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Redrawing the Hydrosocial Cycle Through Treated Wastewater Reuse in the Metropolitan Area of Barcelona

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ABSTRACT: Increasing economic, social and environmental limits to the development of conventional water supply sources have shifted water resource frontiers to alternative sources, most notably desalination and wastewater reuse. In the past few years, critical scholarship has been prolific in its exploration of how desalination may redraw the hydrosocial cycle in different geographies; wastewater reuse, however, has received much less attention. In this article, we aim to contribute to a critical exploration of the implications of different types of wastewater reuse for urban purposes. We do so through an examination of the case of the Metropolitan Area of Barcelona (AMB), an area with a fragile water supply system that has been undergoing a harsh drought in 2022/2023. We examine two examples of how treated wastewater may enter the residential sphere. The first involves the reuse of greywater for toilet flushing in residential buildings. The second is linked to the possibilities that advanced treatment of wastewater open up in terms of making urban water systems more robust and more resilient to recurring droughts; this advanced strategy enables both the bolstering of indirect reuse of reclaimed water for potable purposes and direct reuse through the development of dual networks of supply in new urban areas. In this paper, we attempt to unravel the different economic, social, environmental and political implications of those interventions through the lens of the hydrosocial cycle and resource frontiers. We triangulate a critical review of policy documents with informal conversations with policymakers and, in one of the case studies, previous research.

KEYWORDS: Greywater recycling, indirect potable water reuse, hydrosocial cycle, resource frontiers, Metropolitan Area of Barcelona, Spain

INTRODUCTION

In large parts of the Northern Hemisphere, including California, Europe and China, the summer of 2022 was one of the driest in decades. This once again brought to life the spectre of global water scarcity. Because of an extremely serious reduction in the amount of stored water in reservoirs in Catalonia in early 2023, the Catalan Water Agency banned potable water use for non-essential uses such as street cleaning, ornamental fountains and garden irrigation in the Metropolitan Area of Barcelona (AMB) and in other coastal areas of Catalonia; the desalination plant in the area has, at the same time, been working at full capacity. Desalted water, however, is not the only 'alternative' source being used, as reclaimed water reuse is also gaining momentum.[1] Increasing economic, social and environmental limits in developing conventional sources such as reservoirs are shifting water resource frontiers to alternative sources such as desalination and wastewater reuse. Both sources are infused with rampant technological optimism on the possibilities of creating new water flows that are unaffected by the vagaries of climate change. Wastewater reuse enjoys certain advantages over desalination, mainly in terms of energy costs and, to a certain extent, environmental impacts; however, it also has some drawbacks such as the uncertainties that surround the presence of emergent pollutants (Zhou et al., 2019) and, related to this, a certain social reluctance regarding potable uses (Dolnicar and Schäfer, 2009; Duong and Saphores, 2015; Lee and Jepson, 2020).

The general category of wastewater includes a wide variety of flows; all of them have specific socio-environmental histories that speak of the increasing heterogeneity of current water metabolism processes, especially in cities (Saurí and Arahuetes, 2019). Traditionally, treated wastewater reuse has been kept away from the residential sphere and, when mobilised, it has been directed to agricultural, municipal, leisure or environmental targets, all of which are less demanding in terms of quality than are potable uses. Because of the increasing difficulties in mobilising conventional water resources, however, treated wastewater is now also arriving in the residential sphere (WHO, 2017). Direct potable reuse is a relatively rare option and remains prohibited in many countries, including Spain (Jodar-Abellan et al., 2019). Instead, indirect use (see Meehan et al., 2013) through an environmental medium such as a river or aquifer, in which water treated with advanced techniques is mixed with natural flows, is considered to be acceptable. The resulting mixed flows can then be directed to drinking water treatment plants and potable water distribution systems (Anderson, 2006; Duong and Saphores, 2015).

In 2020, the European Union issued a regulation on the safety of reclaimed water for agricultural use; it will officially come into effect in 2023 (European Parliament, 2020). The regulation was favoured among the drought-stricken countries of southern Europe but raised concerns among its northern members. The German Environment Agency, for example, criticised the regulation for being insufficiently ambitious with regard to quality standards (UBA, 2020). The regulation contained no objections to industrial or environmental uses that fulfil the specific needs of member states, as long as human and animal health was protected; however, direct or indirect potable reuse was not explicitly mentioned. It is important to note, however, that the proposed new directive on urban wastewater treatment published by the EC in late 2022 explicitly mandated "increasing [the safe] reuse of treated water" (European Commission, 2022: 3). Article 15 on "water reuse and discharges of urban wastewater" (formerly Article 12) specifically states that, "member states will be required to systematically promote the reuse of treated wastewater from all urban wastewater treatment plants"; however, it does not mention the uses for which treated wastewater would be acceptable. These new regulations follow from the solidly supportive consensus achieved across the water community with regard to the reuse of treated wastewater; this consensus included technical experts and water managers (Tortajada and van Rensburg, 2020), as well as politicians, environmental NGOs, and international organisations (UNEP, 2017). Wastewater reuse has also captured the attention of water companies. They are attracted by its possibilities as a single resource on its own for agricultural, industrial or municipal purposes; even more, however, they regard it from a promising business perspective, as a source of flows that can be mixed with river or aquifer water to increase potable resources, thus protecting water supply systems from future droughts and shortages.

The ample agreement created around wastewater reuse and its relatively new presence in the water debates probably explains – with some exceptions (see Karpouzoglou and Zimmer, 2016) – the relative lack of critical approaches; this contrasts with the more prolific body of work that explores how desalination may redraw the hydrosocial cycle in different geographies. In this article, we aim to critically explore the social, political and environmental implications of wastewater reuse in the Metropolitan Area

[1] The writing of the revised version of this paper has coincided with the worsening of the drought in Barcelona and the first mobilisation of large quantities of reclaimed water for indirect potable reuse.

of Barcelona (AMB). This dense urban agglomeration attempts to confront recurrent droughts and a fragile conventional water supply system by pushing down consumption and expanding its hydrosocial cycle to incorporate new waters. Desalination has become essential in times of high stress on conventional resources, such as is occurring with the current ongoing drought. At the same time, other non-conventional flows such as treated wastewater are also being explicitly promoted and enhanced in order to improve the resilience of the water system.

We examine two ways by which treated wastewater may enter the residential sphere. The first entry point involves the reuse of greywater – that is, water generated in showers and baths – for toilet flushing in residential buildings; this has been practised in the city of Sant Cugat del Vallès (in the AMB) since 2002. The second way in which the use of treated wastewater is being promoted is more ambitious in scale and scope, that is, centralised and large-scale advanced wastewater treatment; among other things, the latter opens up the option of indirect potable water reuse. This project consists of pumping treated water from the wastewater plant near the mouth of the Llobregat River into the river some eight kilometres upstream of one of the purification plants (located next to the river) that serves Barcelona. Mixed with river flows, part of this water is then captured at the purification plant and piped back into the Barcelona supply system. As we will see, the drought of 2022/2023 accelerated the indirect reuse of regenerated water for potable water uses. Inspired by hydrosocial cycle and resource frontier approaches, and through the critical review of policy documents triangulated with previous research on one of the cases and informal conversations with policymakers, we discuss the different economic, social, environmental and political implications of the two options for reuse of treated wastewater.

