Water Resources Management (2019) 33:725–737
https://doi.org/10.1007/s11269-018-2136-9

Recycled Sewage - A Water Resource for Dry Regions of Southeastern Spain

Encarnación Gil-Meseguer [1] · Miguel Borja Bernabé-Crespo [1,2,3] · José María Gómez-Espín [1]

Received: 16 March 2018 / Accepted: 12 November 2018 /
Published online: 23 November 2018

Abstract
The latitude and layout of the Betic orography make southeastern Spain one of the driest climatic regions in Europe. Most of its territory is part of the Segura Hydrographic Demarcation (DHS). The DHS features a water resources vs water demands deficit equal to 480 hm^3/year (1 hm^3 = 100 m^3) during the 2009–2015 hydrologic planning period. A new paradigm for water policy in Spain has emerged for the hydrological planning period (2016–2021), which calls for a greater contribution of unconventional resources (desalination and reuse of municipal sewage). The investment made in the DHS, in terms of sewage purification and regeneration, produces about 110 hm^3/year of purified sewage annually. Irrigation is the main consumer of these reuse flows. Irrigation districts develop conveyance and storage infrastructure to import treated sewage from Sewage Treatment Plants (STPs) and Water Regeneration Stations (WRSs). Anthropogenically-caused climate change has brought additional stress on surface water and groundwater, thus making water recycling an important component of the water supply portofolio in Spanish arid regions. Recycled water increases the resources of semi-arid regions (up to 10% of total resources), like in the Southeast of Spain. It is of great social value as it contributes to water safety, economic dynamism and biodiversity. Investment made in this sector and public policies make possible the implementation of recycling system, turning this limited resource into a social, political and economic interest, reaching levels of 99.5% purified and 97% reused in Murcia. Similar regions could import this management system and the concessionary model of reclaimed water. In dry regions, these water management models make recycled water, rather than an alternative, a significant complement to local water resources.

Keywords Recycled water · Purification · Sewage reuse · Sewage · Segura hydrographic demarcation · Southeastern Spain

✉ Miguel Borja Bernabé-Crespo
miguelborja.bernabe@um.es

Extended author information available on the last page of the article

1 Introduction

The United Nations Sustainable Development Goals (SDGs) that replaced the Millennium Development Goals (MDGs) introduced new criteria to ensure the availability and the sustainable management of water and sanitation for humanity. In the area of sanitation the SDGs call for access to adequate service and reduction of the amount of discharged, non-treated, sewage, as well as for protection of aquatic ecosystems (United Nations, Economic Commission for Latin America and the Caribbean (ECLAC - Cooperation Network in the Comprehensive Management of Water Resources for Sustainable Development in Latin America and the Caribbean, Circular Letter No. 47. 17-00907) (UNITED NATIONS ECONOMIC COMMISION 2017).

The southeastern climatic region of the Iberian Peninsula corresponds to the territory between the Mediterranean coastline from Cape de la Nao to Cape Gata, with the inland limit marked by the isotherm of more than 16 °C of average annual temperature and an isohyet of less than 400 mm of annual rainfall. This climatic region corresponds to (the littoral and pre-coastal) regions of Murcia, Almeria and the southern half of Alicante with an approximate area of more than 20,000 km^2. A map of this work's study area is shown in Fig. 1. This work focuses on the region of Murcia, with an area of 11,313 km^2, of which 11,180 km^2 lie inside the Segura Hydrographic Confederation (CHS). The Segura Hydrographic Demarcation (DHS) features an area of 20,234 km^2 and extends into the pre-coastal and coastal zones of Alicante, Murcia and Almeria provinces.

The scarcity and irregularity of rainfall is a consequence of its leeward position relative to westerly circulation and Betic reliefs, which generates an orographic shelter and foehn effect

