Rethinking water management: From centralised to decentralised water supply and sanitation models

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Abstract

Since the second half of the 19th Century, centralised water and sanitation systems have been expanding all over the world. However, the limitations of this model are becoming increasingly obvious and, in recent times, a renewed interest for decentralised approaches is emerging owing to the capacity of decentralised systems to enhance water security and minimise environmental degradation. The decentralised alternatives explored in this paper include the use of rainwater harvesting and greywater reuse at the household level. This paper analyses the main distinctive features of decentralised water supply and sanitation systems and the main requirements to achieve a successful transition to decentralised water management.

Key words: decentralised water management; rainwater harvesting; greywater reuse; urban model.

Resum. *Repensant la gestió de l'aigua: D'un model centralitzat a un model descentralitzat de subministrament d'aigua i sanejament*

Des de la segona meitat del segle XIX, els sistemes centralitzats d'aigua i sanejament s'han anat expandint arreu del món. No obstant això, les limitacions d'aquest model són cada vegada més evidents i per això, en els últims anys, ha començat a créixer un interès renovat pel model descentralitzat de subministrament d'aigua i sanejament, ja que aquests darrers sistemes permeten augmentar la seguretat hídrica i minimitzar la degradació ambiental. Aquest article analitza principalment dos sistemes descentralitzats que poden ser instal·lats a nivell domèstic: els sistemes de captació d'aigües pluvials i els sistemes de reutilització d'aigües grises. L'objectiu principal d'aquest article és analitzar les característiques distintives més importants dels sistemes descentralitzats i els requeriments necessaris per assolir una transició amb èxit cap a un model descentralitzat de gestió de l'aigua.

Paraules clau: gestió de l'aigua; models alternatius; captació d'aigües pluvials; reutilització d'aigües grises; model urbà.

Resumen. *Repensando la gestión del agua: De un modelo centralizado a un modelo descentralizado de suministro de agua y saneamiento*

Desde la segunda mitad del siglo XIX, los sistemas centralizados de agua y saneamiento se han ido expandiendo por todo el mundo. No obstante, las limitaciones de estos sistemas son cada vez más evidentes y por ello, en los últimos años, ha empezado a crecer un interés por el modelo descentralizado de suministro de agua y saneamiento, puesto que estos últimos sistemas permiten aumentar la seguridad hídrica y minimizar la degradación ambiental. Este artículo analiza dos sistemas descentralizados que pueden ser instalados en el ámbito doméstico: los sistemas de captación de aguas pluviales y los sistemas de reutilización de aguas grises. El objetivo principal del artículo es analizar las características distintivas de estos dos sistemas descentralizados y los requerimientos necesarios para alcanzar una transición exitosa hacia un modelo de gestión del agua más descentralizado.

Palabras clave: gestión del agua; modelos alternativos; captación de aguas pluviales; reutilización de aguas grises; modelo urbano.

Résumé. *Repenser la gestion de l'eau: D'un model centralisé à un model décentralisé de distribution et d'assainissement de l'eau*

Depuis la deuxième moitié du XIXe siècle, les systèmes décentralisés de distribution et d'assainissement de l'eau se sont répandus dans le monde entier. Cependant, les limites de ce model sont de plus en plus évidentes, c'est pour cela que ces dernières années ont vu grandir un intérêt renouvelé pour le model décentralisé de distribution et d'assainissement de l'eau, puisque ces systèmes permettent d'augmenter la sécurité hydrique et de minimiser la dégradation de l'environnement. Cet article analyse principalement deux systèmes décentralisés qui peuvent être installés au niveau domestique : les systèmes de captage des eaux de pluie et les systèmes de réutilisation des eaux grises. Le principal objectif de cet article est d'analyser les caractéristiques distinctives des systèmes décentralisés et les conditions requises pour atteindre une transition sociotechnique réussie vers un modèle de gestion de l'eau décentralisé.

Mots clé: gestion de l'eau; modèles alternatifs; captage des eaux de pluie; réutilisation des eaux grises; modèle urbaine.

