

# Water reuse and desalination in Spain – challenges and opportunities

Teresa Navarro

## ABSTRACT

This article offers an evaluation of the reuse of reclaimed water and desalination in Spain and aims to provide an overview of the state of the art and Spanish legal framework as far as non-conventional resources are concerned. The fight against the scarcity of water resources in this country, especially in the southeast, has made the production of new alternative water resources a clear priority and has turned the nation into a leader in water reuse and seawater desalination. The assessment presented can be used to help build a more general framework, like the European one, and shed light on other comparative legal experiences.

**Key words** | desalination, non-conventional resources, water governance, water reuse

**Teresa Navarro**  
Institute of Water and the Environment,  
University of Murcia,  
Murcia,  
Spain  
E-mail: [tnavarro@um.es](mailto:tnavarro@um.es)

## INTRODUCTION

The technologies used in industrial water production, desalination and water reuse represent a key tool for tackling water scarcity, adaptation to climate change and facilitating the implementation of a circular economy. Making use of reclaimed and desalinated water leads to a more sustainable use of the resource and contributes additional new resources. Desalinated and reuse of reclaimed water reduces the exploitation of inland water bodies, surface water resources and groundwater. Thanks to these technologies, new flows are introduced into the hydrological cycle, ecosystems are improved, and pollution is mitigated as less wastewater is discharged into the environment. They also help to ensure sufficient quantities of high-quality water, and play a part in meeting the objectives of Directive 2000/60/EC of 23 October 2000, which establishes a European community framework for action in the field of water policy (WFD), by generating sustainable growth, reducing waste and protecting the environment. The use of these technologies is in line with the approach adopted by the

European Commission on the circular economy (Chapter 4, 'Closing the loop – An EU action plan for the circular economy', COM (2015) 614 final).

Through Agenda 2030 for Sustainable Development, the United Nations is also pressing for worldwide adoption of desalination and reuse technologies, as an essential tool for achieving its Sustainable Development Goals (SDGs). In order to ensure water availability, sustainable resource management and sanitation for all (SDG 6), there must be integrated management of water resources. Furthermore, the percentage of untreated wastewater should be halved by 2030, and a substantial global increase is required in the recycling and safe reuse of treated wastewater. This calls for greater international cooperation in activities and programmes relating to water and sanitation, including desalination, wastewater treatment, and recycling and reuse technologies (SDG 6, Goals 6.3, 6.5 and 6.7, Agenda 2030 for Sustainable Development).

Countries facing water scarcity have long been aware of the potential of these technologies for combatting water shortages. In Spain, which suffers from a chronic structural water deficit, water reuse and desalination have been a priority for some time now. The government's White Paper on Water published in 2000 acknowledged that the use of

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non-conventional water resources equated to only 1% of the available conventional resources; it thus proposed specific, ground-breaking legislation to promote the two above-mentioned technologies, while ensuring the required level of safety in all aspects (legal, public health, technological, etc.). In particular, the reuse regulations are fairly stringent: Royal Decree 1620/2007 (RDR) sets out the legal standards for the reuse of reclaimed water, establishing very rigorous criteria in Annex I.A based on maximum permissible values (MPV), and stipulating numerous water quality analyses. This legal framework will be discussed in more detail below, with a particular focus on its application in the Region of Murcia. It is, however, something of a paradox that, in Spain, there are quality regulations that govern the use of reclaimed water for irrigation, but not the use of water directly sourced from natural watercourses (Hernández 2016).

Spain has a highly variable rainfall regime, averaging over 2000 mm/y in some areas (Galicia, the Cantabrian Mountains, the Basque-Navarran Pyrenees, the Central Mountain System and the Sierra de Ubrique) but less than 200 mm/y in the southeast (Almeria and Murcia), one of the lowest rainfall levels in Europe. This complicated water balance is becoming particularly acute in some areas of the country; the Mediterranean coast, which already suffers from water scarcity, is the region worst hit by droughts. Practically all surface water resources in Spain are already stored in reservoirs, and so no new reservoirs are scheduled for construction in the near future. Furthermore, in many cases, groundwater resources are overexploited.

In view of the circumstances described above, no significant future increases are expected in available water from conventional sources, and so in the most vulnerable areas a key role will be played by alternative sources such as reclaimed water and desalination of brackish water and seawater.

## WATER REUSE IN SPAIN

### Reuse as a tool for sustainable water policy

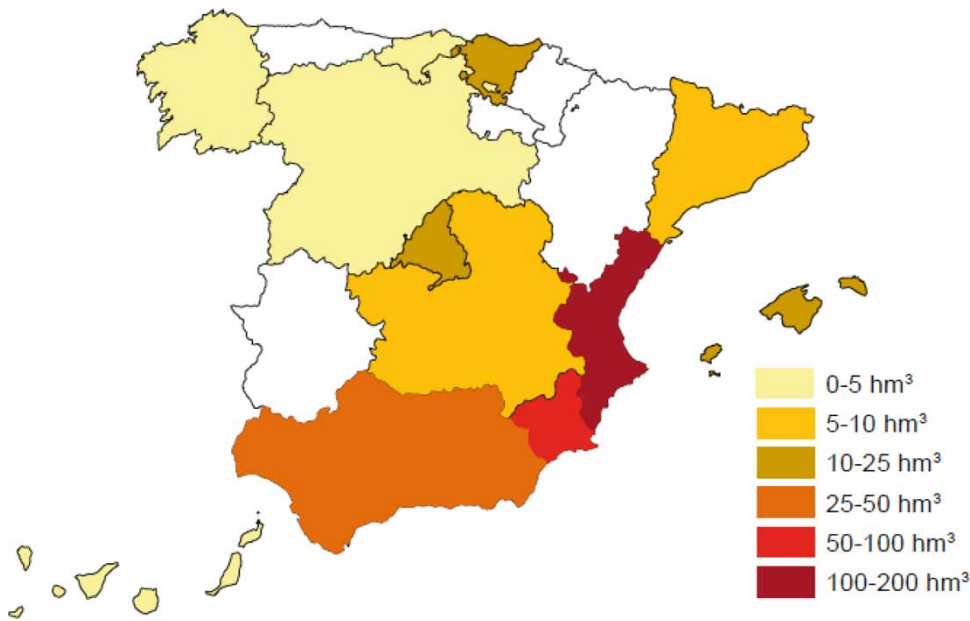
The use of reclaimed water is a tool in the comprehensive, sustainable and cost-effective management of water. It represents

a promising option in countries facing water scarcity and drought, such as Spain (Martin 1996). In this country, water reuse helps to solve issues concerning insufficient allocation of resources to certain uses, halts the degradation of public water resources and the overexploitation of aquifers, and reduces environmental pollution (Figure 1 and Table 1).