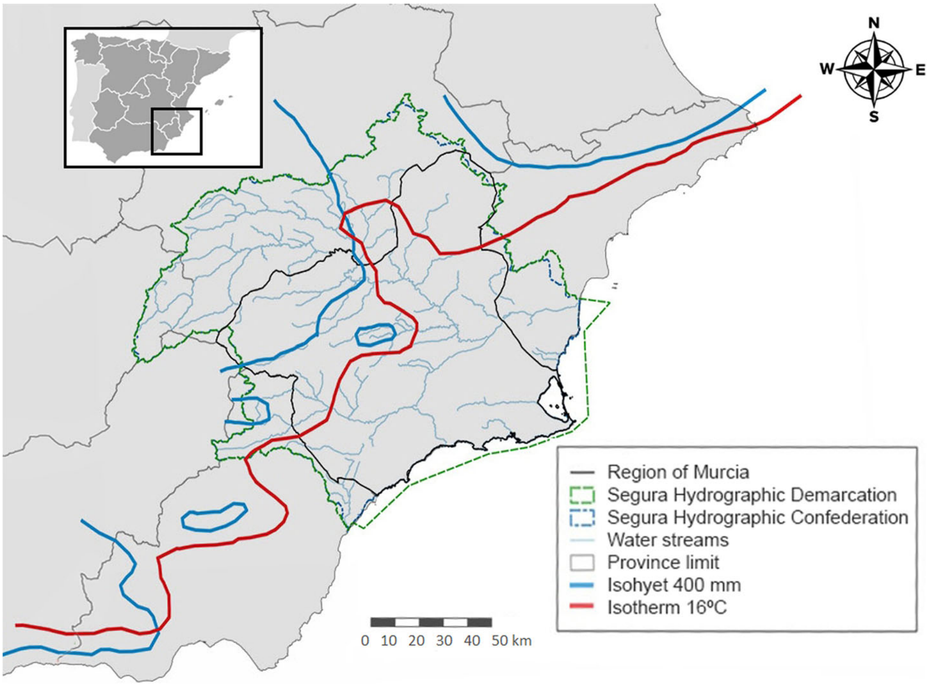

Fig. 1 Regions that constitute the focus of this study

(Gil 2014). The drylands southeast of this pluviometric barrier features subtropical subsidence during summer (Gil 2016).

The arid and semi-arid regions of southeastern Spain feature water scarcity, which has given rise to the development and deployment of unconventional technologies to augment water supply. Examples of these technologies are desalination of seawater and brackish groundwater, as well as purification of sewage for its subsequent reuse after regenerative treatments. These unconventional water sources are essential for regional development (as demonstrated in Ródenas and Albacete 2014). And furthermore, there is political gain with recycled water: in the first place, Water Framework Directive (with respect to quality) will ensure that is complied with, and secondly, it means significant volumes to increase their own resources in semi-arid environments.

Water demand exceds natural water supply in southeastern Spain. The General Draft of the Joint Use of The Hydraulic Resources of Central and Southeastern Spain Tajo-Segura Complex (1967) estimated the hydrological deficit of the Segura basin at 380 hm^3/year and 271 hm^3/year for the South basin. The hydrological planning for the Segura Hydrographic Demarcation (DHS) 2015–2021 estimated a deficit of 480 hm^3/year. Likewise Gómez (2017) estimated a water deficit in the Andalusian Mediterranean Basin (south and east of the Andalusia region), over 160 hm^3/year for the period 2015–2021.

Water scarcity is caused by low and irregular rainfall and high potential evapotranspiration in southeastern Spain. Groundwater withdrawal has alleviated the water deficit in this area. The practices of deficit irrigation, inter-basin water transfers and water-bank exchanges have been introduced to control the water deficit in this paper's study region. Desalination and new techniques for water reuse have also been resorted to. In this respect, Gleick (2010) and Loáiciga (2015), among others, have identified sewage reuse as one of the remedies to increase the water supply in the arid and semiarid regions of the southwestern United States, where water transfers, climatic variability, and environmental impacts pose serious challenges to water supply for human uses. The application of "unconventional" water sources such as desalination, sewage reuse, water banking, water transfers, and water conservation have proven effective in Spain, where the 1992–1996 drought heightened public awareness about the increasing pressures on scarce natural water resources (Rico et al. 1998). For comparison purposes, the City of Los Angeles (California) discharges 1.5 million cubic meters of treated sewage to the Pacific Ocean. This sewage represents a possible source of potable and municipal irrigation water following proper treatment for reuse (Leverenz et al. 2011).

This study presents a historical account of sewage purification applied in the water-deficit region of southeastern Spain, and recommends guidelines for the implementation of these processes to alleviate water scarcity in dry regions with structural water deficits. It presents the use of recycled water in a semi-arid region like the Southeast of Spain, where it becomes a limited but local resource, with enormous social, political and economic interest. It is a limited resource (in terms of volume of water) but it contributes to regional development. Its social value lies in easing water security and helping the development of agriculture and leisure spaces (golf courses) that stimulate the regional economy, including the contribution to biodiversity, through the creation of wetlands. Complying with the European Regulation of Water Quality and the management carried out politically and technically on the operation of the STP, significant volumes are recycled at no cost for subsequent users (costs are assumed by citizens through taxes).

2 Methodology

It is a study of Regional Geographical Analysis, diachronic, with qualitative research (panel of experts), within the paradigm of water resources supply for arid and semi-arid regions, where treated sewage can be a complement of extraordinary social and economic value. It is related to SDG, especially nr. 6, on water management: "Ensure availability and sustainable management of water and sanitation for all" (UN 2015).