Summary

Introduction: The emergence and dominance of centralised water supply and sanitation models

History is a key element for understanding the emergence of centralised water supply and sanitation models in the second half of the 19th century and the hegemony of this approach to date. Until the first half of the 19th century, the main sources of water supply were local and included surface water, groundwater and rainwater (Geels, 2005). As urban areas became more populated, public health concerns arose. The concentration of human and animal faeces resulted in the contamination of surface waters and the outbreaks of devastating diseases such as cholera or typhoid fever were fairly common. The solution to these unhealthy conditions was formulated in 1842 by Edwin Chadwick, an English sanitary reformer, and involved the provision of piped water supply and the construction of a sewage network to evacuate human faeces (Dingle, 2008). Soon after, flushing toilets became the most popular method to dispose human wastes and hence, larger volumes of water were demanded and subsequently polluted (Davison, 2008). As cities grew and needed more water, distant water sources were sought and large-scale infrastructures built (Dingle, 2008). In contrast, local water sources, such as groundwater and rainwater, were progressively abandoned (Kallis and Coccossis, 2003; Bakker, 2003).

Gandy (2004) alerts that besides public health concerns, political control and capital accumulation were also significant drivers of centralised configurations. Piped water supply in urban areas relies on the hydraulic paradigm (Kallis and Coccossis, 2003; Saurí and Del Moral, 2001), in which large-scale infrastructures controlled by the State (Bakker, 2002) such as dams, water transfers, sewage systems, and more recently, desalination plants are built to quench the thirst of urban conurbations and provide for the rapid removal of used waters. Until the 1990s water supply was mostly controlled by the public sphere, and above all, by municipalities (Swyngedouw et al., 2002; Kallis and Coccossis, 2003) but in the recent past, water services have become increasingly marketised and privatised, implying therefore changes of control over the flows of water (Gandy, 2004).

Several authors acknowledge the benefits of the centralised model of water management which provides reliable water supplies, flood control, food production and hydroelectricity generation (Gleick, 2000). However, the costs of large-scale projects are also increasingly recognized and become more obvious (McCully, 1996). In industrialised countries bringing water from new sources is increasingly expensive, as the most accessible water sources have already been developed. Furthermore, in the last decades environmental concerns have aroused and, as a result, the non-market environmental and social costs of large-scale projects are brought into the debate on water policy (McCully, 1996; Gleick, 2000; Kallis and Coccossis, 2003). For instance, political and social refusal to dams and water transfers is growing in the affected areas of both developed and developing countries (McCully, 1996; WCD, 2000; Saurí and del Moral, 2001).

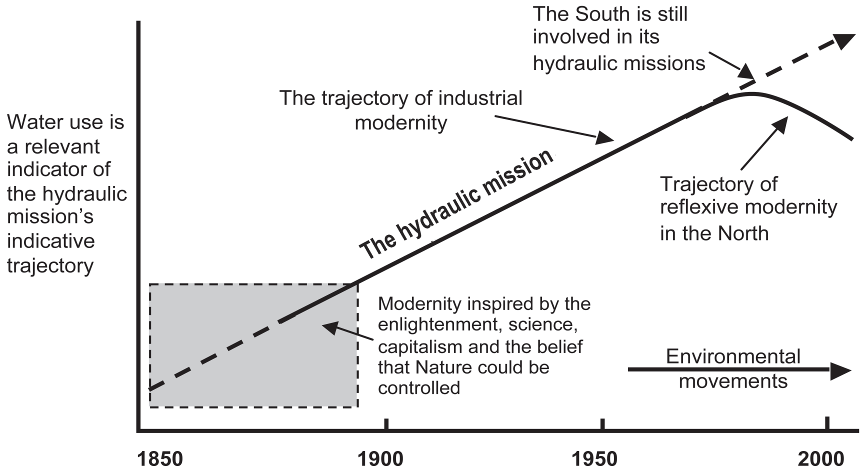

Figure 1. The hydraulic mission, industrial modernity, reflexive modernity. Explaining parallel discourses in the North and the South (adapted from Allan, 2001).