Water reuse is an industrial process that enables an additional use of previously used water before it returns to the rivers or the sea, and after it has undergone a wastewater recovery and treatment process that ensures the legally required quality. The ultimate goal of this process is to secure new resources – reclaimed water – that can be directly offered to other users or exchanged for better quality water. The use of reclaimed water frees up other sources of water, which can then be employed for more strictly controlled uses such as human supply, thus contributing to a more rational use of water (Navarro 2010).

It is worth clarifying the difference between *treated water* and *reclaimed water*, as they are subject to different regulations. RDR defines them as follows: *Treated water* is wastewater that has been treated at the urban wastewater treatment plant (WWTP) to ensure its quality meets wastewater discharge authorization requirements (Article 2 b, RDR). Such water can be returned to any bodies of water as it will not alter their ecological status, and is in fact diluted by its discharge into the receiving water bodies. *Reclaimed water* is wastewater that has been submitted to a more rigorous treatment process in a water reclamation facility (WRF) and can thus be directly employed for more restricted uses (irrigation, industrial uses, environmental uses, etc.), without being diluted by other water flows (Article 2 c, RDR). The intended uses for reclaimed water determine the quality criteria that will be applied in the WRF and that are set as mandatory minimum requirements.

In Spain, the use of reclaimed water helps ensure that there is enough water to meet existing requirements, rather than enabling an increased demand. The aim is to guarantee a regular, reliable water supply, as well as to halt the degradation of water bodies. Since reclaimed water represents a net addition to the water in a river basin, it allows better use of the available flows in each season. Reclaimed water can be used for crop irrigation; can be discharged into perennial streams or into dry channels that filter into an aquifer; or can be returned to the sea.



**Figure 1** | Map showing the volume of reclaimed water in 2014 (hm<sup>3</sup>/y). Source: Asociación Española de Abastecimiento y Saneamiento (Spanish Association of Water Supply and Sanitation) (AEAS).

**Table 1** | Volume of reclaimed water per inhabitant in 2014 (hm<sup>3</sup>/inhab/y). Source: AEAS

	0	20	30	40	50	60	70
Andalucía	10						
Baleares			32				
Canarias		18					
Cantabria	3						
C.-Mancha		19					
C.-León	1						
Cataluña	2						
C.Valenciana				40			
Galicia	1						
Madrid	2						
Murcia						60	
País VASCO	4						
Media	8						

### Legal framework

There are no Europe-wide regulations governing specific uses of reclaimed water although there are quite a number of Directives regulating particular aspects of the protection of water resources, which affect reuse and result in varying legal standards (Molina & Melgarejo 2015). In Spain,

however, there is an established legal framework, RDR, which sets out the legal standards for the reuse of reclaimed water.

### What can reclaimed water be used for?

Spanish law allows the reuse of reclaimed water for certain urban, agricultural, industrial, recreational and environmental uses. In all cases, the public health authorities must first issue a binding report in which they confirm that the proposed uses are appropriate, taking into account the technical proposal, the self-monitoring programme and the risk management programme presented by the applicant for the concession or authorization.

To that end, the Region of Murcia's public health authority requires that the technical proposal should detail, among other things: the wastewater treatment (at least secondary treatment) with a record of the analyses carried out on water at the outflow of the WWTP; and the reclamation treatment, with a diagram of the reclamation process. The tertiary treatment required depends on the intended use; filtration and disinfection is recommended as a minimum. A record of the analyses carried out on water at the outflow of the WRF is also required.

Furthermore, in order to verify that the reclamation treatment complies with the quality requirements stipulated by the RDR, the Region of Murcia's public health authority requires an analytical monitoring programme, or 'self-monitoring' to be carried out. The application should indicate the water sampling points, describe the quality parameters to be monitored and the monitoring frequency for each (in accordance with those established in Annex I.A and Annex I.B of the RDR), and should also identify the laboratory that will perform the analyses.

Finally, the management programme to be presented by the applicant should cover aspects related to user safety measures, primarily with respect to green areas or recreational zones and, where appropriate, preventive measures against legionellosis; environmental protection measures, specifying the procedures to be undertaken to avoid contamination of surface drinking water and the perimeters of sanitary protection areas for water catchments; the corrective measures needed to avoid contamination of the drinking water distribution network; and occupational health and training for workers in contact with reused water.

Annex I.A sets out the quality criteria for reusing water, depending on its intended use. These criteria are expressed in MPV and generally include parameters such as: *Escherichia coli*, helminth eggs, suspended solids, turbidity (mandatory parameters for all uses), *Legionella*, *Salmonella*, BOD5 (biochemical oxygen demand), COD (chemical oxygen demand), heavy metals, conductivity, SAR (specific absorption rate), chlorine/chlorides, nitrogen, phosphorus, and toxic substances including priority substances (for certain uses and in accordance with related legislation) (Table 2).

The use of reclaimed water for human consumption is prohibited, except in situations where a state of emergency has been declared, in which case the public health authority will specify the necessary quality levels for that water. Similarly, reclaimed water is prohibited for uses relating to the food industry, including the manufacture, treatment, conservation or sale of products and substances intended for human consumption; nor is it allowed for cleaning surfaces, objects or materials that may come into contact with food, with the exception of water for processing and cleaning in the food industry provided for in Annex I.A.3, Quality 3.1 c. Reclaimed water is not permitted for use in hospitals and other similar facilities; in aquaculture facilities for

bivalve molluscs; for recreational uses such as swimming water; for use in cooling towers and evaporative condensers, except for the industrial uses specified in Annex I.A.3, Quality 3.2; for use in ornamental fountains and water features in public areas or indoor spaces of public buildings; and, lastly, for any other use that the public health or environmental authorities consider a risk to human health or harmful to the environment, regardless of when that risk or harm is detected (RDR Article 4.4).

The RDR sets out the minimum sampling and testing frequencies for reclaimed water (Annex I.B). The samples for analysis must be taken at the outflow of the WRF, and at all points of delivery to users. Tests are generally performed fortnightly, weekly or twice weekly, although in some cases, daily analyses are carried out to monitor suspended solids and turbidity for certain industrial applications (cooling towers and evaporative condensers) and environmental uses (aquifer recharge by direct injection) (Figure 2).