The paper is organised as follows. In the next section, we develop the theoretical framework that is used to characterise wastewater flows and we discuss the economic, political and social impacts of introducing these flows into non-potable and potable water supply systems; this includes the issue of their public perception and acceptance. The central part of the paper is devoted to the case studies. After briefly presenting the water supply situation in Barcelona and the origins of wastewater reuse in the region, we introduce the two cases of wastewater reuse in the AMB: reuse of greywater and of reclaimed water. For each case study, we explore the technological, perceptual and political-economic frontiers of treated wastewater in order to map out each option's economic, social, environmental and political implications and trade-offs in the context of climate change, increasing stress on conventional water resources, and rising prices of water. The conclusion highlights what we consider to be the relevance of the paper's findings in terms of developing a more critical view of wastewater reuse.

WASTEWATER: A WORLD OF FLOWS, PERCEPTIONS AND POLITICS

Definitions of wastewater abound and may differ in detail. All of them, however, refer to the 'used' or 'degraded' water that is produced mainly from domestic and industrial metabolic processes (Bahadori and Smith, 2016). The term 'wastewater' has come to take the place of 'sewage'. Historically, the latter referred to the product of domestic metabolism; for many centuries and in many cultures, it did not carry the negative connotations of 'waste', but rather had the status of a resource. Aware of this historical precedent and in the current need to "reduce, reuse, and recycle" (Sedlak, 2014), organisations such as the EU define wastewater as, "water that is of no further immediate value to the purpose for which it was used or in the pursuit of which it was produced because of its quality, quantity or time of occurrence". They hasten to add, however, that, "wastewater from one user can be a potential supply to another user elsewhere" (Eurostat, 2013). At the European level, as mentioned in the introduction, new rules on the reuse of wastewater for agricultural purposes are being developed, as is a more generic encouragement of the reuse of treated urban wastewater. The World Health Organization (WHO, 2017) has also produced guidelines to deal with these 'new waters', and a report by the United Nations Environment Programme (UNEP, 2017) presents wastewater as an "untapped resource" (see also Kjellén, 2018, in this journal). Water with a moderate level of pollutants is thus customarily referred to as greywater; it is produced in the domestic sphere from showers, baths or washbasins. Blackwater, on the other hand, is generated mainly by bodily functions and indicates a more severe level of pollution. Each of these types requires specific treatments; these may vary according to their possible destination under the principle of "fit for purpose". This includes potential indirect potable reuse, such as in California's Orange County, in Queensland, Australia, and in Singapore (Saurí and Arahuetes, 2019; see also Meehan et al., 2013).

The theoretical approach used in our analysis departs from the concept of 'resource frontiers' as understood by political economists (Tsing, 2003; Cons and Eilenberg, 2019) as well as from the concept of the hydrosocial cycle (Bakker, 2002; Linton and Budds, 2014). The concept of the hydrosocial cycle articulates a relational – dialectical approach to water whereby water is not a passive object of socio-economic and political processes, nor is it something that is deemed purely natural; rather, it is regarded as being shaped by, and shaping, social structures (power relations) and sociotechnical systems. According to Linton (2014; see also Linton, 2008), the concept of the hydrological cycle is characterised by an ontological understanding of water that he calls 'modern water'; this understanding, says Linton, abstracts water from its social, historical, ecological and cultural context and reduces it to a common abstract and timeless identity that can be represented as 'H_2O'. While 'modern water' is portrayed as being devoid of social content, it internalises social practices and ideology such that it is impossible to intervene in the water cycle without effecting changes in society; in other words, water embodies and expresses the relations through which it is reproduced. As Bakker (2002: 774) argues,

> whereas H_20 circulates through the hydrological cycle, water *as a resource* circulates through the hydrosocial cycle – a complex network of pipes, water law, meters, quality standards, garden hoses, consumers, leaking taps, as well as rainfall, evaporation, and runoff (…). [W]ater is simultaneously a physical flow (the circulation of H_20) and a socially and discursively mediated thing implicated in that flow.

Through this lens, we understand treated wastewater (both greywater recycling and reclaimed water reuse) as a new resource frontier that entrenches an assemblage of technology, perceptions linked to the materiality of wastewater, and political-economic processes that, in turn, operate as 'frontiers' that modulate those new waters and the reshaping of the urban hydrosocial cycle. We first address the technological frontier of wastewater reuse. Technology in the treatment of water pollution has advanced to the point of producing flows of a quality very close, or even equivalent, to natural flows that are abstracted and treated for drinking water purposes. The frontier is now located in the area of so-called 'emergent pollutants' – whose effects still are largely unknown – and the economic costs of treatment, especially in terms of energy (Cardoso et al., 2021), including the likely repercussions on water prices and taxes. A second frontier lies in the human perception of treated wastewater; this may be problematic because of opposition to the use of treated flows under the 'toilet to tap' motto, especially if these flows are incorporated into the drinking water treatment chain. In this case, the frontier could be in the area of the trust and credibility of institutions that are regulating the technology and management of water recycling, as well as in the insistence that the public accept this resource or suffer the consequences of increasingly stressful episodes of water scarcity under a changing climate. Finally, the political-economic dimension of these new waters may open up different avenues, although these have been largely underexplored by critical scholarship.

In reference to the technological frontier, a fundamental characteristic of domestic wastewater is the tremendous heterogeneity of flows that are generated by households, especially those that are well-off. These flows can comprise used water from kitchen and bathroom sinks, showers, bathtubs, toilets, washing machines and dishwashers (USGS, 2018). The heterogeneity of substances found in these waters ranges from the bacteria, viruses and parasites that are associated with conventional human waste, to the so-called emerging pollutants found in cosmetics, pharmaceutical drugs and a myriad of other home products; all of this results in differential pollution loads (Yang et al., 2017). The technology for treating wastewater has made enormous progress in adjusting to these challenges; thus, together with desalination (March, 2015; Williams, 2022), wastewater reuse is becoming an important option for enhancing water supply to confront current and future episodes of water stress. The repertoire of water treatment technologies also facilitates the principle of 'water fit for purpose', whereby water quality is matched with specific uses. The greatest challenge, however, is to make treated flows potable again. In this sense, treatment systems such as ultraviolet light, advanced oxidation, microfiltration, and reverse osmosis can produce effluents of near-potable quality, although at a critical economic cost (Plumlee et al., 2014) that is likely to be passed on to consumers through water bills.

Technology, however, is not the only hurdle to overcome. Social acceptance of treated wastewater reuse must be ensured for it to become a realistic option. This acceptance may be problematic in some cases, as the public may embrace 'toilet to tap' narratives; they may thus reject projects that involve the potable (direct or indirect) use of treated effluents because of attitudes of mistrust that are exacerbated by the many unknowns related to the so-called emerging pollutants (Hurlimann and Dolnicar, 2010). There is a significant body of literature that explores the public perception of water reuse (Brannstrom et al., 2022; Lee and Jepson, 2020; Wilcox et al., 2016; Po et al., 2003); this includes studies in rapidly growing urban areas with fragile water equilibriums, such as Nevada (Redman et al., 2019), California (Binz et al., 2016), and Texas (Brannstrom et al., 2022), and countries such as Israel (Friedler et al., 2006). The 'yuck factor' is an instinctive disgust or repugnance related to health concerns that may be felt by the general population when confronted with treated wastewater. It has been portrayed as a critical barrier to the expansion of this technology (Ching, 2010; Duong and Saphores, 2015; Dolnicar and Hurlimann, 2009). Negative public perception is thus seen as a significant barrier to developing water reuse schemes (Hurlimann and Dolnicar, 2010; Wilcox et al., 2016). Lee and Jepson (2020) conducted an extensive review of studies on the drivers and barriers of water reuse covering 54 urban areas in 20 countries; they argue that while environmental factors, and more specifically drought, may be a catalyst of its implementation, "a nexus of place-based factors combined with economic, regulatory and political alignment [is] more likely to foster systemic change in water systems" (ibid: 100073).