The current water crisis (World Water Assessment Programme, 2009) and the evident limitations of the hydraulic paradigm to solve this crisis are leading to a water management shift (Gleick, 2000; Allan, 2001) (figure 1). A more localised water management involving the fragmentation and shrinking of the water cycle and the introduction of micro-scale infrastructures is increasingly recognised as a promising alternative to the centralised end-of-pipe approach (Syme, 2008).

Rediscovering local water sources: stormwater and wastewater reuse

A fundamental change in the way water management is understood is currently taking place in both developed and developing economies. Instead of using distant water resources, aims are increasingly placed in how best water can be allocated to meet human needs (Gleick, 2003). Part (if not all) of the water demand may be supplied by a portfolio of local water sources including stormwater, rainwater, wastewater and greywater. These local water sources have traditionally been treated as «nuisances» in urban areas (PAP/RAC, 2007) but in recent times, these flows are increasingly appreciated as valuable resources.

The use of local water resources is also linked with the existing debate on urban sustainability which recognises the importance of local solutions and the key role of local governments and citizens in the search of sustainable development. This principle has been put into practice in Europe and elsewhere through the local Agenda 21 (Agenda 21, 1992; Echebarria et al., 2004). In the Metropolitan Area of Barcelona, the Agenda 21 process has been the starting point of various local regulations approved to promote the use of local water resources (rainwater harvesting, greywater reuse and swimming pool water reuse) in new buildings. The first municipality that approved such regulation was Sant Cugat del Vallès in 2002 but soon after other municipalities of the region —more than 45 at the moment of writing— approved similar regulations.

Stormwater management

Stormwater runoff is defined as runoff generated from all urban surfaces while rooftop rainwater is generally synonymous with the runoff collected from rooftops (Hatt et al., 2006). In urban areas soil sealing reduces stormwater infiltration and groundwater recharge. Consequently, the generation of stormwater run-off increases substantially (Burns et al., 2005). From the second half of the 19th Century until recently, urban stormwater was drained and evacuated as quickly as possible with the objective of preventing floods. These systems were first developed in cities with humid climates but soon after, other countries with dry climates, such as Spain, followed, perhaps erroneously, this technological approach (Niemczynowiez, 1999). However, since the 1990s there is a growing interest in achieving «stormwater sustainability». New approaches —named water sensitive urban design (WSUD) in Australia and low impact development (LID) in the United States— are emerging with the objective of promoting stormwater reuse as well as source control micro-scale solutions such as rainwater harvesting systems, ponds, wetlands, green roofs, rain gardens, permeable pavements, and other infiltration techniques (Brown, 2005). However, the widespread extension of these measures is still hampered by a series of multi-dimensional impediments. Roy et al. (2008: 344) identify the following barriers to the adoption of source-control measures: «uncertainties in performance and cost; insufficient engineering standards and guidelines; fragmented responsibilities; lack of institutional capacity; lack of legislative mandate; lack of funding, and effective marked incentives, and resistance to change».

Wastewater management

Domestic wastewater includes different flows with particular «colours» (Langergraber and Muellegger, 2005): blackwater (a mixture of urine and faeces); greywater (wastewater without excreta), yellowater (separately collected urine) and brownwater or faecal matter (separately collected faeces with water or without water respectively). All these wastewater flows are mixed and collected at the end-of-the-pipe, in wastewater treatment plants and once treated, returned to the receiving water bodies together with valuable nutrients that become lost in the process. In response, chemical fertilisers are increasingly being used (Langergraber and Muellegger, 2005).

Wastewater has been treated as «unspoken water» for long time but in recent times, a conception shift is taking place and wastewater is rapidly becoming «spoken water» (Gray and Gardner, 2008). In certain countries such as Japan, Singapore, Israel, Spain or the United States (California), wastewater is more and more subjected to advanced treatment and reused in various purposes such as irrigation, ecological restoration and industrial uses (Angealakis and Durham, 2008). Planned water reuse is frequently based on a centralised model by which wastewater from different locations is directed to a wastewater treatment plant and distributed after treatment through a dual pipe system. Reclaimed water reuse appears as «both an environmental and a commercial opportunity that can be facilitated by giving "third-party" access to established public-sector sewage infrastructure and —importantly— to the sewage» (Gray and Gardner, 2008: 115-116).