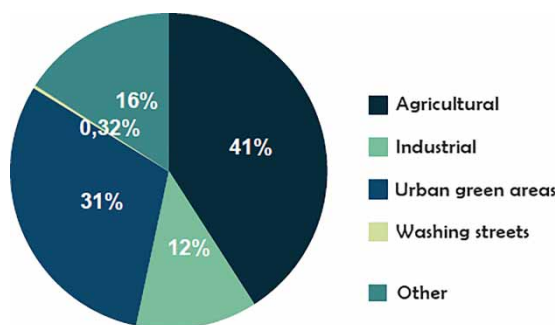
### How to get a water use permit

The RDR establishes different administrative titles depending on who is applying to use reclaimed water. If the applicant is a third party, that is, someone who is neither a primary-use concession holder nor a discharge permit holder, he or she must obtain a reuse concession from the Administration (the corresponding regional water authority). To do so, these applicants must follow the procedure set out under Spanish water legislation, which stipulates that a reuse plan must be submitted, as part of a competitive call for proposals from potentially interested parties (RDR Article 10).

On the other hand, if the person applying to use reclaimed water is already a primary-use concession holder, he or she must obtain a reuse concession, but in this case does not have to compete with other proposed uses. These applicants will thus have priority over third-party applicants. Nevertheless, although the simplest approach would be to amend the existing concession to cover the requested reuse, applicants must complete and submit the form provided in Annex II, outlining their intentions for the reclaimed water and indicating the use for which it is requested, along with a detailed reuse proposal describing all the relevant elements of the request (RDR Article 8.3). The water authority examines the documentation and if it is in accordance with the

**Table 2** | Uses permitted under spanish law (RDR, Annex 1.A)

Use	Quality
1. Urban	1.1. RESIDENTIAL <ul style="list-style-type: none"> <li>a) Watering private gardens</li> <li>b) Discharge from sanitary appliances</li> </ul> 1.2. SERVICES <ul style="list-style-type: none"> <li>a) Irrigating urban green areas</li> <li>b) Washing streets</li> <li>c) Fire-fighting systems</li> <li>d) Industrial vehicle washing</li> </ul>
2. Agricultural	2.1. Irrigation of crops with a water application system that allows the reclaimed water to come into direct contact with the edible parts of crops intended for human consumption and to be eaten raw 2.2. <ul style="list-style-type: none"> <li>a) Irrigation of crops intended for human consumption with a water application system that does not prevent the reclaimed water from coming into direct contact with the edible parts; however, the crops will undergo subsequent industrial treatment rather than being eaten raw</li> <li>b) Irrigation of pastures for feeding milk- or meat-producing livestock</li> <li>c) Aquaculture</li> </ul> 2.3. <ul style="list-style-type: none"> <li>a) Localized irrigation of tree crops where reclaimed water is prevented from coming into contact with the fruits intended for human consumption</li> <li>b) Irrigation of ornamental flowers, nurseries and greenhouses, without direct contact between the reclaimed water and the produce</li> <li>c) Irrigation of industrial (non-food) crops, nurseries, silage, cereals and oilseeds</li> </ul>
3. Industrial	3.1. <ul style="list-style-type: none"> <li>a) Water for processing and cleaning, except in the food industry</li> <li>b) Other industrial uses</li> <li>c) Water for processing and cleaning, for use in the food industry</li> </ul> 3.2. <ul style="list-style-type: none"> <li>a) Cooling towers and evaporative condensers</li> </ul>
4. Recreational	4.1. <ul style="list-style-type: none"> <li>a) Irrigation of golf courses</li> </ul> 4.2. <ul style="list-style-type: none"> <li>a) Ornamental ponds, bodies of water and flowing water features, which the public is prevented from accessing</li> </ul> 5.1. <ul style="list-style-type: none"> <li>a) Aquifer recharge by localized percolation through the ground</li> </ul> 5.2. <ul style="list-style-type: none"> <li>a) Aquifer recharge by direct injection</li> </ul>
5. Environmental	5.3. <ul style="list-style-type: none"> <li>a) Irrigation of woodland, green areas and other spaces that are not accessible by the public</li> <li>b) Silviculture</li> </ul> 5.4. <ul style="list-style-type: none"> <li>a) Other environmental uses (maintenance of wetlands, minimum stream flows and similar)</li> </ul>

**Figure 2** | Uses of reclaimed water in Spain (2014). Source: AEAS.

River Basin Water Plan, processes the water rights application. This review of the application involves a particular focus on the potential impact of water reuse on the ecological flows that may be affected by the resulting reduction in the water returning to the river.

Lastly, applicants that are already discharge permit holders (for water they use and treat themselves) need only a supplementary authorization. To encourage investment in water reclamation, the RDR gives preference over other applicants (third parties and primary-use concession holders) to those who are already involved in wastewater treatment (RDR



Articles 3.3 and 3.4) and also exempts them from having to submit a competing proposal. This is because the legislation aims to promote water reuse; discharge permit holders already have the necessary infrastructure for wastewater treatment and will be able to take on the activity at a lower cost. However, it is clear that prioritizing such users confers an additional benefit on the main discharge permit holders, town councils and public sanitation companies, which already charge for the treatment services they provide (Bravo 2010).

It should be noted that one of the main problems with assigning reclaimed water is the fact that owners of treatment facilities (for example, town councils) do not typically have a discharge permit; moreover, those who do hold a discharge permit are not normally the owners of the land where the reclaimed water will eventually be used (a requirement stipulated in Articles 8 and 9). This means that those applying to use reclaimed water generally have to go through the most onerous procedure to gain reuse rights; namely, the procedure set out in Article 10 of the RDR.

This issue could be successfully addressed if a future amendment to the RDR permitted reuse applications made by municipalities for municipal uses of water sourced from treatment plants within their urban centres to be processed as a new concession or a modification of an existing one, without having to take part in a competitive call for proposals (Bravo 2010).

In any case, the holder of the water reuse concession or authorization is responsible for the quality of the reclaimed water and for monitoring it from the time the treated wastewater enters the WRF to the point of delivery of the reclaimed water. However, it is the user of the reclaimed water who is responsible for preventing any deterioration in its quality from the point of delivery to its points of use (RDR Articles 5.4 and 5.5). In all cases, in accordance with Article 11.3 of the RDR, the holder of the concession or authorization has to cover the costs of carrying out any building works, operations and maintenance necessary to ensure the water reuse meets the quality requirements stipulated by current regulations. However, in accordance with Article 61.3 of the Consolidated Text of the Water Act (TRLA), if the water authority chooses to substitute water flows from concessions with others from reuse, it will only assume the costs directly resulting from the substitution work, and those costs could be passed on to the recipients.