The methodology followed consists of a bibliographic search to frame the background and status of recycled water at an international and regional level. Subsequently, meetings were held with experts in charge of the management of recycling and sanitation, with later visits to various pilot plants where different systems of purification (biological treatment, tertiary treatment with UV disinfection, chlorine) were carried out, both in Murcia and in California. Research work has consisted in the comparative analysis, elaboration of cartography and graphics, and writing of conclusions and proposals, with the aim of highlighting the value of this management model and spreading it to other arid and semi-arid regions.

The methodology used in this article outlines the role of interviews with experts in sewage treatment and managers of irrigation communities that make use of reclaimed water for irrigation. Questions were related to characteristics of the plant and the processes used, destination of the reclaimed water, infrastructures and investments made for its modernization. The methodology of "panel of experts", with open questions, allowed us to delve into the management models of purified water and the concession of reclaimed water. A comparative analysis has been carried out with the case of California: Orange County Water District's (OCWD) infrastructures were visited, where there is an intense debate between the IPR (Indirect Potable Reuse) and DPR (Direct Potable Reuse). OCWD is a worldwide pioneer in sewage treatment and recycling water. Miguel Borja Bernabé-Crespo, co-author of this article and visiting scholar at the University of California (Santa Barbara), visited OCWD to learn about techniques and their application in semi-arid environments with great demographic pressure, taking into account their significance for the urban supply of urban agglomerations. Quantitative, qualitative analysis and prognosis have been conducted about the future of this model of water resources exploitation in dry environments.

3 Sewage Treatment, Regeneration, and Reuse as a New Source to Meet Water Demand in Arid Regions

Sewage treatment and regeneration is well developed in many parts of the world (Trapote 2016). The largest consumer of reclaimed water is agriculture, although it is expected large coastal cities will become the predominant reusers of treated sewage for drinking water. IPR and DPR involve the coexistence of water supply and demand within a system of water use and reuse. IPR involves the blending of sewage with freshwater (lakes, rivers, aquifers) prior to reuse. A well-known example of IPR is the system operated by the OCWD located in southern California. A Groundwater Replenishment System (GWRS) provides 20% of the water that recharges the Orange County aquifer, which supplies two million citizens (Grant et al. 2012). DPR treats sewage to required standards for reuse without blending with freshwater. Among the advantages of DPR is the supply of populated areas where the water-supply and treatment infrastructure are linked in a feedback system (Leverenz et al. 2011). DPR is operational in places such as Windhoek (Namibia), Cloudcroft (New Mexico, USA), and Big Spring (Texas, USA). There is ongoing debate about the relative advantages and disadvantages of DRP vis a vis IPR (Scruggs and Thomson 2017). In the Spanish case, although water may be of a sufficient quality to be potable, this use is not considered. However, certain indirect reuse is studied in some areas (Cartagena-Mar Menor aquifer), i.e. injection in aquifers to prevent marine intrusion.

Traditionally the water system of the Segura basin in Spain has practiced indirect reuse of irrigation returns in the upper basin (Vega Alta), and the reuse of drainage in the middle and lower basin (Vega Media and Vega Baja, respectively) through small conveyances called *azarbes*. The irrigation and drainage effluents are mixed and diluted with the scarce flow of the Segura River and are employed for irrigation in downstream areas. This has been a traditional practice involving a river that only flows into the Mediterranean after large floods (Ródenas 2002). The integrated water resources management of water-deficit regions, the Segura basin among them, relies increasingly on the direct reuse of sewage and return flows to meet the water supply of arid regions. Several countries in the Middle East (e.g., Dubai and Israel) rely heavily on desalination and sewage reuse to overcome the challenges of water scarcity and climate change (Qadir et al. 2010; Rygaard et al. 2011; Sowers et al. 2011; McDonnell 2014). Water reuse meets many functions such as landscape watering, street washing, agriculture and forestry, fire fighting, cooling of thermal plants and industrial facilities, aquifer recharge, wetlands support, recreation and leisure (irrigation of golf courses, filling of recreational ponds, see, e.g., Mujeriego 1994).

The choice of the type of sewage treatment system depends on factors such as: land use, climatic conditions (such as cold and warm cycles), topography and soils, experience with purification technologies, and economic capacity. Accordingly, 'the selection of appropriate technologies for sewage treatment depends on the characteristics of the influent and effluent sewage, investment and maintenance costs, available technical capacity' (Rodríguez and De Caldas 2009).

Within the European Union, sewage treatment is regulated by Directive 91/271/EEC (D271), partially modified by Directive 98/15/EC, which contains stipulations regarding the collection, treatment, and disposal of urban sewage from industrial sources. Sixteen EU Member States employ sewage treatment more stringently than secondary treatment within their entire territories. The remaining 12 States, including Spain, apply secondary treatment throughout most of their territories, and a more stringent treatment in the "sensitive" areas (European Commission 2016).