Instead of adopting a centralised wastewater reuse management approach such as the one described, wastewater can be separated and treated at source following an ecological sanitation approach by which the closure of the material flow cycle as well as the use of decentralised systems are promoted (Langergraber and Muellegger, 2005). Rainwater harvesting and greywater reuse systems follow the principles of ecological sanitation, as we will expose in the following section.

Decentralised water supply and sanitation systems: rainwater harvesting and greywater reuse

Rooftop rainwater and greywater display better qualities than their respective resultant products —stormwater and wastewater— and therefore, their collection at the source, before they are mixed with other pollutants, leads to a more efficient use of available water. Another peculiarity shared by these two sources is the scale of production and reuse: both are generated at the household level, and may be reused on-site with the installation of relatively simple technologies.

Rainwater harvesting and greywater reuse systems range from simple installations at the household level to more complex installations that collect water from a cluster of buildings, a neighbourhood or a municipality. The main focus of this review is the most decentralised form of water reuse which takes place at the household or building level.

Rooftop rainwater harvesting

Some places receive large amounts of rain, others receive lesser amounts, but it virtually rains everywhere and access to this source is rarely restricted. At the same time its high quality makes rainwater originally suitable for almost every use. With all these properties it is not surprising that throughout history many ancient civilisations utilized this resource to fulfil their water demand (Pandey et al., 2003). In the Iberian Peninsula, both Romans and Arabs built traditional systems —*impliviums* and *al-yûbbs*— in order to collect, store and reuse rainwater (Gutiérrez-Ayuso, 2000-2001).

Table 1. Major benefits of an extensive use of rainwater harvesting in urban areas

	Direct benefits	Indirect benefits
Short term	Reduced drinking water consumption High collection and distribution efficiency.	Reduced pressure on external water sources. Conservation of water bodies (rivers, aquifers, lakes). Preservation of aquatic ecosystems.
	Reduction of flood risk.	Reduced risk for disadvantaged groups. Reduced economic losses.
	Self-sufficiency.	Smaller dependency on distant water sources.
	Major control and awareness of the water consumed.	Enhanced rational use of water.
Long term	Reduction of stormwater flows treated in the wastewater plant.	Reduction of energy consumption. Reduced use of chemical reagents. Reduction of operation and maintenance costs of wastewater treatment plants.
	Transporting water from far away is less necessary.	Reduction of energy consumption. Less necessity for building hydraulic infrastructures (dams, water transfers, desalination plants). Restoration of the hydrological cycle.
	Savings in the water bill.	Increased purchasing power.
	Reduction of non point water pollution.	Recuperation of aquatic ecosystems.

Rainwater harvesting includes a wide variety of modalities that range from the storage of water in ponds or other type of containers to the collection of water in the soil (UNEP, 2009). This review centres on the use of rooftop rainwater harvesting which may be defined as the collection of runoff generated from rooftops and its subsequent storage for later use. Rooftop rainwater harvesting is increasingly practised in areas with very different rainfall patterns and needs such as Kenya, India, Brazil, Australia or Spain.

The main inconvenient of rainwater harvesting is the impossibility of predicting reliable availabilities. However, even if rainwater harvesting may not be an absolute solution for a household, it still presents many associated benefits (table 1). Some of these benefits have been widely analyzed in the literature. Coombes et al. (2002) proves that in a region of Australia with 450,000 people, rainwater harvesting technologies can delay the construction of new large scale infrastructures up to 34 years. The water saving potential of rainwater harvesting has been discussed in many studies. Drinking water savings may vary widely depending on the location and the technical features of the system (Mikkelsen et al., 1999; Fewkes, 1999; Villareal and Dixon, 2005; Zhang et al., 2009). The contribution of rainwater harvesting to minimise flood risks by reducing the size of discharge peaks produced after heavy rainfall episodes is considered in Vaes and Berlamont (1999). Financial benefits are also analysed in various studies (Rahman et al., 2010; Zhang et al., 2010). Pay-back periods of between 8.6 and 13.7 years were calculated for rainwater harvesting systems installed in multi-storey buildings of Melbourne, Sydney, Perth and Darwin assuming an annual discount rate of 6.5% (Zhang et al., 2010).