## Water reuse in the Region of Murcia

### A region located in a basin with a chronic water resources deficit

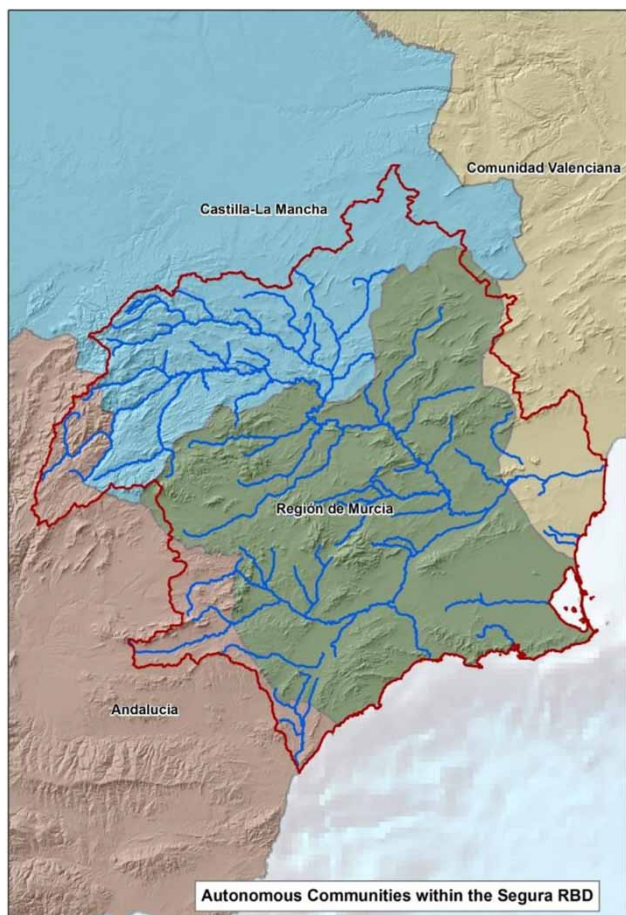
The Segura River Basin District (SRBD) is in the southeast of the Iberian Peninsula and comprises the territory covered by the river basins that flow into the Mediterranean Sea. It covers an area of approximately 18,870 km<sup>2</sup>, and practically the entire Region of Murcia falls within its boundaries. The Segura River Basin is the only one classified as having a 'chronic water resources deficit' by the White Paper on Water, which clarifies that, 'taking into account current demands, this assessment indicates that the systems thus categorized have a structural deficit, regardless of the infrastructure in place and even if the policy on water use and saving is optimized to the maximum extent theoretically possible' (White Paper on Water in Spain 2000) (Figure 3).

The Region of Murcia, in southeastern Spain, covers an area of 11,313 km<sup>2</sup>, had a population of 1,469,656 in 2016 and belongs to the SRBD.

The climatic region in southeastern Spain, where the Region of Murcia is located, has the highest level of exposure to the risk of naturally occurring droughts in the Iberian Peninsula. There are a number of different reasons for this: it is on the leeward side relative to the westerly winds, close to a subtropical subsidence region and in close proximity to Africa. In addition, it is set back from the western Mediterranean basin, and the fairly mountainous terrain creates a foehn effect on the westerly flows and provides shelter from Atlantic storms (Gil 2004). Furthermore, this part of the peninsula is vulnerable to desertification as a consequence of its physical framework which incorporates climatological, edaphological, vegetation and anthropic variables. Increasingly common water scarcity situations lead to direct impacts triggering a chain of desertification effects, which in the long term also affects soil quality (López 1985) (Figure 4).

## Water reuse in the Region of Murcia

The Region of Murcia forms part of the most water-stressed river basin in Spain (Navarro & Martínez 2007). The imbalance of water resources in this basin and recurrent drought has driven continuous improvement in water management.



**Figure 3** | Autonomous communities within the SRBD and geographical area. Source: SRBD.

In particular, given the historical and socio-economic importance of agriculture in this region, the reuse of water in agriculture has been a key priority: of the 154,680 hectares of irrigable land, 100,337 (64.86%) can make use of water from WWTPs (ESAMUR 2014) (Figures 5 and 6).

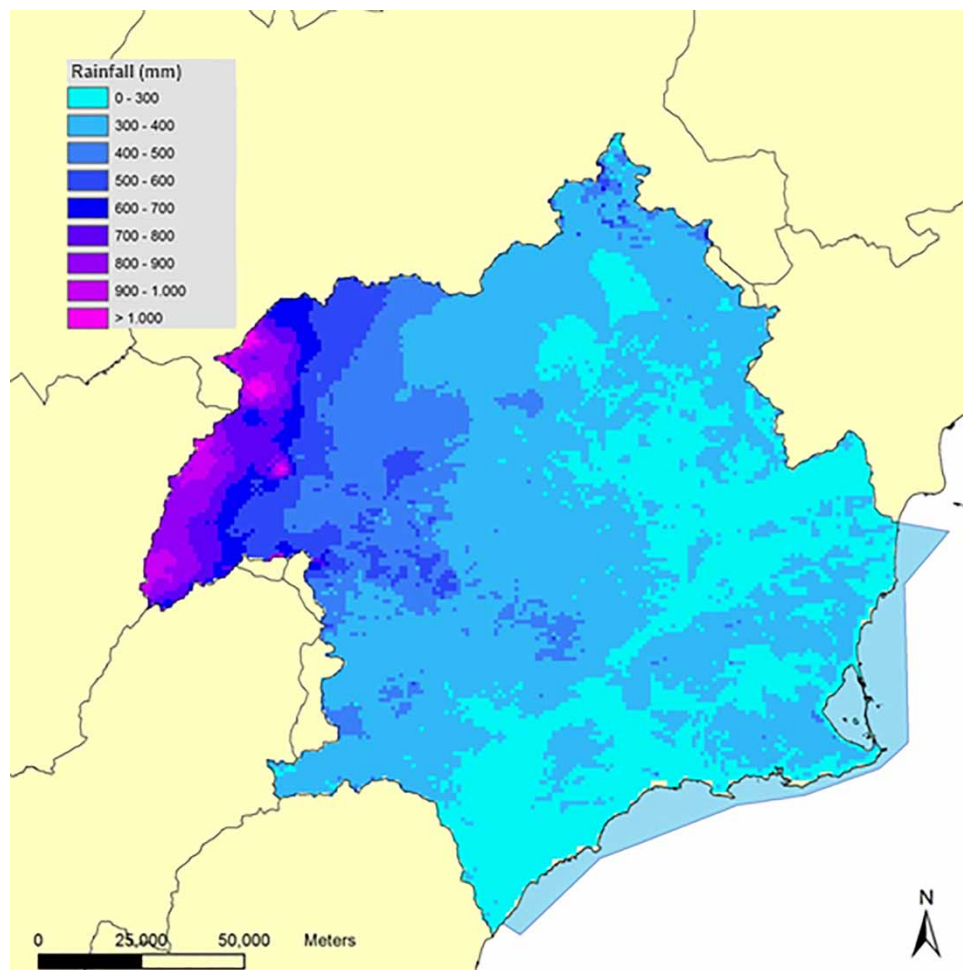
As a result, the region has made major efforts with respect to the reuse of reclaimed water. Its determined push towards the reuse of reclaimed water began with Law 3/2000 of 12 July on Sanitation and Wastewater Treatment in the Region of Murcia, which introduced a new management system for wastewater treatment and reuse. The region took on responsibility for the management, use and monitoring of wastewater, and created the Sanitation and Wastewater Treatment Agency for the Region of Murcia (known by its initials in Spanish as ESAMUR). The General Sanitation and Wastewater Treatment Plan