The Spanish Law on Waters of 1985 started a policy of improving water quality by reducing pollution, within the framework of sustainable and efficient use of natural resources. Regarding the reuse of wastewater, this Law, in its Article 101, states "the Government will establish the basic conditions for the reuse of water according to the purification processes, its quality and the intended uses", in accordance with the Royal Decree (RD) 1620/2007, which is the reference standard in Spain. The Law of Water establishes the legal mechanisms that allow wastewater to be treated as an alternative resource, promoting plans for reuse and more efficient use of the resource (Trapote 2016). The RD of Reuse establishes six types of water quality (A, B, C, D, E and F) according to their bacteriological characteristics, since a key main determinant of sewage regeneration is the level of disinfection.

Large-scale sewage treatment and purification in Spain began with the National Plan of Sanitation and Treatment (1995–2005), whose main objective was to meet the Directive 91/271/CEE (BOE n°113, of May 12, 1995). The volume of treated wastewater rose from 0.13 m^3

per capita in 1996 to 0.31 m^3 per capita in 2006 (Melgarejo and Gómez 2016). In 2007, the Water Quality National Plan: sanitation and treatment (2007–2015) was approved, whose main objective was to achieve full compliance with Directive 91/271/EEC and the Water Framework Directive (60/2000/CE). These plans have been developed by the Spanish Ministry of the Environment, Water Sanitation and Treatment in collaboration with the Autonomous Communities of Spain, through entities like the Sanitation Authority of the Region of Murcia (ESAMUR), the Public Water Sanitation Organization of the Valencian Community (EPSAR), the Water Catalan Agency (ACA), Navarra Local Infrastructures SA (NILSA), the Canal of Isabel II in Madrid, and others. The result of such activity in water sanitation and treatment is that Spain complies with Directive 91/271/EEC in 84% of its territory, comparable to the compliance achieved by most of the EU countries.

4 Discussion of the Murcia Region's Experience with Sewage Reuse

This work's review of sewage purification and reuse in the Murcia region (Spain) was based on data obtained both from the Segura Basin Water Commissioner, on the concessions of reclaimed water from 2007 to 2016, and the Autonomous Community of the Region of Murcia, regarding the financing of infrastructures for irrigable areas supplied by the water reuse system (WRS). The authors communicated with technical personnel responsible for the maintenance of sewage treatment plants (STPs) operated by ESAMUR, EPSACV, and the Water Company of Murcia – EMUASA. Several STPs and WRSs were visited (Mazarrón, Puerto Lumbreras, Cabezo Beaza-Cartagena, Murcia East, Mar Menor, San Pedro del Pinatar and San Javier), where different treatment processes are implemented to meet various purposes of reclaimed (reused) water. Managers and users of reclaimed water concessions, such as the Irrigation Communities of Puerto Lumbreras and Arco Sur-Mar Menor, were interviewed.

More than 90 sewage treatment plants (STPs) managed by ESAMUR directly or in collaboration with other companies such as Aguas de Murcia-EMUASA treat more than 100 million m^3/year of sewage in the region of Murcia following the General Plan for Sanitation and Treatment of 2001 (Table 1). It has been a process of STP modernization, where in 10 years the treatment capacity has been increased and reused volumes reach a constant percentage higher than 90% of the treated sewage. Sewage treatment has restored water quality in the Segura River -considered a few years ago one of the most polluted rivers in Europe- and is used for aquatic sports and recreation as it runs through the city of Murcia (McCann 2012).

The STPs in the Murcia region have treatment capacities varying from more than 35 hm^3/year in Murcia East, to the smallest ones installed in rural areas with less than 0.5 hm^3/year (see Fig. 2). Besides Murcia East, other large STPs are Mar Menor South, Cabezo Beaza (Cartagena), Campo Téjar (Molina de Segura), Lorca, El Raal (Murcia) and Mazarrón. Most experts indicated that the process depended on the characteristics of sewage, where seasonality of tourism plays an important role.

Murcia East STP has a daily treatment capacity equal to 100,000 m^3/day and serves a population of 350,000 inhabitants. This STP and others in the region of Murcia employ several unit treatment processes as the sewage moves through the STP. Those processes include filtration, de-sanding, degreasing, primary clarifying, biological treatment (A_2O, a variant of the conventional treatment called 'activated sludge'), secondary clarifying, and chlorination.