Rainwater quality studies are also numerous (Yaziz et al., 1989; Pinfold et al., 1993; Lye, 2009) although no definitive results have been achieved. Rainwater may contain different amounts of contaminants depending on the presence of atmospheric pollutants, the leakage of contaminants from system components and the deposition of bird and other animal faeces on the roof (Fewkes, 2006). Operation and maintenance practices are critical to ensure the collection of good quality water and to minimise risks. Nevertheless, a general lack of knowledge about the habits and behaviour of rainwater harvesters and the health risks associated to the consumption of rainwater (for an exception see Heyworth et al., 2006) is detected in the literature.

Greywater reuse

Greywater may be defined as «wastewater without any input from toilets» —i.e. without urine, faeces and toilet paper—, «which means that it corresponds to wastewater produced in bathtubs, showers, hand basins, laundry machines and kitchen sinks, in households, office buildings, schools, etc.» (Eriksson et al., 2002: 85). Greywater may be also defined as low polluted wastewater since the concentration of micro-organisms and some nutrients (e.g. nitrogen and potassium) is lower than in combined wastewater (Warner, 2006). The greywater sources with lower concentration of pollutants (showers and hand basins) are those more frequently reused. Greywater can reduce household potable water usage between 30 to 50 percent (Jeppesen, 1996) by replacing potable water used for toilet flushing, garden watering or car washing for greywater.

In developing countries, untreated greywater may be reused in urban agriculture and rural kitchen gardens as a means for improving food and water security and ultimately, alleviating poverty (Faruqui and Al-Jayyousi, 2002). In industrialised countries facing water shortage such as the United States (California, Arizona or Florida) or Australia, direct reuse of un-treated greywater for garden watering is not rare. Using greywater for irrigation may pose some risks to health and the environment and accordingly, a series of precautions such as the use of subsurface irrigation systems and sodium-free detergents needs to be considered (Jeppesen, 1996). Furthermore, greywater can be treated on-site with small-scale domestic treatment technologies that range from relatively simple systems to more complex technologies and, in this way, potential risks are minimised.

The risk associated with greywater reuse depends on various factors including the level of microbial contamination, the number of users, human exposure, time elapsed between generation, and application and the health and age of the users (Dixon et al., 1999). Warner (2006) suggests that if on-site greywater reuse is voluntary, as it happens in many single family houses, users are likely to tolerate higher levels of risk than the general public. However, this condition would be inexistent in, for instance, many municipalities of the Metropolitan Area of Barcelona, where new apartment buildings are forced by law to incorporate greywater reuse systems. If greywater reuse is made mandatory, the communication of the associated risk becomes critical to promote understanding and acceptance of «what appears to be a radical departure from accepted norms» (Dixon et al., 1999: 323). The widespread use of greywater technologies is also conditional on public and practitioners' acceptability since greywater reuse has specific requirements that need to be understood and accepted (Bagget et al., 2006). Moreover, greywater management responsibility falls on private individuals rather than public utilities and therefore, the proper operation of greywater reuse systems is dependent on user's practices and behaviour. In brief, a cultural shift in relation to water management and social learning processes are very important requirements to achieve a successful transition to greywater reuse.

Main obstacles for a successful implementation of decentralised water supply and sanitation systems

Achieving a paradigm shift in water management may be a hard task due to the inertia that accompanies existing technological regimes (Geels, 2002). Sunk investments and well-established socio-technical regimes create path dependencies that favour the prevalence of the existing centralised model (Krozer et al., 2010). At the institutional level, the main stakeholders involved in water management may be reluctant to install decentralised technologies owing to a series of perceived risks: developers may object cost penalty concerns, engineers may show concerns for loss of functionality while municipalities may point at risk of failure and concerns for maintenance requirements. On their part, public health bureaus may emphasize risk of disease, water supply agencies may be worried by risk of losing revenue, and finally, plumbers and other professionals may highlight the risks associated with doing work not authorized by a standard (Argue, 1995; Roy et al., 2008). Other impediments to decentralised water management may be found in Brown et al. (2009), Krozer et al. (2010) and Baggett et al. (2006).