(PGSD in Spanish), which was approved for the entire region, detailed the works to be carried out, basic design criteria, and the quality targets in each case. A new tax, the 'sanitation fee' was created: managed and administered by ESAMUR, it is intended principally as a way of covering the costs of operating and maintaining the sanitation and treatment facilities in the region, as well as the costs of refurbishing WWTPs or small plants in more remote towns and villages (Navarro 2012).

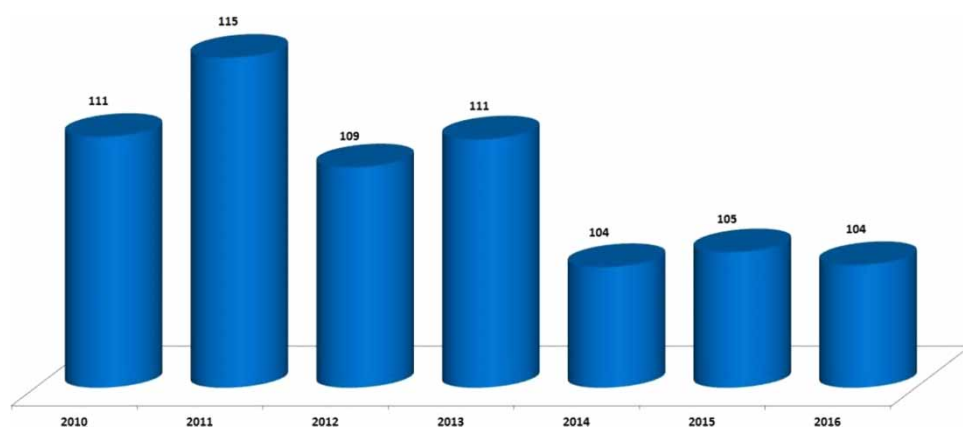
### The general sanitation and wastewater treatment plan

The PGSD laid out three objectives. The first aim was to comply with Directive 91/271/EEC, which required certain levels of wastewater treatment to be set and stipulated that, by 2005, all towns with more than 2,000 inhabitants had to subject wastewater to secondary treatment. Second, in response to the structural water deficit in the Segura River Basin, which includes the Region of Murcia, the PGSD sought to make more water available through the reuse of reclaimed water. This meant developing further supplementary treatment, cleaning the wastewater not only to secondary standards, but also implementing tertiary treatments to guarantee optimum conditions for reusing reclaimed water according to its intended use. Third, the plan had an important environmental objective: to protect and restore the regional water environment, particularly with respect to the Segura River, and its extremely degraded streams, aquifers and wetlands. To that end, new high-performance WWTPs were built in the towns and cities along the course of the river (Calasparra, Cieza, Abarán, Blanca, Archena, Ceutí, Lorquí, Las Torres de Cotillas, Molina, Murcia, Santomera and Beniel). The water produced by some of those plants is directly allocated to irrigation, while water from the others represents an important base flow to the Segura River, helping to maintain its good ecological status.

The PGSD created a comprehensive system of infrastructure and management measures to plan and coordinate all the actions relating to sanitation and wastewater treatment in the Region of Murcia. These actions are reinforced by other essential measures, such as monitoring wastewater discharges to the sewer system, source control in the industrial sector, the design of a collection

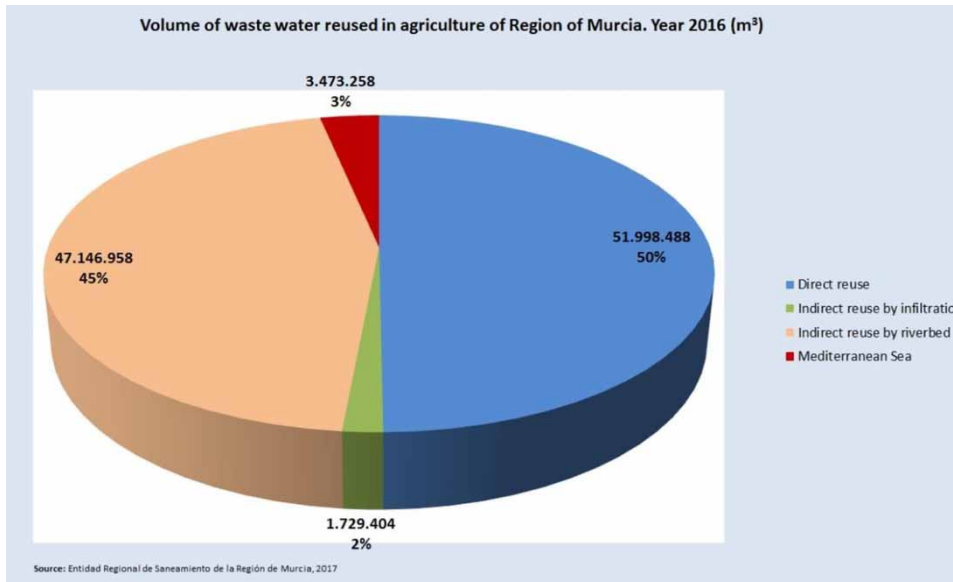


**Figure 4** | Spatial distribution of average yearly rainfall (mm/y) in the SRBD (1980/81–2011/12). *Source:* SRBD, Ministry of Agriculture and Fisheries, Food and Environment.