Among policy drivers, these authors mention the existence of policy or guidelines, stakeholder engagement, a large and stable role played by government, and political support; as economic drivers, they mention financial support and the demonstration of cost savings by those systems. Social drivers are considered to include environmental awareness, good public education programmes, and/or social pressure, with public perception of risk acting as a barrier. In the legal and institutional sphere, Lee and Jepson (2020) highlight the crucial role of relevant laws and cooperation between departments. Binz et al. (2016) develop an original interpretative framework to explore the unfolding of early phases of technology legitimation; they use the example of potable water reuse in California. Wilcox et al. (2016) propose a framework for the socio-economic and environmental assessment of decentralised water reuse practices, using the case study of a neighbourhood water reuse scheme in London. Khan and Anderson (2018), likewise, detail three approaches to potable water reuse in Australia: groundwater replenishment for drinking purposes in Perth, a large potable reuse project in Queensland to supplement a surface water reservoir, and purifying water and pumping it upstream into the catchment above a drinking water plant. This last project is very similar to one in Barcelona, which we discuss below.

While there is extensive work on the previous two frontiers, work on the political economy dimension of wastewater reuse is still incipient (Karpouzoglou and Zimmer, 2016); notable exceptions to this include the work by Beveridge et al. (2017) on water reuse politics in Berlin-Brandenburg (Germany) and the political ecology of reclaimed water reuse in the southwestern United States (Ormerod, 2019). Wastewater reuse and desalination – which are largely explored by political ecologists and critical water scholars – may break down the accumulation frontier that is represented by conventional, but exhausted, systems such as dams and water transfers. They may thus constitute new sources of water that attract private capital whose aim is to secure water supplies for their businesses in the face of increasing pressure on conventional resources. Reclaimed water may either reinforce the accumulation frontier of private capital (water companies) or open up the possibility of further public control over new resources. It may become a new arena of confrontation and power struggles over the hydrosocial cycle. Greywater reuse, in parallel, constitutes an example of decentralised and citizen-led water management.

Possible objections, fears and concerns regarding indirect reuse of water for potable purposes are often dismissed under the discourse in which reclaimed water is put forward as the best, and sometimes only, alternative to future climate change related scarcities (Sapority and Robins, 2021). Reintroducing such flows into urban hydrosocial cycles may also imply the circumventing of alternatives that would be able to reconfigure this cycle in more just and sustainable ways; these could include dual networks, rainwater and stormwater harvesting, or even greywater reuse, which is another type of wastewater reuse that we explore in this paper. Large-scale solutions regarding indirect potable reuse, infused by the dominant hydraulic paradigm (Saurí and del Moral, 2001) that championed centralised and large-scale interventions in the hydrosocial cycle, could also remove voluminous water flows from public control and place it in the hands of private or private-controlled water supply companies.

In sum, reclaimed water, as well as other types of new waters such as recycled greywater, may redraw urban hydrosocial cycles through the interaction between novel technological assemblages (advanced wastewater treatment) and undesired flows (wastewater, greywater); this may produce new waters that, through direct or indirect use, may be incorporated into the portfolio of urban water sources. It remains to be seen, however, how the interplay of these new waters with public acceptance and social power structures (following the hydrosocial lexicon) unfolds. Our paper aims, through the case of metropolitan Barcelona, to shed light on those changes in the hydrosocial cycle that are motivated by the introduction of new waters.

THE SMALL SCALE: GREYWATER RECYCLING IN RESIDENTIAL BUILDINGS

Sant Cugat del Vallès (henceforth Sant Cugat) is one of the most affluent municipalities in the AMB and is among the ten richest in Spain. Although it has a compact urban core, an important part of Sant Cugat is made up of low-density residential neighbourhoods of single homes and condominiums, many of which have gardens and swimming pools. Around the year 2000, the expansion of this urban model drove the city to record one of the highest levels of water consumption in the AMB. The presence of an extensive golf course also contributed to the lush green environment of much of this urban area. After an environmental audit of the city was completed in 2001, the local council realised that water, energy and waste costs were escalating and, in response, they decided to develop a programme based on Local Agenda 21 principles. The city council undertook to reduce consumption of water by increasing the efficiency of water-based fixtures, especially toilets and showers; they also began to promote the use of resources such as rainwater and greywater, which were independent of the municipal supply network. As there was no specific Spanish or Catalan legislation on greywater and rainwater, the city council could enact and enforce its own regulations on these resources through a city ordinance. The first City Ordinance on Water Savings was approved in 2002 and has been modified several times since, most recently in 2018. The ordinance includes regulations about indoor and outdoor water use. For indoor uses, it stipulated that all residential buildings having eight or more apartments must have a greywater reuse system that recycles water from showers for use in toilet flushing (Vallès-Casas et al., 2016).

Although it was a mandatory policy and flats were purchased with the systems pre-installed, at least initially users welcomed such installations. According to a 2008 survey of 14 residential buildings and 120 respondents, the rate of acceptance was close to 90% (Domènech and Saurí, 2010). Perceived risk was low or very low, economic costs were not a concern, and benefits expressed in terms of water savings were often mentioned. There were negative views, however, as the performance of some systems was relatively poor. Users complained about smells, colour and residues in greywater tanks that used chlorine for disinfection. Lack of experience with these systems with regard to, for example, the periodicity and amount of chlorine needed appeared to be a significant problem (Valles et al., 2016). It is important to mention that the 2008 survey which found such high support for greywater reuse in Sant Cugat took place in the context of one of the most severe droughts ever experienced in Catalonia. Public opinion thus highly supported such alternative water resources as recycled greywater. As no significant droughts reoccurred until late 2022, residents may have become less concerned about water scarcity; they may thus have begun to consider the obligation of using greywater for toilet flushing as an unnecessary cost and a nuisance. According to the environmental manager on Sant Cugat's city council (Pers. comm.; 2022), lack of maintenance of older systems and excess use of chorine may have damaged water pipes in the buildings.

Over the last 10 years, cleaner and more efficient membrane-based systems have replaced the initial chemical-based systems. They are more expensive and use more energy, but in general their maintenance is relatively simple and performs much better than the older systems. The city council is also subsidising the replacement of chemical greywater installations with membrane-based systems. Currently, about 80% of greywater systems in Sant Cugat are membrane-based, 15% use a chemical component, and the rest are biological. In 2022, the city had about 200 greywater systems in operation, serving an estimated population of 25,000, that is, more than a quarter of the total population (ibid).

Catalonia entered a new and severe drought episode in 2022, experiencing harsh effects in 2023. As the price of water in the city has risen to about 80% higher than in 2008, savings from reusing greywater may increasingly be of interest to residents. The economic incentive, together with environmental awareness (which is perhaps even more relevant for places like Sant Cugat), may improve water savings through the adoption of more efficient habits and the use of non-network water such as greywater. In this respect, part of the increase in domestic water consumption that was observed during the forced confinement of the COVID-19 pandemic, and the ensuing increase in working and studying from home, could have been absorbed using treated greywater. In sum, changing consumption patterns and the likely increase of stress on conventional water resources in coming decades may make alternatives such as greywater more necessary. The downside of increased greywater reuse, however, especially in the case of membrane-based systems, is the rise in energy costs.

In the case of greywater reuse, the technological frontier has been reconfigured through the extension of membrane-based systems that are able to filter out extremely tiny particles (diameter of 0.05 μm), which is more than enough for toilet flushing; however, their capacity to filter out emerging pollutants at tiny concentrations remains unknown. Regarding our case study of Sant Cugat, users were not particularly concerned with the possible health impacts of greywater systems, although they complained vigorously about the deficiencies of the early chemical-based systems. Health professionals also agreed to their use, but only after systematic and extensive analysis of treated effluents. Some users were more concerned about economic maintenance costs than about health effects. Finally, concerning broader issues of power and control, these new flows are generated and reused by residents under the regulatory supervision of the local council. Technology providers, at least in Sant Cugat, consist of small and medium-sized enterprises, as installing these systems has not attracted large companies from the sanitation sector.