In order to deal with the risks and uncertainties associated to the emerging water paradigm, policy-makers and private actors may be interested in facilitating a successful transition towards more sustainable water management by adopting transition management strategies (Rotmans et al., 2001). In the next section, the main requirements to achieve a successful transition to decentralised water management are discussed (see also table 2).

Table 2. Main features of centralised and decentralised water management

Factor	Centralised water management	Decentralised water management
Scale	Large scale systems.	Small scale systems (domestic).
Type of water sources	Distant and local water sources.	Local water sources.
Governance	Top-down governance model.	Multi-level governance model.
Ownership	Water supply and sanitation infrastructure is owned by the public sector.	Water supply and sanitation systems are owned by private individuals.
Control of the water cycle (power)	Controlled by the public sector and/or private companies.	Controlled by private individuals.
Participation	Very limited public participation in water management.	Active public participation in water management.
Awareness	Citizens are alienated from the water cycle.	Citizens become more aware of the water cycle.
Cost sharing	Highly subsidised.	Full cost recovery.
Water quality	Very high water quality for all uses.	Different water qualities and fit-for-purpose water use.
Health risks	Health risks are very controlled.	Risk management by the individuals is required.
Environmental impacts	Environmental impacts are significant.	Environmental impacts are reduced.
Social conflicts	Dam construction and water transfers usually give rise to social conflicts between regions.	Social conflicts are less likely.
Resilience capacity	Limited adaptation capacity to extreme situations.	Enhanced capacity of adaptation to different situations.

Main requirements to achieve a successful adoption of decentralised technologies.

Policy and institutional domains: new governance arrangements

Governments should play a guiding role in the promotion of decentralised technologies because they have the capacity of setting a collective learning environment and encouraging other actors to participate. Governments may also stimulate the use of these systems by developing new policies and regulations such as in the Metropolitan Region of Barcelona where various local governments have enacted local regulations to promote the use of decentralised systems. Some municipalities in the region have also made available subsidies or other incentives to encourage the installation of these systems.

The implementation of decentralised water systems requires also a series of changes in the formal and informal water management institutional framework. Centralised systems are managed by public and private companies that are subjected to a certain control from governments. In contrast, decentralised systems are managed by private individuals or communities, usually families or neighbourhood associations. These new institutional arrangements lead to the atomisation of the power held over the water cycle by governments and large water supply companies and to its redistribution between civil society and small companies. The top-down model associated to centralised approaches is replaced by a multi-level governance model that involves a higher number of actors and the creation of new inter-relations between actors. The large number of actors involved in the management of decentralised water systems in a multi-family building is shown in figure 2.

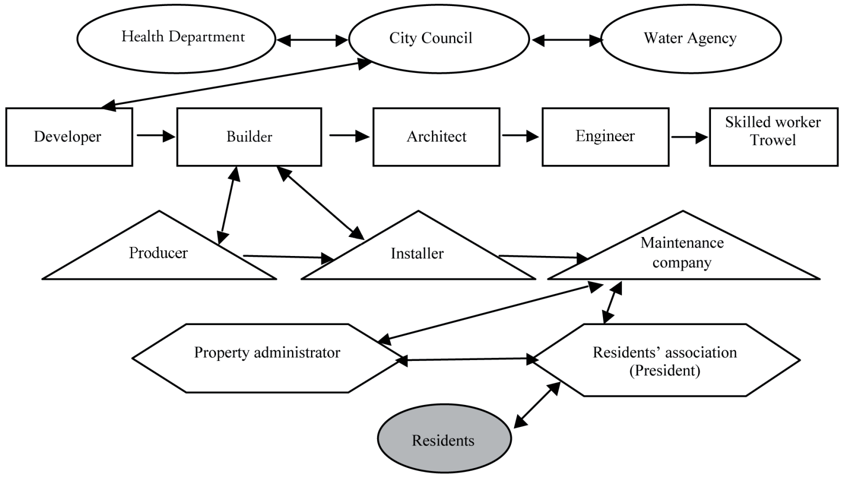

Figure 2. Main actors involved in the management of a decentralised water supply and sanitation system in a multi-family building.