**Figure 5** | Recorded volumes of treated wastewater in the Region of Murcia (hm³/y). *Source:* ESAMUR (2017).





**Figure 6** | Volumes of water from WWTPs used for irrigation in the Region of Murcia in 2016 (m<sup>3</sup>). Source: ESAMUR (2017).

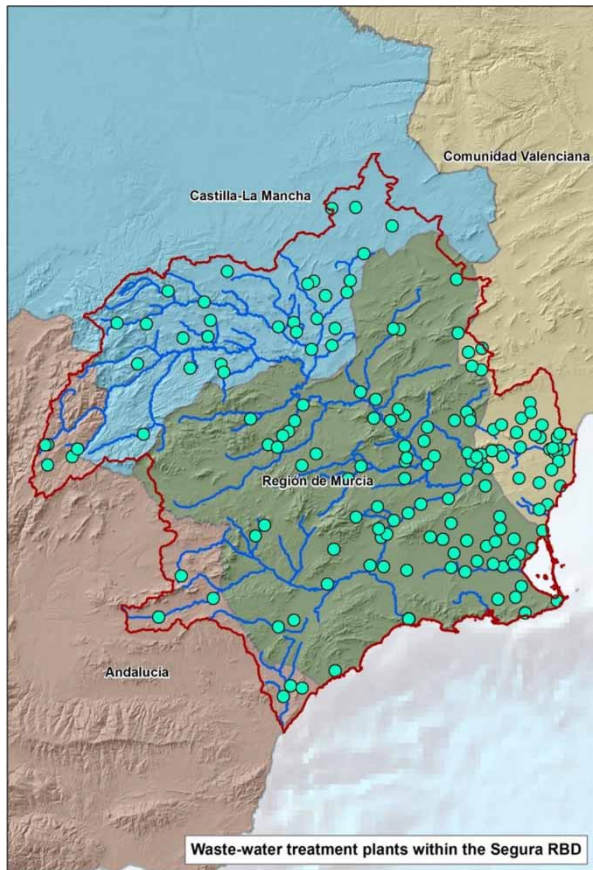
and conveyance system for wastewater from population centres, and the construction of rainwater drainage infrastructure such as stormwater tanks. The Region of Murcia currently has 93 WWTPs, most of which provide advanced tertiary treatment, and which serve more than 99% of the population. Virtually all of the resulting treated water is reused, either directly, or more often indirectly. It is treated to a very high standard, removing around 99% of BOD<sub>5</sub>, well above the level required by Directive 91/271. This is especially important bearing in mind that, in 2011, the Court of Justice of the European Union sanctioned Spain for non-compliance with Directive 91/217/EC, as 38 urban centres with more than 15,000 inhabitants failed to fulfil their obligations regarding the collection and treatment of wastewater (Judgment of the Court of 14 April 2011, Case C343-2010) (Figures 7 and 8).

The PGSD has also had notable environmental effects: (1) it has combined wastewater reclamation with the conservation of endangered aquatic species; and (2) it has led to the creation of a number of constructed wetlands, which have been declared Ramsar sites. The conservation of biological diversity in constructed wetlands helps create ecosystems that attract a multitude of wetland species, restoring populations of the native avifauna. Thus, a number of WWTPs were built on old lagoon treatment

facilities, and the reclaimed water was subjected to more rigorous treatment before being used to fill the old lagoons. These old treatment plants filled with reclaimed water have become a lure for highly endangered species, with waterfowl such as the white-headed duck (*Oxyura leucocephala*) and the marbled teal (*Marmaronetta angustirostris*) settling there, as well as other species considered a high conservation priority, such as the ferruginous duck (*Aythya nyroca*) and the western swamphen (*Porphyrio porphyrio*). Such activity has been recorded in the Campotéjar and the Moreras lagoons, which are both listed under the Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat, as well as the Alhama de Murcia treatment facilities.

As such, when modern WWTPs discharge their effluent into the former lagoon treatment plants, it makes the agricultural use of reclaimed water compatible with the conservation of biodiversity. In these old lagoons, a strip of vegetation bordering the water develops (reeds, bulrushes, tamarisk), converting these artificial pools into naturalized lagoons. This system fulfils an economic and social function, since the old facilities become reservoirs for treated water that will later be used for agricultural irrigation. At the same time, they serve a biodiversity-conservation function, as the pools provide a home to a wide range of wetland





**Figure 8** | Wastewater treatment plants within the SRBD. Source: SRBD, Ministry of Agriculture and Fisheries, Food and Environment.

Construction work was carried out on 15 desalination plants: Águilas, Marbella, Mutxamel/Campello, Torrevieja, Moncófar, Oropesa, Sagunto, Bajo Almanzora, Vega Baja, Denia, Adra, Western Costa del Sol and Níjar, including expansion works at Jávea and Mojón. The official budget for this work was set at €721 million (Navarro 2013).

At the time, desalination was considered an extremely promising option, if production costs could be brought down.

### The high cost of desalination: a pending issue

It soon became clear that desalination would have to overcome certain difficulties in order to become a viable alternative. Physical limitations and high prices suggested that only a few specific uses of desalinated water would be cost-effective: urban water supply or the most economically

competitive agricultural production (Embido 1998). These concerns have proved to be well founded.

Today, the cost of desalination in Spain remains a major obstacle to achieving its full potential. Moreover, this cost has increased in the last few years due to the liberalization of the Spanish energy sector. Although the development of state-of-the-art membranes can help cut energy consumption in desalination systems, it seems that improving the process is not enough, in and of itself. Other options should also be considered, such as cogeneration and grouping desalination plants together with energy and/or WWTPs. Such measures can reduce costs by up to 10% (Ibáñez & Valerdi 2009).

It is difficult to provide current figures on the total cost of desalination in Spain. The most recent official data available come from the Secretary of State for the Environment, provided in the Senate Committee on Environment and Climate Change on 4 March 2013, which set Spain's investment in 51 planned desalination plants at €1.83 billion. At that time, it was judged that a further €711 million would be needed to complete the desalination plant programme, which, on top of the investment already made, would bring the total investment to €2.54 billion.