Neither the (private) water company serving the town nor the regional water authority intervenes in the recycling and reuse of these flows. Economic costs for users derive mainly from maintenance tasks and, as mentioned earlier, for some users these costs may be higher than the amount of money paid when flushing the toilet with network water. This has not been confirmed, however, and as water prices keep increasing, recycled greywater may become more competitive. In sum, greywater recycling at the scale of residential buildings in this city achieves, an acceptable level of technological efficiency and – at least with regard to health concerns – user acceptance; there is also what appears to be a relatively fair and sustainable degree of user control of the flows.

Twenty years after Sant Cugat adopted the City Ordinance on Water Savings, however, the mainstreaming of the greywater recycling initiative spearheaded by the municipality remains very limited. In the AMB, only five municipalities include greywater reuse in their local water-saving ordinances (BR, 2022). A recent study nonetheless confirms the existence of tangible economic savings (above the maintenance costs) in buildings with over 20 apartments (BR, 2022: 569). This study only considers buildings that have parking spaces and are therefore able to accommodate the greywater infrastructure. It assumes that given the current renewal rate in the area, savings of some 3.8 million cubic meters (Mm^3) per year by 2050 may be attainable (ibid), which is to say a reduction of water consumption by about 22 litres per capita per day (ibid).

DIRECT AND INDIRECT RECLAIMED WATER REUSE IN METROPOLITAN BARCELONA

As shown in the case of Sant Cugat, greywater recycling shows interesting potential in terms of water savings and local/user control; at the metropolitan level, however, the preferred option for treated wastewater is the large 'regeneration' plants present in the area. A wastewater treatment plant may include tertiary treatments such as the removal of pollutants that were not adequately eliminated in primary and secondary wastewater treatment processes; these can include nitrogen and phosphorous. In Catalonia, such treatment plants are referred to as water regeneration plants (*estació regeneradora d'aigua*, or ERAs) (BR, 2022).

The enforcement of tougher restrictions in response to the critical drought of 2022/2023 was accompanied by a public announcement that the use of regenerated water was increasing the resilience of the metropolitan water system. Reclaimed water flows that are thus obtained may play an essential role in reconfiguring the hydrosocial cycle of the AMB, especially in a future that is plagued by recurrent droughts that stress conventional water resources. Several projects of advanced wastewater treatment for reclaimed water reuse in metropolitan Barcelona are currently on the policy table or at the planning, early development, or pilot stages. Some of them are being activated to face the current drought. It was the severe drought episode of 2008 in Catalonia, however, that signalled a turning point in regenerated water reuse; in that period, 54 Mm^3 of treated wastewater was put to agricultural, environmental and industrial purposes in what constituted the peak in wastewater reuse to date (BR, 2022: 204). Some of the more ambitious projects discussed in this section also originated during the crisis-ridden period of 2007 and 2008. Although in different degrees, they all have in common a clear intention to break down the frontiers of reclaimed water reuse in Catalonia, from agricultural and environmental uses to the domestic sector and for both non-potable and potable functions.

The AMB harbours four wastewater treatment plants (BR, 2022) that are equipped with a tertiary treatment capacity that allows them to produce high quality reclaimed water for reuse. The most important of these is in El Prat de Llobregat, located south of Barcelona, which treats the wastewater of over two million people. The so-called water regeneration plant in El Prat de Llobregat can treat up to 110 Mm^3 of water per year (ACA, 2022); it uses a physicochemical regeneration process with filtration and disinfection by ultraviolet rays and is able to produce a reliable flow of 300,000 m^3/day of high quality water. Since 2007, and through an additional treatment of ultra-filtration and reverse osmosis, reclaimed water has been produced and injected into wells to create a hydraulic barrier against seawater intrusion in the aquifer of the lower Llobregat Delta (ACA, 2022). This plant is endowed with advanced wastewater treatment technologies that facilitate the direct use of water for some specific functions that are regulated by the Spanish Real Decreto 1620/2007 on water reuse; they include environmental (wetland regeneration and maintenance), recreational (golf courses and ornamental fountains), industrial, agricultural (for watering crops and pastures), and urban uses (street cleaning, garden watering and fire prevention). Some residential uses are also included, such as the watering of private gardens and toilet flushing. While the Spanish regulations on water reuse prohibit directly reusing reclaimed water for potable purposes (Ministerio de la Presidencia, 2007), an additional pipe that pumps water into the Llobregat River 15 kilometres upstream (Mujeriego et al., 2008) allows for indirect water reuse for potable purposes through the drinking water treatment plant of Sant Joan Despí; this plant is located some kilometres downstream the point where reclaimed water is released.

In 2019, the Catalan Water Agency and the Metropolitan Authority signed an agreement by which the drinking water plant of Sant Joan Despí (a key infrastructure for producing potable water from the Llobregat River) could maintain its authorised withdrawal without having to worry about instream flows, part of which would be supplied with reclaimed water (BR, 2020). That year some 92 Mm^3 of high quality reclaimed water was produced in the ERA of El Prat de Llobregat (with a potential of over 100 Mm^3). Only a meagre 9% of this water was reused, however, and it went for environmental targets such as being returned to the Llobregat River (7.9 Mm^3) and being used for the seawater intrusion barrier (0.27 Mm^3) (Cabello Bergillos, 2021; BR, 2022).

In 2020, the Drought Plan of Catalonia was approved (Generalitat de Catalunya, 2020a, 2020b); it established the different types of actions that should be taken according to the severity of drought episodes. Arguably, it was this plan that explicitly put on the table the indirect reuse of reclaimed water for potable purposes. The plan specifically acknowledges the importance of non-conventional water sources. First, it regulates the volume of desalted water produced in the AMB, depending on how much water is stored in the reservoirs that supply the conurbation. Most importantly for this article, the plan also establishes guidelines and thresholds around the use of reclaimed water from the water regeneration plant of El Prat de Llobregat; these vary depending on drought conditions. Interestingly, it maps out the possibility of indirect potable water reuse by redirecting flows of regenerated water into the Llobregat River upstream of the city; this infusion of water into the river increases the flow of pre-potable water than can then be abstracted and treated at the Sant Joan Despí drinking water plant. According to the Drought Plan, this option would come into effect when the drought entered the phase of 'exceptionality' (reserves below 145 Mm^3 and less than 24% of full capacity) or of 'emergency' (reserves below 100 Mm^3 and less than 16% of full capacity), both of which are defined by the plan as being "very infrequent". The Drought Plan recognises the relatively low cost of regenerated water, but calls for activating indirect reclaimed water reuse for domestic purposes only in emergency situations. This can be attributed to the social and sanitary concerns that remain despite the robustness of the required treatment process for regeneration – potabilisation and the constant monitoring of reliability (Generalitat de Catalunya, 2020b). The use of regenerated flows before reaching the level of exceptionality or emergency is encouraged; the aim is to compensate for restrictions in agricultural, industrial or municipal uses during the 'alert' phase when reservoirs are at 35 to 44% of capacity, depending on time of year. Once the 'emergency' phase is reached, priority is given to flows to the drinking water treatment plant. The Drought Plan forecasts that in a situation of 'exceptionality', the ERA of El Prat de Llobregat would provide some 4.25 Mm^3 of water per month – 1.14 Mm^3 for agriculture and 3.11 Mm^3 to the river to be reused (ibid).