This new governance model which may be referred to as governance-beyond-the-state (Swyngedouw, 2005) demands a greater involvement of citizens and community people since they are called out to actively participate in the management of water services. Householders become responsible for the operation and maintenance of decentralised systems, as they become the owners of the system. Decentralised systems also favour the appearance of new private marked actors at the local level since new windows of opportunity for business emerge.

Socio-cultural domain: changing water cultures, fit-for-purpose water use and health risks

In urban settings, water undergoes constant transformations from a physico-chemical point of view as well as from a social, symbolic and cultural perspective to the point that, as a result, «metabolised water» is obtained. This perspective draws on the idea of a «hydrosocial cycle» which considers urban water as a hydrid, formed by nature and society components at the same time (Swyngedouw, 2004). Some features of the hydrosocial cycle are also prone to change during the transition to decentralised water management. In most urban areas, water is allowed to enter the house after being purified and is quickly removed and visually excluded after use (Head, 2008; Kaika, 2005). Localised strategies for water collection, storage and distribution are more visible than centralised networks of water supply and therefore, the alienation of water consumers from the urban water cycle is less likely to occur (Head, 2008). Given that water users are also more in contact with the means of water production, it is to be expected that water conservation attitudes would become more entrenched in the everyday life of householders (Herman and Schmida, 1999).

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 require the same level of quality. In industrialised countries potable water is usually employed to meet all domestic demand, regardless of the small percentage strictly requiring the use of high quality water. A large fraction of the demand —the non-potable water demand including toilet flushing, laundry cleaning and irrigation— can be met with decentralised sources which are frequently of lower quality than piped water.

Risk management is critical for the successful adoption of the fit-for-purpose water use principle as any failure with effects on public health may undermine public confidence and bring to a halt these initiatives (Hatt et al., 2006). Brown et al. (1999: 24) argue that «the provision of centralised protection of public health has been instrumental to the urban-water hydrosocial contract […]; hence challenging this deeply embedded practice will be complicated». The health risks perceived by practitioners and citizens associated with the use of non-potable water may constitute an important barrier for the widespread adoption of decentralised systems. Questions about public acceptability and the willingness of citizens to make sacrifices and renounce to part of their comfort to attain environmental benefits arise in this context (Head, 2008). Some other factors such as the water scarcity context, trust on authorities and the level of awareness about sustainability issues may also influence the predisposition of individuals to adopt and accept decentralised technologies.

Therefore, new cultural relationships with water need to be developed and new skills learned in order to ensure the optimal operation of decentralised systems. Citizens' behaviour affects directly water quality and therefore, users need to develop new capacities to adapt to new settings. In sum, social learning processes which involve developing new institutional arrangements, new types of knowledge, and new individual capacities are essential elements of successful transitions to more sustainable societies (Pahl-Wostl et al., 2008).

Economic domain: redistribution of financial burdens

Decentralised water supply systems are usually perceived as more costly than centralised systems due to the misrepresentation of sunk costs and a lack of consideration of avoided costs (Fane and Mitchell, 2006). A study conducted in Australia demonstrated that the use of domestic rainwater tanks is more economically efficient than the use of conventional systems due to the reduced need for constructing new supplies and expensive stormwater infrastructure (Coombes et al., 2002).

The cost perspective widely varies depending on the actor (water agency, developer, user, whole society) performing the economic analysis (Fane and Mitchell, 2006). A critical impediment to the installation of decentralised systems may be the perception by house owners that these systems are costly because house owners are frequently called to assume the full cost of decentralised systems (capital cost and maintenance cost). Furthermore, the subsidised price of water overshadows to some extent the benefits of decentralised systems.

Decentralised systems shift the financial burden from the public sector to the users and as a result, they favour cost recovery. In contrast, large-scale water supply projects do not comply with the full recovery principle increasingly demanded in new water policies such as the Water Framework Directive in Europe. Large hydraulic projects are usually subsidized by governments and international organisations (Gleick, 2000; Kallis and Coccossis, 2003) and become highly capital-intensive and therefore inflexible.