Table 1 History of sewage treatment in the Murcia region

Year	No. of STPs	Treatment capacity m³/day	Treated volume m³/year	Reused volume m³/year	% reused
2003	71	418,547	96,151,823	90,911,128	94.5
2004	77	441,452	106,061,244	98,150,572	92.5
2005	80	441,452	105,722,706	98,656,082	93.3
2006	80	451,552	100,737,687	94,952,187	94.3
2007	83	505,707	102,507,727	95,011,548	92.7
2008	89	503,676	99,590,833	89,864,111	90.2
2009	96	511,694	102,133,776	92,038,185	90.1
2010	97	522,319	110,981,421	104,646,345	94.3
2011	91	521,459	115,081,983	107,019,568	93.0
2012	88	534,490	109,406,674	100,677,776	92.0
2013	90	549,961	110,855,235	102,090,687	92.1
2014	90	551,451	104,267,024	95,929,455	92.0
2015	93	549,984	105,010,205	99,618,953	94.9
2016	91	549,511	101,146,035	92,754,600	91.7

Source: ESAMUR

The treated sewage is discharged to the Segura River to increase its ecological flow. Primary sludge is produced by sewage treatment in the primary clarifier; biogas and biomass resulting from it are used for composting and the energy can be used locally, in this case, to power vehicles of the City of Murcia. This means an added value to the implementation of the purification.

Not all treated sewage is reused in the Segura Hydrographic Demarcation (DHS), where about 110 hm³/year are reused (68.75%) of each 160 hm³/year of purified sewage are reused. Most of treated (reclaimed) sewage in the Segura basin is destined for agricultural use (89.37%), followed by recreational use (9.74%), such as the irrigation of golf courses (see Table 2), which suggests a significant presence of recycled water as a water resource for irrigation (in a region whose economy relies, in large measure, on the agricultural sector and is cataloged as the "Europe's vegetable garden").

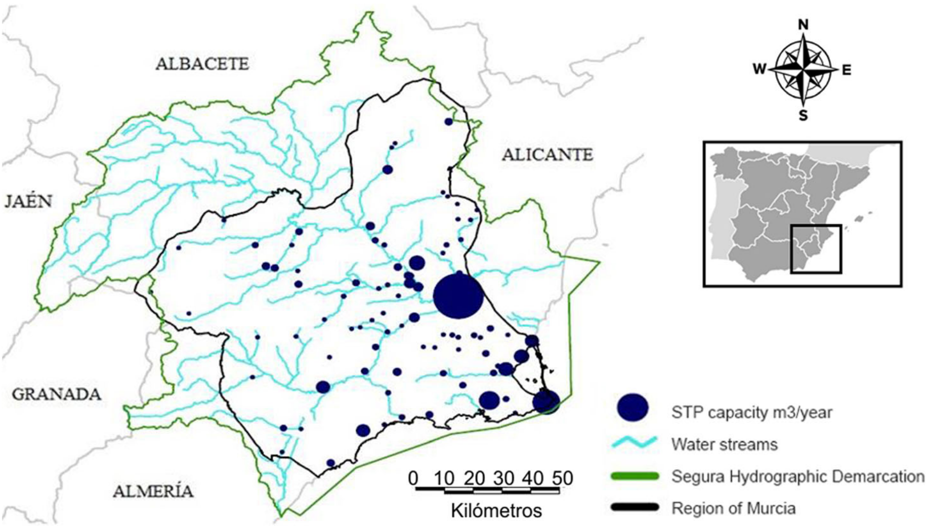

Fig. 2 Map of STPS in the Murcia region (June 2017)

Table 2 Volumes of reclaimed water in the Segura Basin according to concessions and uses

Use of reclaimed water	m^3/year	%
Agriculture	89,288,568	89.366
Recreational (golf)	9,728,912	9.737
Parks	890,975	0.892
Ecologic	4059	0.004
Industrial	760	0.001
Total	99,913,274	100

Source: Data from 2007 to 2016 concessions of the Water Commissioner of the Segura Basin (Confederación Hidrográfica del Segura, CHS)

The Autonomous Community of the Region of Murcia gave a series of grants directly from public funds to communities of irrigators in the period 2008–2016 to convey reclaimed sewage from the WRS to their irrigable fields. The grants were paid for pipes and reservoirs to store the reclaimed sewage. These investments help to optimize this unconventional resource to be easily integrated into the Murcian economy. A list of these grants, amount and concession of reclaimed water can be seen in Table 3, with a total amount of € 10,605,295 in 8 years. In addition to this direct investment, there is a "purification canon": a tax included in the bill of domestic users to maintain all STPs. These costs that are not borne by farmers, who obtain the concession of these flows for free.