Pilot tests of indirect regenerated water reuse were carried out in 2010 with "very positive results" (Generalitat de Catalunya, 2020c). The steady mobilisation of these flows, however, requires "exhaustive monitoring" well before (that is, two months before) the exceptionality phase is activated (ibid). The Drought Plan considers the economic cost of monitoring and data collection on the procedure's performance (ibid). In 2018, the Catalan Water Agency (ACA), the AMB, and the Catalan government created a board of experts to analyse the possibility of enabling permanent indirect reuse of regenerated water for potable water purposes beyond drought periods. The aim was to turn an emergency measure into a structural water supply source in order to enhance metropolitan water self-sufficiency (BR, 2022: 205). In 2019, new pilot tests of indirect potable water reuse were carried out to determine different health risks (Cabello Bergillos, 2020). Finally, and as far as we know, there are no studies in the AMB on the public perception of direct or indirect use of regenerated water for potable uses; the public announcement that regenerated water is key to withstanding the effect of the drought, however, may open up the future possibility of evaluating public perceptions.

The severity of the 2022/2023 drought materialised the options included in the Drought Plan. By the end of January 2023, a 0.6 cubic metres per second (m^3/sec) flow of regenerated water was reaching the Llobregat River upstream to be mixed with river water and later extracted, treated and distributed for domestic water use. By February, it was already at 0.8 m^3/sec, with a potential to increase up to 2 m^3/sec if the situation worsened (*La Vanguardia*, 2023). By 28 February 2023, the AMB had reached the exceptionality phase; this has opened the doors to publicly recognising the role of, and increasing, indirect potable water reuse.

Beyond drought 'exceptionality', the prospects of reclaimed water use indicate that it could become a critical resource in the mix of metropolitan water if fully developed. It could be reused indirectly for domestic water purposes as well as directly for other purposes. Recent calculations estimate the potential demand for reclaimed water for urban services and industry at 13.6 Mm^3, mainly around the lower part of the Llobregat River (BR, 2020). In agricultural irrigation, there is a potential demand for some 44 Mm^3 of reclaimed water (ibid) as the lower Llobregat River valley remains an important producer of vegetables for Barcelona markets. In terms of environmental uses, and beyond its use for the recharge of ponds in the delta wetlands and as a hydraulic barrier against saline intrusion, it is possible to return up to 31.5 Mm^3 per year to the Llobregat River as environmental flows (ibid). Beyond the direct use of reclaimed water for purposes that do not require potable water standards, it is worth mentioning the exploration of direct water reuse for the domestic sphere in a way that resembles the use of greywater in Sant Cugat, as described in the previous section. Two pilot programmes are worth noting with regard to the direct use of reclaimed water at the domestic level. The first of these is the use of some 0.22 Mm^3 per year in the new 12,000-apartment urban development of the Marina del Prat Vermell (Cabello Bergillos, 2021). This project will host the largest concentration of public housing in Barcelona (some 5000 apartments), with the first 1500 apartments scheduled to be finished by 2026 (*La Vanguardia*, 2022). Some 0.125 Mm^3 per year of regenerated water will also be provided to the new housing developments of El Prat de Llobregat, which has already incorporated a double metering system in residential buildings south of the city (BR, 2020). The last case includes pilot programmes for watering green zones and flushing toilets in the Barcelona Airport (Cabello Bergillos, 2021). A potential demand of up to about 1.2 Mm^3/year of reclaimed water (in the long term, if the network is expanded) is expected to cover part of the non-potable water demand for 123 facilities, including sports centres, educational centres and nursing homes (BR, 2020).

Although the severity of the 2022/2023 drought is rapidly reconfiguring the frontiers of reclaimed water reuse, the economic costs of expanding those networks, especially in the case of direct water use for non-potable purposes, has emerged as a challenge (BR, 2022). An interesting, but still largely undefined, proposal is being discussed around the creation of a metropolitan network of reclaimed water flows that would connect the different metropolitan regeneration plants (Cabello Bergillos, 2021); there has also even been discussion of purchasing these types of flows from beyond the metropolitan area (ibid). Along these lines, the draft of the Strategic Plan for the Integral Water Cycle of the Metropolitan Area of Barcelona (PECIA) envisages the development of a new drinking water plant in the Besòs River, north of Barcelona, and an upgrading of the existing wastewater treatment plant with advanced tertiary treatment to produce high quality reclaimed water. In this case, the scheme would replicate that of the Llobregat, pumping water into the Besòs River 8 km upstream so it can be later captured from the river by a drinking water plant (to be built) and then fed into the city network (BR, 2022). Another scenario foresees the connection of this infrastructure with the Llobregat River basin, enhancing the potential of water treatment in the drinking water plant of Sant Joan Despí (BR, 2022). These alternatives would imply a cost of between €101 and €132 million (ibid: 582) and would require an energy expenditure of around 2.38 kWh/m^3 (ibid). The costs are similar (or more expensive for the most complex alternative) to expanding one of the desalination plants in the metropolitan region (some €102 million) but they are below the energy intensity of the desalination plant (3.61 kWh/m^3) (ibid).

The draft project of the Water Plan of Catalonia 2022-2027 (still under review) states that, "the demands for water for uses that, in accordance with current regulations, can be met with reclaimed water, must be met preferably with this type of resource and, where possible, with resources from regenerated water distribution networks" (Article 51.1, Generalitat de Catalunya, 2021a, authors' translation). This draft foresees the construction of more than 25 regeneration plants in Catalonia (Generalitat de Catalunya, 2021b). The plan states that, "there is great potential to increase the reuse of water, generating water resources that can help improve resilience to episodes of drought, to maintain ecological flows in rivers, and to reduce the pressure of dry periods on rivers and aquifers" (ibid: 24). Finally, it also contemplates the possibility of integrating the cost of those treatments into the water tax charged on domestic and industrial water bills (Generalitat de Catalunya, 2021b).

DISCUSSION AND CONCLUSIONS

The reuse of treated wastewater has not raised much interest in critical water scholarship, with notable exceptions such as Meehan et al. (2013) and Ormerod (2019). Desalination, in contrast, has received extensive attention with robust theoretical and empirical work (see March, 2015; Swyngedouw and Williams, 2016; Fragkou and Budds, 2020; Williams, 2022). However, the high priority given to water reuse by international organisations, public and private water companies, and water-related NGOs (Saurí and Arahuetes, 2019), and the ample number of projects around the world (Goyal and Kumar, 2021) make it plausible to assume that in the following decades reclaimed water will constitute a significant component of water resource portfolios, especially in urban areas (Wilcox et al., 2016). In 2020, the European Union for the first time recognised the importance of these 'new waters' by regulating the reuse of reclaimed water for agricultural irrigation as demanded by the southern European member states. More recently, discussions on the revision of the European urban wastewater directive have been stressing the importance of reclaimed water as a critical resource for alleviating drought episodes. In this paper, we have proposed approaching treated wastewater reuse from the standpoint of the hydrosocial cycle (Linton and Budds, 2014) and the resource frontiers metaphor as applied to natural resources (Tsing, 2003) and particularly to commodities (Campling and Baglioni, 2019). In the case of treated wastewater, frontiers – interpreted through the hydrosocial cycle lens – are profoundly shaped by the materiality of the resource ('treated wastewater'). They are also shaped by their technological nature, that is to say their capacity to produce safe flows for a variety of uses including directly or indirectly obtained drinking water. Wastewater frontiers are also perceptional, being influenced by the social acceptance of flows, and political-economic, which has to do with the potential for capital accumulation that is offered by these flows.