In the Segura River Basin, reductions in the price of desalinated water have been made on an exceptional basis for irrigators in the Region of Murcia, and these are protected under special agreements. In 2015, in the midst of the drought declared by Royal Decree 356/2015 of 8 May, €8 million was allocated to subsidize 50 hm<sup>3</sup> from the Torrevieja desalination plant. The final price of this desalinated water for the farmer was 0.30 €/m<sup>3</sup>. To date, this precarious situation has not improved and so Royal Decree 335/2016 of 23 September extends the drought declaration in the Segura River Basin. Meanwhile, irrigators are calling for a new agreement to establish social pricing for desalinated water, which would involve further subsidies for agricultural irrigation water.

### Desalinated water, public water, private water

In Spain, desalinated water has been considered either public water or private water, depending on the legislative programme of the government of the day (González-Antón

2000). Desalination was first regulated by Royal Decree 1327/1995 on seawater desalination facilities. At that time, desalinated water was deemed public water, as it was considered part of the public water resources; that is, once it had been produced, desalinated water was introduced into the water cycle along with inland water and renewable groundwater resources. However, during the sixth parliamentary term (1996–2000), the conservative government of the Popular Party undertook a major reform of the water legislation through Law 46/999 of 13 December. This reform was enacted within a framework of liberalization that sought to foster private provision of desalination, and so desalinated water was considered private property while it remained in the desalination plant. At that time, desalination was not restricted and could be carried out by anyone who so chose. If the owner of the desalination plant was a private individual, the desalinated water was also privately owned and, until it became part of the public water resources, it was not subject to the water legislation in force. Moreover, since this water was private property, it could be sold.

That legislative regime remained in force until the eighth parliamentary term (2004–2008), when the new government of the Spanish Socialist Workers' Party made the water public once again. Law 11/2005 set out that water produced by desalination forms part of the public water resources and, as such, is permanently subject to public water legislation.

All this draws attention to a number of issues: first of all, the political significance of desalination, since each government in turn has modified regulations to bring them in line with its political ideology. Second, it highlights the legal practicalities of deciding whether, under the law, desalinated water is a public good or private property. This will depend on whether the current law regulating desalination is based on a more liberal or more interventionist political ideology (Jiménez 2009).

### Legal framework

The laws governing desalination are set out in Article 13 of the Consolidated Text of the Water Act (TRLA in Spanish), approved by Royal Legislative Decree 1/2001 of 20 July. Desalination operations require a concession since they

involve the private use (excluding third parties) of public water resources. Other authorizations and concessions are also required under coastal legislation and other laws (for example, permits are required to occupy part of the public shoreline, to discharge brine, to convey water to its destination, carry out construction work, etc.).

Spanish legislation allows both public desalination operations (TRLA Article 13.2) and private initiatives (TRLA Article 13.5). The desalinated water produced by private parties can be used to supply residential developments, holiday resorts that lack sufficient resources, and even for irrigation. The public administration can develop desalination operations, building infrastructure through public works that can be declared to be in the general interest of the State. These public works can be run directly by the Ministry, by regional water authorities or by commercial companies set up for this purpose (e.g. Acuamed). Irrigation communities can also be direct beneficiaries of the works and facilities in their area; they can be granted the concession for desalinated water directly, without having to compete with other potential users for the rights.

### Desalination in the Segura River Basin

The SRBD suffers from a structural deficit. The available resources do not enable the achievement of good water status (one of the basic objectives of the WFD), nor do they meet the demands of its users. As a result, water has to be transferred from other basins, which makes the SRBD unique among Spanish river basin districts.

A central tenet of river basin planning in the Segura River Basin has always been that, in order to accomplish environmental goals relating to groundwater bodies, the over-exploitation of groundwater resources must be halted by replacing them with new, external resources. To that end, the Segura River Basin District Water Plan (SRBDWP) 2015–2021, approved by Royal Decree 1/2016 of 8 January (Official State Gazette, 19 January 2016), proposes measures aimed at modernizing irrigation, reusing treated wastewater, desalination and replacing non-renewable groundwater resources with new external resources (Table 3, Figure 9).

According to the above-mentioned SRBDWP 2015–2021, the maximum desalination capacity forecasted for the SRBD is 332 hm<sup>3</sup>/y for the 2015 horizon and



**Table 3** | Non-conventional water resources in the Segura River basin ( $\text{hm}^3/\text{y}$ ). Source: SRBD, Ministry of Agriculture and Fisheries, Food and Environment

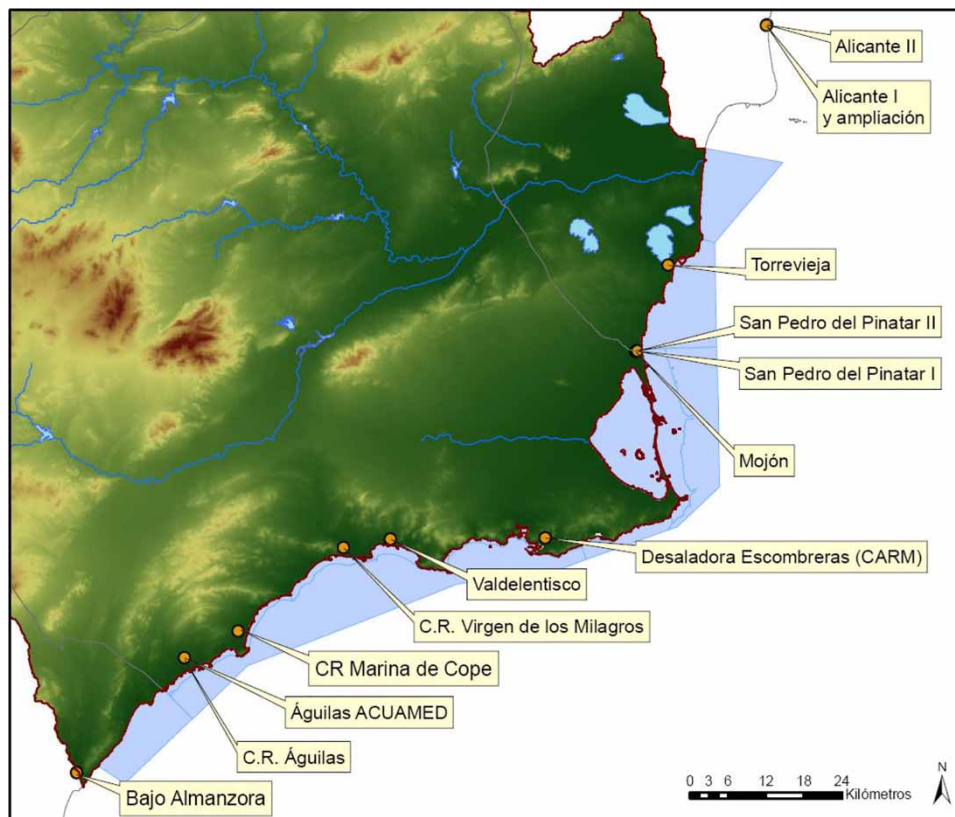
Water resource	SRBDHP 2009/ 15 Horizon 2015	SRBDHP 2015/ 21 Horizon 2015	Difference (%)
Seawater desalination	139	158	14
Direct/Indirect treated urban wastewater reclamation	144	144	0