Waters are public property in Spain, but they are operated under a concession regime. Thus, sewage generated by a municipality must be treated at the municipal level or through a concert with a supramunicipal company (case of ESAMUR in Murcia). It is the basin organism (CHS)

Table 3 Grants to convey reclaimed sewage to irrigation fields in the region of Murcia

Beneficiary	Year	STP	Concession (m^3/year)	Approved aid (€)
S.A.T. "Los Rodeos-Mula"	2008	Ceutí & Lorquí	2,077,065	655,477.90
C.R. "Puerto Lumbreras"	2008	Puerto Lumbreras	1,675,000	447,415.08
C.R. "Campo de Cartagena"	2008	Fuente Álamo & Torre Pacheco	2,504,000	464,827.92
C.R. "Heredamiento de Aguas de la Puebla de Mula"	2008	Mula	400,000	59,130.88
C.R. "Campo Alto"	2008	La Paca (Lorca)	60,155	179,022.20
C.R. "Pozo de Santiago"	2009	Yecla	800,000	284,273.49
C. R. "Arco Sur-Mar Menor"	2010	Mar Menor-Sur	4,864,120	1,229,827.30
C.R. "Costera Norte-Sierra de Carrascoy"	2010	Alhama de Murcia	297,906	85,663.79
C.R. "Hoya Mollidar-El Portichuelo"	2011	Yecla	1,200,000	718,447,10
C.R. "Lorca"	2011	Lorca	2,000,000	488,950.00
C.R. "Miraflores"	2011	Jumilla	1,500,000	2,868,985.00
C. R. Campo de Cartagena	2012	Los Alcázares	2,611,141	1,665,000.00
Heredamiento de Aguas de Alguazas	2016	Alguazas	1,259,618	269,556.00
Zona V Sectores I y II de Ceutí	2016	Torres de Cotillas	1,432,900	1,126,071.00
C. R. TT Segura Sangonera la Seca	2016	Alcantarilla	1,755,250	62,648.00
Total	2008–2016	Multiple	24,437,155	10,605,295.66

Source: Own elaboration based on data from the Office of Agriculture and Water of the Autonomous Community of the Region of Murcia that indicates the concession of recycled water in each STP. Different uses are given to reclaimed sewage in the region of Murcia. Table 4 shows the water recycled in the STPs managed by the municipal company Aguas de Murcia-EMUASA (95,224 m^3/year were destined for agricultural use; 307,981 m^3/year for leisure and sports; and 12,536,413 m^3/year, most of it, to an environmental use). The rest corresponds to discharges of recycled water into the public domain, pending concession for reuse.

The contribution of reclaimed water to the annual water consumption of irrigation districts such as the Irrigation Community (IC) of Puerto Lumbreras (Table 5) amounts to 25.35% of the water consumption, whereas reclaimed water contributes to almost 100% in the IC of Arco Sur-Mar Menor (Table 6). The concession of 540,000 m^3/year from the Puerto Lumbreras STP exceeds the water from springs and rainwater collection. The IC Arco Sur-Mar Menor has a concession of treated sewage from the STP Mar Menor Sur since 2008, that is further purified in its desalination plant (reverse osmosis and ultrafiltration processes) for irrigation application. Other waters with high nitrates concentration are collected in draining galleries before reaching the Mar Menor (a coastal lagoon) and purified at the desalination plant for the purpose of irrigation use. The STP and the desalination plants share an underwater outfall to discharge purified unused water and brine to the Mediterranean Sea.

Table 6 lists the volume of sewage treated at the Mar Menor Sur STP and the volume of the reclaimed water applied by the IC Arco Sur-Mar Menor. It is evident that the volumes of treated sewage and reclaimed sewage reused for irrigation have increased steadily over time. Success in the use for irrigation was found in the possibility of mixing reclaimed water with other types of water, in order to enhance the mineralization before its use.

As mentioned earlier, in Spain the debate on the IPR and DPR has barely been opened. So far, most of the Spanish Autonomous Communities have made a commitment to IPR, especially considering its application to irrigation. The new hydrological planning 2021–2027 contains a proposal from EU related to the quality of purified water, with the aim of

Table 4 Treated volume and reuse sewage produced in STPs of the municipality of Murcia, managed by EMUASA

STP	Treated sewage (m^3/year)
Murcia-Este	35,730,300
La Murta	26,526
Baños y Mendigo	18,420
Los Cañares	25,761
El Valle	48,948
Nueva Corvera	113,945
Los Martínez del Puerto	30,512
Casas Blancas	7956
Cabezo de la Plata	9068
Mosa Trajectum	40,873
El Escobar	38,662
Hacienda Riquelme	101,379
Barqueros	38,336
El Raal	3,603,838
Sucina 2	118,992
Total annual	39,953,516

Source: EMUASA

Table 5 Origin of the water used for irrigation (m3) in the IC of Puerto Lumbreras (Region of Murcia)

Origin & years	Stormwater	Wells in Alto Guadalentin aquifer	STP Puerto Lumbreras	Desalination (Águilas-Guadalentín) desalination plant & others)	Other springs	Total annual
2012	80,000	1,150,000	540,000	0	300,000	2,070,000
2013	8000	1,115,000	540,000	0	50,000	1,713,000
2014	6000	950,000	540,000	0	30,000	1,526,000
2015	20,000	740,000	540,000	0	20,000	1,320,000
2016	25,000	740,000	540,000	2,700,000	15,000	4,020,000
Total	139,000	4,695,000	2,700,000	2,700,000	415,000	10,649,000

Source: Data from IC Puerto Lumbreras (Region of Murcia)

DPR (Aldaya et al. 2017:24). Murcia holds a high level of recycling water to cope with situations of drought. Efforts are being made to get society's approval also for DPR, social and cultural management. Material improvements, infrastructure of good quality and efficient processes show this region as one of the most prepared regarding this issue.

