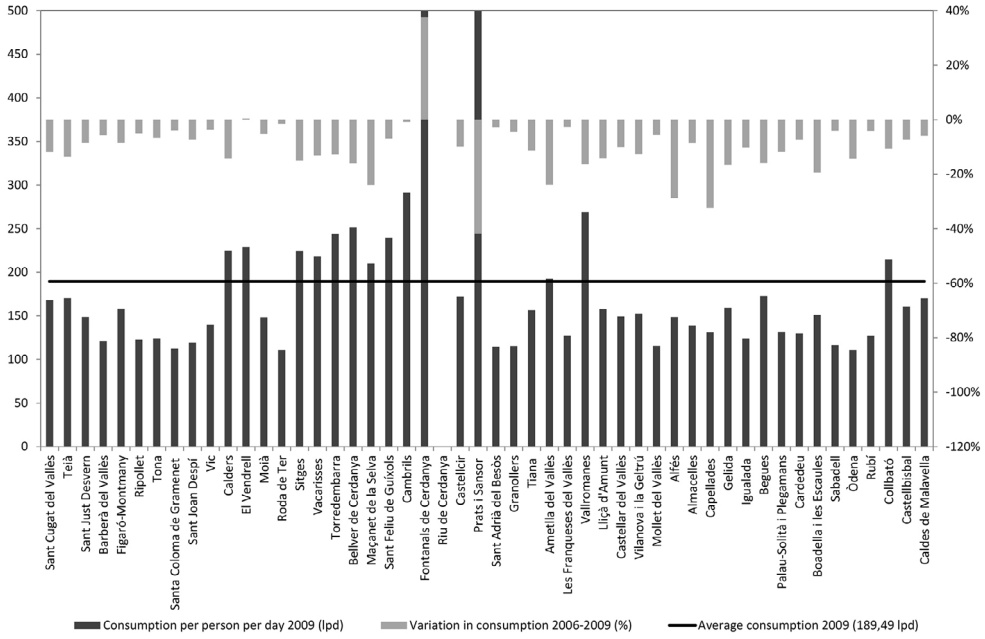
An important impediment to the greater expansion of alternative water supply systems is the fact that these systems are only installed in new buildings. In recent times, the economic crisis has held back the construction of new buildings and accordingly, the installation of rainwater and greywater reuse systems has declined. Yet, some companies working in this field had to cease their business due to the lower number of systems installed. As most of the housing stock is already built, the rehabilitation and retrofitting of already constructed buildings opens a new field of possibilities to increase the adoption of water saving technologies. In order to encourage the installation of water saving devices in already constructed buildings, Sant Cugat del Vallès made available for several years subsidies of a maximum of 1200 euros or up to 50% of the cost of the new technology to those households installing on their own initiative water saving technologies including rainwater or greywater reuse systems.

Besides the economic crisis, a further hurdle for up-scaling decentralized systems has been the change in the regional government in late 2010. Given the critical financial condition of the Catalan Water Agency, the new regional government has dismantled many of the initiatives undertook by the previous administration (inspired in the *New Water Culture* described before). Alternative water resources ceased to be a priority for the new managers and therefore, scaling-up these resources and the work done (in quality standards, for instance) may be more difficult now. In contrast, the economic crisis and the private control of centralized infrastructures might accelerate the application of the full cost recovery principle to domestic water (especially if cross-subsidies are being eliminated) which may favor the competitiveness of decentralized water technologies.

An important point in the assessment of these local water ordinances in the Barcelona area is whether or not they have accomplished their primary target which was to reduce water consumption from the general water network. Taking again Sant Cugat del Vallès as an example, water consumption per capita per day in this town dropped from 278 lpd in 1998 to 151 lpd in 2011; that is, a reduction of 44.5%. In general, between 2006 and 2009 domestic water consumption decreased in most of the municipalities with a water saving regulation, with an average reduction of 10% (Figure 3) (Vallès *et al.*, 2011). Of course it would be absurd to attribute this reduction to the ordinance alone. Other factors such as awareness campaigns during the multiple drought episodes experienced in this period (March *et al.*, 2013); improvements in the distribution networks; more efficient water using devices, and more sluggish expansion of low density developments have contributed also to this decline in important ways.

Perhaps more realistically, a number of environmental managers interviewed in the survey commented before believed that water savings directly related to the application of ordinances could lie in the region between 5 to 15% of initial values. Savings beyond these values, according to some managers, would probably require the introduction of more centralized systems such as reclaimed water from wastewater treatment plants. This is also an option explored in the ordinances and one that could potentially compete with greywater. Thus, some municipalities plan the installation of double networks which will use reclaimed water coming from wastewater treatment plants. This recycled water may also be used for toilet flushing and gardening purposes. Hence the debate between centralized and decentralized systems could be reproduced at this level.

Figure 3. Domestic water consumption (liters per person per day) and variation between 2006 and 2009 in the municipalities with a water saving ordinance



Source: Vallès *et al.* (2011). Own elaboration.

6. CONCLUSIONS

Water supply companies (either public or private) have traditionally been responsible for supplying drinking water through centralized networks. However, with these new local regulations there is a change in the scale of governance and local actors have a greater role to play in water management. Citizens become the owners of the systems and as a result they are ultimately responsible for the proper operation and maintenance of the systems. Citizens become both water "producers" and "consumers" and accordingly, they need to understand and adapt to the new requirements of decentralized systems.

At the same time, municipalities have to act as facilitators and provide and enabling environment to make sure that health risks are minimal and safe water is reliably distributed. While technology development and improvement was very important during the first years of these regulations, nowadays, it is in the sphere of social and institutional learning where more efforts are needed, especially in promoting communication and public dialogue, building and maintaining trust and setting external monitoring mechanisms and water quality standards for rainwater and greywater sources. A multidirectional learning environment also needs to be promoted to ensure a proper use of decentralized systems and risk minimization.

Social acceptance for greywater reuse is still an issue, as the uneven adoption of greywater reuse technologies suggests. While greywater may gain more acceptance at the local level with the new membrane technologies on the market and therefore increase its participation in the transition towards more sustainable water management, the upscaling of this resource towards the regional and national levels appears more problematic.

Concluding, in many parts of the world urban water supply will increasingly become characterized by a combination of water sources with different qualities. In certain areas such as the Metropolitan Region of Barcelona, traditional large scale supply systems (e.g. reservoirs, inter-basin transfers) appear to have reached a limit and are accompanied by non-conventional but also centralized and large scale systems such as desalination or wastewater treatment plants. At the same time, a growing number of municipalities are developing more local and decentralized resources such as rainwater or greywater. All these sour-

ces are likely to coexist in the future but if the use of decentralized water systems becomes widespread, the most environmentally damaging technologies such as desalination plants may become less necessary.

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