$339 \text{ hm}^3/\text{y}$  for the horizons 2021, 2027 and 2033. The expected production from a total of 13 desalination plants is  $158 \text{ hm}^3/\text{y}$  for the 2015 scenario ( $96 \text{ hm}^3/\text{y}$  for agricultural use and  $62 \text{ hm}^3/\text{y}$  for urban use),  $193 \text{ hm}^3/\text{y}$  for the 2021 scenario ( $126 \text{ hm}^3/\text{y}$  for agricultural use and  $67 \text{ hm}^3/\text{y}$  for urban use) and  $209 \text{ hm}^3/\text{y}$  for the 2027 scenario ( $126 \text{ hm}^3/\text{y}$  for agricultural use and  $98 \text{ hm}^3/\text{y}$  for urban and other uses) (SRBDWP Report 2015–2021). These data are reported in Table 4.

## CONCLUSIONS

The current shortage and uneven distribution of water resources is a global problem. Even in areas where rainfall or freshwater resources are abundant, shortages can occur, which are exacerbated by population growth and the rising water demand in agriculture, industry and households. Moreover, drought and scarcity have been endemic problems in certain countries in southern Europe, such as Spain, which has long sought to tackle these extreme hydrological situations and has a mature and well-developed legal framework for doing so.

The global nature of water scarcity challenges cannot be addressed in isolation from the similarly pressing problem of climate change, as the two are directly connected. Several studies have shown that the incidence of droughts in Europe has increased by 20% since 1976, and although the frequency of torrential rainfall will increase, average annual rainfall is set to decrease throughout Spain, with a



**Figure 9** | Seawater desalination plants recorded in the Segura River Basin District (2017) Planning process. Source: SRBD, Ministry of Agriculture and Fisheries, Food and Environment.



**Table 4** | Seawater and/or brackish water desalination plants recorded in the Segura River Basin District planning process, and their expected output per use and planning horizon. *Source:* SRBD, Ministry of Agriculture and Fisheries, Food and Environment

Water Desalination Plant	Location (ETRS89 H30)		Horizon 2015		Horizon 2021		Horizon 2027		Horizon 2033	
	X	Y	Irrigation (hm <sup>3</sup> )	Urban, industrial & services (hm <sup>3</sup> )	Irrigation (hm <sup>3</sup> )	Urban, industrial & services (hm <sup>3</sup> )	Irrigation (hm <sup>3</sup> )	Urban, industrial & services (hm <sup>3</sup> )	Irrigation (hm <sup>3</sup> )	Urban, industrial & services (hm <sup>3</sup> )
Alicante I	716,589	4,241,982		–58 urban MCT townships		–63 urban MCT townships		–79 urban MCT townships		–87 urban MCT townships
Alicante II	716,744	4,242,072								
San Pedro del Pinatar I	696,103	4,190,773		–2 industrial non connected		–2 industrial non connected		–2 industrial non connected		–2 industrial non connected
San Pedro del Pinatar II	696,196	4,190,777		–2 golf		–2 golf		–2 golf		–11 golf
Valdelentisco	657,210	4,161,124	27		37		37		37	
Águilas ACUAMED	624,617	4,142,482	34		48		48		48	
Escombreras (CARM)	681,629	4,161,292	7		7		7		7	
Torre vieja	701,374	4,204,425	5		11		11		11	
El Mojón	695,981	4,190,695	2		2		2		2	
CR Virgen de los Milagros	649,764	4,159,822	10		10		10		10	
CR Marina de Cope	633,119	4,146,662	2		2		2		2	
CR Águilas	624,617	4,142,183	2		2		2		2	
Bajo Almanzora	607,533	4,124,376	7		7		7		7	
<b>TOTALS</b>			<b>96</b>	<b>62</b>	<b>126</b>	<b>67</b>	<b>126</b>	<b>83</b>	<b>126</b>	<b>100</b>
			<b>158 hm<sup>3</sup></b>		<b>193</b>		<b>209 hm<sup>3</sup></b>		<b>226 hm<sup>3</sup></b>	

particular impact on the southern third of the Iberian Peninsula.

Faced with this scenario of increasing global scarcity and drought, industrial water production techniques such as desalination and reuse have started to play a more prominent role. This paper has shown the legal framework and current status of these techniques in Spain, a country which has come to be recognized as a key point of reference in this respect. This can help in the construction of a more general framework, like the European one, and shed light on other comparative legal experiences.

The fight against the scarcity of water resources in Spain has made the production of new alternative water resources a clear priority, turning the country into a leader in reclaimed water use and seawater desalination, especially in the southeast. The call to regulate this activity and make it sufficiently robust in all aspects (legal, public health, technological, etc.) led to the approval of pioneering state regulation in Spain. As a general rule, reusing reclaimed water requires a permit. However, if it is requested by the holder of a discharge permit, only a supplementary administrative authorization is required, which goes against the general regime for using public water resources in Spain.

On the other hand, Article 13 of TRLA sets out the Spanish legal regime governing desalination. It establishes that desalination is subject to the regime exclusively for public water resources, meaning that a concession is required, notwithstanding applicable authorizations and approvals in accordance with specific legislation.

In summary, it can be said that reuse and desalination have gained importance over recent years in countries that suffer from drought and water scarcity. In Spain, the most well-developed and widely implemented technique is the reuse of water, mainly for agricultural use, although urban and industrial uses have also reached significant levels. With regard to desalination, while there has been clear political support for it, its high production costs continue to be an issue, and users have demanded reduced rates for desalinated water.

In view of the finite nature of water and global increases in demand, an ongoing commitment to industrial water production on a worldwide level is crucial. Governments must continue to drive research, development and innovation programmes (R&D&I), thus boosting related technological progress, and resulting in the implementation of

programmes that will enable them to ‘do more with less’ in their territories, thereby promoting a rational and sustainable use of their water resources.

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