In our case study, which is supported by an analysis of different plans and projects, we highlight a profound reconfiguration of the hydrosocial cycle in Barcelona, where treated wastewater is called in to play a significant role in enhancing the AMB’s capacity to withstand recurrent droughts. The harsh drought of late 2022/2023 may precisely speed up and 'normalise' this reconfiguration. The architecture opened up by these new waters in a context of fragility seems to suggest shelving (definitively?) conventional options that are based on the expansion of surface river water extraction through dams and through intra-basin and inter-basin water transfers. In Spain, desalination could be defined as 'new wine in old bottles' with regard to the political economies it reinforces (see, for instance, March et al., 2014; Swyngedouw and Williams, 2016); it could be considered as a reshuffling of the hydraulic paradigm that is characterised by large infrastructures and centralised modes of governance (Saurí and del Moral, 2001). There is, however, a gap in the understanding of how reclaimed water will impact the choreographies of power over the urban and metropolitan hydrosocial cycles. To the extent that treated wastewater flows are produced in the plants from raw sewage, they can be considered a commodity, much like desalinated flows (Williams, 2018). It also remains to be seen whether these reclaimed flows, if scaled up, are perceived as safe and acceptable by the public. The current political economy of water supply in metropolitan Barcelona is largely controlled by private actors, although most planning and regulatory powers remain under public control. It is likely that indirect reuse of reclaimed water for potable water purposes may serve to reinforce the role of private actors in guaranteeing the availability of water in future severe drought conditions. As in other areas that are facing similar challenges, such as Australia, private entities are more capable of adapting to the 'new normal' of scarce conventional resources in the mid and long term (Anderson, 2006). Still, the business model of the infrastructural assemblages for indirect reclaimed water reuse remains to be scrutinised. There are also uncertainties regarding who will pay the cost of treatment and how it will be monetised, although this will probably be settled through water pricing and taxation that is borne by the final users.

Given the public ownership of the metropolitan infrastructure for producing high quality reclaimed water, an important question is whether the management and ownership of regeneration plants will be the next target for private players, once more conventional water sources and technologies have shown their limitations. What can be observed is a powerful discourse from private companies in favour of reclaimed water; they explicitly argue for using these flows for human uses not only in periods of crisis but also in normal situations, even conceding to overcome the 'old paradigm' and forget about water transfers or dam developments. In this sense, regenerated waters are portrayed as "the only viable solution", while at the same time it is being clearly voiced that the public sphere should be responsible for investments in developing these resources (see the advertising report by the AGBAR group in *La Vanguardia*, 2017). Concerning the connection between desalination and treated wastewater reuse, the large-scale adoption of desalination technology for improving the quality of Llobregat River waters intertwines with the technological optimism of purifying reclaimed water for potable uses. The possibility of applying reverse osmosis to reclaimed water, ensuring its potable use, is a crucial technological step; in the Catalan context, this came after it was first used in treating the flows of the Llobregat River for salinisation caused by potash mining (Gorostiza and Saurí, 2019; Valero and Arbós, 2010). New potabilisation technologies that reconfigure the technology frontier are welcomed for their capacity to almost wipe clean the "water pollution palimpsest" of this river (Gorostiza and Saurí, 2017) and, in the process, provide a high quality resource. This portrayal of water as safe is vital if citizens are to accept regenerated waters. It nevertheless also raises the provocative question of whether it is better to avoid public consultation in introducing water from alternative sources (Dolnicar and Hurlimann, 2009).

Last but not least, closer scrutiny is required to further understand the political economy of direct reclaimed water reuse for domestic non-potable uses in the massive housing developments south of Barcelona, once they are finished in the second half of the 2020s. There is still no information on the business model of providing high quality reclaimed water directly to homes for non-potable uses (toilet flushing or watering green zones), although a water company partially owned by the AGBAR group (Aguas de Alicante, in southeastern Spain) sells reclaimed water to private houses for garden irrigation (Morote et al., 2019). This could, however, point to another potentially important business opportunity for private capital. As mentioned earlier, there are many points of contact between desalted and regenerated water flows. As Williams argues (2018, 2022), desalted water is produced like a commodity. The same argument could probably be used for reclaimed water for direct reuse at home (toilet flushing or garden watering); the picture gets more complicated, however, when desalted and reclaimed water flows are mixed with river and aquifer flows (indirect reuse). There will be a need to determine how surface water rights concessions to water companies will reflect the fact that part of the water may not be just river water upon which the concession was negotiated; this is especially relevant if the deterioration of conventional supplies makes the use of regenerated water more the rule than the exception, particularly in drought periods. Above all, the main concern in distributive terms is the impact of all those changes on the water bills of the most vulnerable populations of the metropolitan area and how these changes may reinforce or limit water poverty. Neither official documents nor enthusiastic discourses from private companies say much about how the costs associated with the new water architecture will be passed on to users; specifically, they do not address the question of whether the cost of new flows for toilet tanks will be reflected in water prices or new taxes, or who will benefit from it all.

Linked to the distributive impacts of introducing these new waters into the metropolitan water supply is the question of to what extent they will be socially accepted once use is generalised beyond emergency situations and once dual systems are installed in the new urban developments. Project proposals and plans only make cursory statements about two fundamental issues in regenerated water; the first of these is the health concerns and the concomitant role of health regulators and professionals, and the second is risk perception, especially with regard to indirect potable reuse. If some segments of the population are already consuming bottled water in significant quantities because they do not trust tap water (Pierce and Gonzalez, 2017), this tendency may further intensify when regenerated water enters the supply mix, no matter in what quantity or proportion. This may burden the urban poor, who may suffer from mounting water prices for this most basic commodity (Barlow, 2009).

It does not seem that the big players in metropolitan water supply see a business niche in greywater reuse, and the prospects for this resource in the coming years at the metropolitan level show a reduced impact. There is some potential in the hotel sector and for other public uses, but a more limited presence is projected for new urban developments. In principle, therefore, alternatives such as those put in place in Sant Cugat do not appear to have a promising future in terms of scalability at the metropolitan level. The greywater recycling programme in Sant Cugat is a decentralised and user-led alternative that has inspired guidelines on water conservation for more than 50 municipalities in Catalonia. Even so, after 20 years it somehow remains insulated from the dominant hydraulic paradigm and continues to be an isolated example of alternative water management and governance practices for treated greywater flows. The reasons for this are many. They include the preference of many municipalities for more conventional water-saving options; health and economic concerns about greywater; and, more generally, a lack of political will for implementing alternative water practices.

In sum, the expansion of the political and economic frontiers of wastewater reuse depends on the possibility of these flows becoming a business opportunity for private interests and a new source for capital accumulation in the hydrosocial cycle; its expansion may, on the other hand, follow from becoming an example of decentralised and citizen-led water management. There are, to be sure, many different possibilities on the continuum between the two. While there is extensive work in the two frontiers of technology and perceptions, work on the frontier of political-economic processes in the case of wastewater reuse is still incipient. In Barcelona and elsewhere, technology legitimisation (Binz et al., 2016) for indirect potable water reuse or double networks of direct reuse will likely imply higher prices and taxes and remains an open question. At present, new European regulations on reclaimed water reuse are limited to agricultural uses. Regulations that more generally promote regenerated water reuse, however, such as the new urban wastewater directive, may call more strongly than ever for taking seriously how treated wastewater has the potential to redraw urban hydrosocial cycles.

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REFERENCES

ACA (Agència Catalana de l'Aigua). 2022. *ERA a la demarcació de Barcelona*. https://aca.gencat.cat/ca/laigua/infraestructures/estacions-de-regeneracio-daigua/era-demarcacio-barcelona/index.html, (accessed 24 November 2022)

Anderson, J.M. 2006 Integrating recycled water into urban water supply solutions. *Desalination* 187: 1-9.