5 Conclusions

It is vital to develop sewage management systems capable of recycling or reusing sewage to augment water sources in arid regions, while avoiding adverse environmental impacts. The development and application of such reclaim and reuse systems are justified under the following conditions:

- There is water scarcity that combined with economic activities exert high stress on existing water resources (this motivates economic investment in depuration and reuse).
- There is high demand for water supply to support growth driven by tourism, industry, municipal expansion, and agriculture (since it is very low population, it is not profitable).
- High technological development and economic, political, and social means promote research and innovation, and thus, obtain quality water for human consumption.

Table 6 Volume of sewage treated at the Mar Menor Sur STP, and volume of reclaimed sewage applied by the IC Arco Sur-Mar Menor

Year	STP "Mar Menor Sur"		
	Treated	Discharged to sea	Reuse for irrigation by IC
2008	3,521,089	1414.221	2,106,868
2009	3,661,534	1464.776	2,196,758
2010	3,792,200	1730.994	2,061,206
2011	3,587,387	889,033	2,698,354
2012	3,389,103	792,550	2,596,553
2013	3,484,442	347,328	3,137,114
2014	3,480,651	81,080	3,399,571
2015	3,460,081	150,600	3,309,481
2016	3,588,609	81,487	3,507,122

Source: Mar Menor Sur STP

These conditions are met by the regions cited in this article and have propelled the treatment and regeneration of urban waters for reuse in the Murcia region and other regions in the southeastern Iberian Peninsula. They also explain the rapid growth of sewage reuse in central and southern California (where water transfers are under discussion), and several Middle Eastern countries (UAE has no rivers) herein cited. The current and future trend of growing cities (moving from rural areas) forces a greater regulation and a new management of resources.

Grant et al. (2012) propose "substitution", i.e., treated sewage be dedicated to uses such as agriculture or industry, rather than being reused after regeneration sewage for human consumption, the so-called Direct Potable Reuse (DPR). The reason for this is the resistance by many to dedicate regenerated sewage as a source of potable water (Grant et al. 2012:685). In actuality, however, DPR is already occurring in some parts of the world.

The southeastern region of Spain accomplished this substitution by regenerating annually 92.7% of the total sewage in the period 2003–2016, of which 89.4% is destined for agricultural use. In contrast, other regions with similar aridity characteristics, such as Jordan, where treated sewage accounts for 12% of the water for irrigation, 30% in Tunisia, and reached 36% in Israel during the 2007–2008 drought (Sowers et al. 2011). With the data shown in this article, the deficit of 480 hm^3/year in DHS, if not for the volume of water recycled would rise to almost 600 hm^3/year, as Murcia provides 100. Due to the structural deficit, every resource is welcome. Recycled water is not an alternative to desalination, but a complement. Costs are lower but it is a limited resource as it depends on domestic consumption.

Innovation in research and development and political will through grants and concessions have proven effective in combating water scarcity in the Murcian region, where sewage reuse has allowed the development of agriculture, leisure and recreational activities, street washing, and firefighting, usually in combination with other sources of water. Its social value contributes to water safety of dry regions, and in the case of Murcia (and the Southeast of Spain), to the development of agriculture and leisure spaces (golf courses) that are important drivers of the regional economy. Its value is also ecological through the creation of wetlands.

Recycled water is considered a model of resources' offer. It may seem a policy of remedy, but in reality, it has a preventive nature, which is to alleviate the structural deficit with a quasi-permanent and limited resource. Research and findings are expected regarding the improvement of the purification systems and reduction of costs, but the volume of recycled water will scarcely increase in the Southeast of Spain, as it reaches an almost full reuse. It could be increased in other Mediterranean regions of the south and center of Spain.

Other arid and semi-arid regions of the world can learn from the successful experience of water recycling models of OCWD, developing a campaign of reliable awareness to achieve water security; and from Southeast of Spain the management model, rather than the techniques and processes used. This model is managed by the basin organization. The supraprovincial territorial organization, taking the hydrographic basin as a reference, shows greater success in the management of water resources, despite the fact that it overlaps with other administrative limits. The inclusion of a specific tax (purification canon) in domestic users' water receipt allows to maintain and invest in all STPs and keep them functional, recycling water and turning it into a finite but local resource needed to alleviate the structural deficit and to deal with water shortages.

Acknowledgments Dr. Hugo A. Loáiciga of the University of California at Santa Barbara provided valuable recommendations for the writing of this work.