Technological innovations

A great variety of rainwater harvesting and greywater reuse technologies are available in the market. Technological innovation to adapt decentralised systems to current needs of society is still required to make this technology more attractive to users; this is particularly true for greywater reuse systems, as they are still being developed at the niche level. Technological improvements should be directed at reducing health risks, maintenance requirements and costs. Technological designs of decentralised water systems should also be context specific since users' needs and system requirements may differ significantly from place to place. This is particularly relevant in the rural areas of developing countries where the easy procurement of materials and low-cost solutions may be critical to achieve a widespread adoption of these technologies.

Urban planning: high and low density urban developments

The type of urban development model determines to some extent the performance and management requirements of decentralised systems. These differences need be considered while designing new policies and awareness campaigns aimed at promoting these technologies.

The water saving potential per capita of decentralised water technologies is larger in low-density developments because of two factors. First, low density residential areas consume more water because of outdoors uses —mainly landscape irrigation— for which decentralised water sources would be especially appropriate. In the Metropolitan Region of Barcelona, the volume of water used for irrigation in single family houses has been estimated at 75 LCD or 36 percent of the total water demand (Domene et al., 2004). Second, population density is logically lower in disperse residential areas, i.e. there is greater catchment area per capita and therefore, the amount of rainwater runoff that is produced per capita is higher in these areas. In addition, in single family houses there is more space available to install storage tanks which may favour the installation of decentralised systems in existing buildings.

The housing type also affects the efficiency of the rainwater harvesting system. The collection efficiency is larger in high density towns because water consumption pattern per hectare is greater in these areas and therefore, all water collected is more likely to be consumed (Herman and Schmida, 1999). However, Coombes and Kuczera (2003) argue that in areas with fairly low and uneven rainfall like Barcelona, the number of residents does not affect much the increase in efficiency due to the sporadic and rapid saturation of the rainwater tank.

Greywater reuse technologies seem to be more suitable in multi-family buildings due to the greater volume of water demanded and wastewater produced. The local regulation that has been approved in Sant Cugat del Vallès, for instance, mandates to collect greywater from showers and reuse it for toilet flushing in new buildings with either more than eight apartments or consuming more than 400 m^3 of water per year (Ajuntament de Sant Cugat del Vallès, 2008). The installation of decentralised technologies in multi-family buildings may be favoured by economies of scale and cost sharing arrangements. In multi-family buildings the cost of the system is divided between the residents of the building and therefore, the cost of the system per apartment is much lower than in single family houses where one family has to assume the full cost of the system.

Finally, management arrangements are also different in single and multi-family buildings. While in single family buildings the house owner usually takes care of the system and accordingly, stays in closer contact with the hydrosocial cycle, in multi-family buildings an external company is generally hired to carry out the maintenance tasks of the system and as a result, residents are less aware of that cycle.

Final remarks

Decentralised forms of water supply were common in many ancient civilisations but with the advent of large-scale solutions fell to oblivion in many places. Only recently, these systems are re-emerging as partial solutions to water scarcity and as a way to minimise environmental impacts. In addition, decentralised water systems can provide adaptation opportunities to climate change. Decentralised technologies such as rainwater harvesting and greywater reuse systems share a series of peculiarities —multi-level governance models, enhanced public participation, enhanced full cost recovery and reduced environmental and social impacts— which are all appealing for achieving a sustainable use of water resources.

In order to advance in the use of decentralised water management alternatives, numerous changes need to take place at different levels and domains and a series of conditions need to be favoured: public acceptability of users and other social actors needs to be guaranteed, costs need to be reasonable; health, technical and environmental risks need to be acceptable, new regulations and incentives need to be made available and social learning processes and adaptation capacities need to be developed.

Transition management will be fundamental to achieve a successful transition to more sustainable water management. Governments are called upon to assume a leading role in this process but the involvement of the rest of the actors is also critical to transform the current water management regime. External factors such as regulations, climate change or water scarcity conditions will also be important determinants of the future that lies ahead for decentralised water and sanitation systems.

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