Bakker, K. 2002. From state to market? Water mercantilización in Spain. *Environment and Planning A: Economy and Space* 34 (5): 767-90.

BR (Barcelona Regional). 2020. *Estudi sobre el potencial desenvolupament del sistema d'aigües regenerades en l'àmbit metropolità. Tom 1 Memòria*. Barcelona: Barcelona Regional and Àrea Metropolitana de Barcelona.

BR (Barcelona Regional). 2022. *Pla estratègic del cicle integral de l'aigua de l'àrea metropolitana de Barcelona. Tom 1*. Barcelona: Barcelona Regional and Àrea Metropolitana de Barcelona.

Barlow, M. 2009. *Blue covenant. The global water crisis and the coming battle for the right to water*. New York: The New Press.

Bahadori, A. and Smith, S.T. 2016 "*Wastewater*". Dictionary of Environmental Engineering and Wastewater Treatment. Heidelberg: Springer.

Beveridge, R.; Moss, T. and Naumann, M. 2017. A socio-spatial understanding of water politics: Tracing topologies of water reuse. *Water Alternatives* 10(1): 22-40.

Binz, C.; Harris-Lovett, S.; Kiparsky, M.; Sedlak, D.L. and Truffer, B. 2016. The thorny road to technology legitimation – Institutional work for potable water reuse in California, *Technological Forecasting and Social Change* 103: 249-263.

Brannstrom, C.; Jepson, W.; Beckner, S.; Sneegas, G. and Seghezzo, L. 2022. Not a silver bullet: Social perspectives on desalination and water reuse in Texas. *Urban Water Journal* 19(10): 1025-1037.

Cabello Bergillos, F. 2020. La reutilització d'aigües i la seva progressiva entrada en servei. *54a Reunió General Tècnica CUADLL*, March 6, Barcelona. https://www.cuadll.org/media/getAnnex/250

Cabello Bergillos, F. 2021. La reutilització de l'aigua a l'àrea Metropolitana de Barcelona: Situació actual, reptes i perspectives de futur. In ICWS2021 (Ed), 2*nd International Congress on Water and Sustainability* (Terrassa, Barcelona), pp. 111-19. Terrassa: OmniaScience.

Campling, L. and Baglioni, B. 2019. The political economy of natural resources. In Kobayashi, A. (Ed), *International Encyclopedia of Human Geography*, 2nd Edition. London: Elsevier.

Cardoso, B.R.; Rodrigues, E.; Gaspar, A.R. and Gomes, A. 2021. Energy performance factors in wastewater treatment plants: A review. *Journal of Cleaner Production* 322(1): 129107.

Ching, L. 2010. Eliminating 'yuck': A simple exposition of media and social change in water reuse policies. *International Journal of Water Resources Development* 26(1): 111-124.

Cons, J. and Eilenberg, M. (Eds). 2019. *Frontier assemblages: The emergent politics of resource frontiers in Asia*. New York: Wiley.

Dolnicar, S. and Hurlimann, A. 2009. Drinking water from alternative water sources: Differences in beliefs, social norms and factors of perceived behavioural control across eight Australian locations. *Water Science & Technology* 60 (6): 1433-1444.

Dolnicar, S. and Schäfer, A.I. 2009. Desalinated versus recycled water – Public perceptions and profiles of the accepters. *Journal of Environmental Management* 90(2): 888-900.

Domènech, L. and Saurí, D. 2010. Socio-technical transitions in water scarcity contexts: Public acceptance of greywater reuse technologies in the Metropolitan Area of Barcelona. *Resources, Conservation and Recycling* 55 (1): 53-62.

Duong, K. and Saphores, J.D.M. 2015. Obstacles to wastewater reuse: An overview. *WIREs Water* 2(3): 199-214.

European Parliament 2020. Regulation (EU) 2020/741 of the European Parliament and of The Council of 25 May 2020 on minimum requirements for water reuse. (accessed 6.3.2023).

European Commission. 2022. Proposal for a Directive of the European Parliament and of the Council concerning urban wastewater treatment. COM(2022) 541 final 2022/0345. Brussels, 26.10.2022. https://environment.ec.europa.eu/system/files/2022-10/Proposal%20for%20a%20Directive%20concerning%20urban%20wastewater%20treatment%20%28recast%29.pdf (last accessed 23 March 2023)

Eurostat. 2013. Statistics Explained. *Glossary: Wastewater*. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary: Wastewater

Fragkou, M.C. and Budds, J. 2020. Desalination and the disarticulation of water resources: Stabilizing the neoliberal model in Chile. *Transactions of the Institute of British Geographers* 45(2): 448-463.

Friedler, E.; Lahav, O.; Jizhaki, H. and Lahav, T. 2006. Study of urban population attitudes towards various wastewater reuse options: Israel as a case study. *Journal of Environmental Management* 81: 360-370.

Generalitat de Catalunya. 2020a. ACORD GOV/1/2020, de 8 de gener, pel qual s'aprova el Pla especial d'actuació en situació d'alerta i eventual sequera. *Diari Oficial de la Generalitat de Catalunya*, 8039 10.1.2020 1-139. Barcelona: Generalitat de Catalunya.

Generalitat de Catalunya. 2020b. *Pla especial d'actuació en situació d'alerta i eventual sequera. Memòria Tècnica*. Barcelona: Agència Catalana de l'Aigua, Generalitat de Catalunya.

Generalitat de Catalunya. 2020c. *Pla especial d'actuació en situació d'alerta i eventual sequera. Memòria Econòmica*. Barcelona: Agència Catalana de l'Aigua, Generalitat de Catalunya.

Generalitat de Catalunya. 2021a. *Projecte de Decret /2021, de de , pel qual s'aprova el Pla de gestió del districte de conca fluvial de Catalunya per al període 2022-2027, i es deroguen el Decret 328/1988, d'11 d'octubre, pel qual s'estableixen normes de protecció i addicionals en matèria de procediment en relació amb diversos aqüífers de Catalunya, i el Decret 329/1988, d'11 d'octubre, pel qual es declara la sobreexplotació de determinats sectors dels aqüífers subterranis o unitats hidrogeològiques*. Barcelona: Generalitat de Catalunya.

Generalitat de Catalunya. 2021b. *Management plan for the river basin district of Catalonia and programme of measures. 2022-2027 Synthesis document 2021*. Barcelona: Agencia Catalana de l'Aigua, Generalitat de Catalunya.

Gorostiza, S. and Saurí, D. 2017. Dangerous assemblages: Salts, trihalomethanes and endocrine disruptors in the water palimpsest of the Llobregat River, Catalonia. *Geoforum* 81: 153-62.

Gorostiza, S. and Saurí, D. 2019. Naturalizing pollution: A critical social science view on the link between potash mining and salinization in the Llobregat River Basin, Northeast Spain. *Philosophical Transactions of the Royal Society B* 374 (1764): 20180006.

Goyal, K. and Kumar, A. 2021. Development of water reuse: A global review with the focus on India. *Water Science and Technology* 84(10-11): 3172-3190.

Hurlimann, A. and Dolnicar, S. 2010. When public opposition defeats alternative water projects – The case of Toowoomba Australia. *Water Research* 44(1): 287-297.

Jodar-Abellan A.; López-Ortiz M.I. and Melgarejo-Moreno J. 2019. Wastewater treatment and water reuse in Spain. Current situation and perspectives. *Water* 11(8): 17-22.

Karpouzoglou, T. and Zimmer, A. 2016. Ways of knowing the wastewaterscape: Urban political ecology and the politics of wastewater in Delhi, India. *Habitat International* 54: 150-160.