Compliance with Ethical Standards

Conflict of Interest None.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

References

Aldaya MM, Custodio E, García J, Fernández MF, Llamas MR (2017) Análisis académico del Plan Hidrológico de la Demarcación Hidrográfica del Segura 2015-2021 a la luz de modernos conceptos de la ciencia de los recursos del agua. Fundación Botín. 82 p

EUROPEAN COMISSION (2016) [November 30, 2017] http://ec.europa.eu/environment/water/water-urbanwaste/implementation/factsfigures_en.html

Gil E (2014) El Sureste peninsular. Rasgos de un medio semiárido como el de Pulpí y su entorno. In: El dinamismo del regadío de Pulpí. Comunidad de Regantes de Pulpí, Murcia

Gil A (2016) Acondicionamiento, rectificación y regulación del Segura. Publicaciones de la Universidad de Alicante, Alicante

Gleick P (2010) Roadmap for sustainable water resources in southwestern North America. Proc Natl Acad Sci (PNAS) 107(50):21300–21305

Gómez JM (Coord.) (2017) El Trasvase Tajo-Segura. Propuestas para su continuidad y futuro. Editorial Académica Española, Saarbrucken

Grant SB, Saphores JD, Feldman DL, Hamilton AJ, Fletcher TD, Cook PLM, Stewardson M, Sanders BF, Levin LA, Ambrose RF, Deletic A, Brown R, Jiang SC, Rosso D, Cooper WJ, Marusic I (2012) Taking the "waste" out of "wastewater" for human water security and ecosystem sustainability. Science 337:681–686

Leverenz HL, Tchobanoglous G, Asano T (2011) Direct potable reuse: a future imperative. Journal of Water Reuse and Desalination 01(1):2–10

Loáiciga HA (2015) Managing municipal water supply and use in water-starved regions: looking ahead. J Water Resour Plan Manag 141(1):01814003/1–01814003/4

McCann B (2012) Wastewater reuse brings life back to Spain's Segura river. Water 21:28–33

McDonnell RA (2014) Circulations and transformations of energy and water in Abu Dhabi's hydrosocial cycle. Geoforum 57:225–233

Melgarejo J, Gómez I (2016) Depuración y reutilización de aguas en España. Agua y Territorio 8:22–35

Mujeriego R (1994) La reutilización planificada del agua: elemento básico de la gestión de los recursos hidráulicos. In: Recursos hidrogeológicos y recursos hidráulicos no convencionales. Ministerio de Obras Públicas, Transporte y Medio Ambiente, Madrid

Qadir M, Wichelns D, Raschid-Sally L, McCornick PG, Drechsel P, Bahri A, Minhas PS (2010) The challenges of wastewater irrigation in developing countries. Agric Water Manag 97:561–568

Rico AM, Olcina J, Paños V, Baños C (1998) Depuración, desalación y reutilización de aguas en España. Oikos-Tau, Barcelona

Ródenas MA (2002) La reutilización del recurso. La Confederación Hidrográfica del Segura (1926–2001). 75° Aniversario. Ministerio de Medio Ambiente, CHS, Murcia

Ródenas MA, Albacete M (2014) The river Segura: reclaimed water, recovered river. Journal of Water Reuse and Desalination 4(1):50–57

Rodríguez JP, De Caldas FJ (2009) Selección técnico–económica del sistema de depuración de aguas residuales. Tecnología del Agua 306:22–31

Rygaard M, Binning PJ, Albrechtsen HJ (2011) Increasing urban water self-sufficiency: new era, new challenges. J Environ Manag 92:185–194

Scruggs CE, Thomson BM (2017) Opportunities and challenges for direct potable water reuse in arid inland communities. J Water Resour Plan Manag 143(10)

Sowers J, Vengosh A, Weinthal E (2011) Climate change, water resources, and the politics of adaptation in the Middle East and North Africa. Clim Chang 104:599–627

Trapote A (2016) Tecnologías de depuración y reutilización: nuevos enfoques. Agua y Territorio 8:48–60

UNITED NATIONS (2015) Sustainable development goals. 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015 [November 3, 2018] https://sustainabledevelopment.un.org/sdgs

UNITED NATIONS ECONOMIC COMMISION (2017) [November 30, 2017] https://www.cepal.org/es/publicaciones/42143-carta-circular-la-red-cooperacion-la-gestion-integral-recursos-hidricos

Affiliations

Encarnación Gil-Meseguer[1] • **Miguel Borja Bernabé-Crespo**[1,2,3] • **José María Gómez-Espín**[1]

[1] Department of Geography, University of Murcia, Murcia, Spain

[2] Predoctoral fellow (FPU), Ministry of Education, Culture and Sports of Spain, Madrid, Spain

[3] Research Visiting Scholar at University of California, Santa Barbara, USA