Khan, S.J. and Anderson, R. 2018. Potable reuse: Experiences in Australia. *Current Opinion in Environmental Science & Health* 2: 55-60

Kjellén, M. 2018. Wastewater governance and the local, regional and global environments. *Water Alternatives* 11(2): 219-237.

La Vanguardia. 2017. *Las mil caras del agua, monográfico especial La Vanguardia* 22 March 2022. Barcelona: *La Vanguardia*.

La Vanguardia. 2022. La Marina de Barcelona, un barrio pensado para vivir. *La Vanguardia*, 7 April 2022, online. www.lavanguardia.com/local/barcelona/20220407/8180651/marina-unbarrio-pensado-vivir-brl.html (last accessed 1 December 2022)

La Vanguardia. 2023. *El 20% del agua del área metropolitan de Barcelona ya es regenerada.* La Vanguardia, 26 January 2023. www.lavanguardia.com/local/baix-llobregat/20230126/8712348/20-agua-area-metropolitana-regenerada.html (last accessed 24.3.2023)

Lee, K. and Jepson, W. 2020. Drivers and barriers to urban water reuse: A systematic review. *Water Security* 11: 100073.

Linton, J. 2014. Modern water and its discontents: A history of hydrosocial renewal. *WIREs Water* 1(1): 11-120

Linton, J. 2008. Is the hydrologic cycle sustainable? A historical-geographical critique of a modern concept. *Annals of the Association of American Geographers* 98(3): 630-649

Linton, J. and Budds, J. 2014. The hydrosocial cycle: Defining and mobilizing a relational-dialectical approach to water. *Geoforum* 57: 170-180.

March, H. 2015. The politics, geography, and economics of desalination: A critical review. *WIREs Water* 2(3): 231-243.

March, H.; Saurí, D. and Rico-Amorós, A.M. 2014. The end of scarcity? Water desalination as the new cornucopia for Mediterranean Spain. *Journal of Hydrology* 519: 2642-2651.

Meehan, K.; Ormerod, K.J. and Moore, S.A. 2013. Remaking waste as water: The governance of recycled effluent for potable water supply. *Water Alternatives* 6(1): 67-85.

Ministerio de la Presidencia. 2007. Real Decreto 1620/2007, de 7 de diciembre, por el que se establece el régimen jurídico de la reutilización de las aguas depuradas. *Boletín Oficial del Estado*, 21092 50639. Madrid: BOE.

Morote, A.F.; Olcina, J. and Hernandez, M. 2019 The use of non-conventional water resources as a means of adaptation to drought and climate change in semi-arid regions: South-eastern Spain. *Water* 11: 93.

Mujeriego, R.; Compte, J.; Cazurra, T. and Gullón, M. 2008. The water reclamation and reuse project of El Prat de Llobregat, Barcelona, Spain. *Water Science & Technology* 57(4): 567-574.

Ormerod, K.J. 2019. Toilet power: Potable water reuse and the situated meaning of sustainability in the southwestern United States. *Journal of Political Ecology* 26(1).

Pierce, G. and Gonzalez, S. 2017. Mistrust at the tap? Factors contributing to public drinking water (mis)perception across US households. *Water Policy* 19(1): 1-12.

Po, M.; Kaercher, J.D. and Nancarroiw, B. 2003. *Literature review of factors influencing public perceptions of water reuse. CSIRO Land and Water Technical Report 54/03*. https://www.clearwatervic.com.au/user-data/research-projects/swf-files/16-laying-the-foundation-for-confident-barrier-free-water-conservation-and-reuse-literature-review.pdf (last accessed 13 January 2023)

Plumlee, M.H.; Stanford, B.D.; Debroux, J.F.; Hopkins, D.C. and Snyder, S.A. 2014. Costs of advanced treatment in water reclamation. *Ozone: Science & Engineering* 36(5): 485-495.

Redman, S.; Ormerod, K.J. and Kelley, S. 2019. reclaiming suburbia: Differences in local identity and public perceptions of potable water reuse. *Sustainability* 11(3): 564.

Sapority, N. and Robins, E. 2021. *Scaling up water reuse: Why recycling our wastewater makes sense. Development and a Changing Climate. World Bank Blogs*. https://blogs.worldbank.org/climatechange/scaling-water-reuse-why-recycling-our-wastewater-makes-sense (last accessed 30 November 2022)

Saurí, D. and Arahuetes, A. 2019. Water reuse: A review of recent international contributions and an agenda for future research. *Documents d'Anàlisi Geogràfica* 65(2): 399-417.

Saurí, D. and del Moral, L. 2001. Recent developments in Spanish water policy. Alternatives and conflicts at the end of the hydraulic age. *Geoforum* 32(3): 351-362.

Sedlak, D. 2014. *Water 4.0 The past, present and future of the world's most vital resource*. New Haven, Connecticut: Yale University Press.

Swyngedouw, E. and Williams, J. 2016. From Spain's hydro-deadlock to the desalination fix. *Water International* 41(1): 54-73.

Tortajada, C. and van Rensburg, P. 2020. Drink more recycled wastewater. *Nature* 577, 26-28.

Tsing, A.L. 2003. Natural resources and capitalist frontiers. *Economic and Political Weekly* 38(48): 5100-5106.

UBA (Umwelt Bundesamt) 2020. New EU Regulation on Minimum Requirements for Water Reuse. https://www.umweltbundesamt.de/en/topics/water/water-resource-management/water-reuse/new-eu-regulation-on-minimum-requirements-for-water#objectives-and-core-elements-of-the-eu-regulation (last accessed 8 March 2023)

UNEP (United Nations Environment Programme). 2017. The United Nations World Water Development Report 2017. Wastewater: The untapped resource, https://wedocs.unep.org/20.500.11822/20448 (last accessed 13 January 2023)

USGS (United States Geological Survey). 2018. Wastewater treatment water use. https://www.usgs.gov/special-topics/water-science-school/science/wastewater-treatment-water (last accessed 31 October 2022)

Valero, F. and Arbós, R. 2010. Desalination of brackish river water using Electrodialysis Reversal (EDR). Control of the THMs formation in the Barcelona (NE Spain) area. *Desalination* 253(1-3): 170-74.

Vallès-Casas, M.; March, H. and Saurí, D. 2016. Decentralized and user-led approaches to rainwater harvesting and greywater recycling in a Mediterranean area: The case of Sant Cugat del Vallès (Barcelona, Spain). *Built Environment* 42(2): 243-257.

Wilcox, J.; Nasiri, F.; Bell, S. and Rahaman, Md.S. 2016. Urban water reuse: A triple bottom line assessment framework and review. *Sustainable Cities and Society* 27: 448-456.

Williams, J. 2018. Assembling the water factory: Seawater desalination and the technopolitics of water privatization in the San Diego-Tijuana metropolitan region. *Geoforum* 93: 32-39.

Williams, J. 2022. Desalination in the 21st century: A critical review of trends and debates at the water desalination frontier. *Water Alternatives* 15(2): 193-217.

WHO (World Health Organization). 2017. Potable reuse: Guidance for producing safe drinking-water. World Health Organization. https://apps.who.int/iris/handle/10665/258715 (last accessed 13 January 2023)

Yang, Y.; Ok, Y.S.; Ki-Hyun, K.; Kwon, E.E. and Tsang, Y.F. 2017. Occurrences and removal of pharmaceuticals and personal care products (PPCPs) in drinking water and water/sewage treatment plants: A review. *Science of the Total Environment* 596-597: 303-320.

Zhou, Y.; Jing, M.; Zhang, M.; Chen, S.; He, B.; Zhao,H.; Li, Q.; Zhang, S. and Wang, T. 2019. Which type of pollutants need to be controlled with priority in wastewater treatment plants: Traditional or emerging pollutants? *Environment International* 131: 104982.