Water reuse in the management of island water resources: the case of the Canary Islands and the Region of Madeira

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ABSTRACT

The integrated management of water resources has taken on great importance in recent years, especially in insular environments such as the Canary Islands and Madeira, which share geological, environmental, and economic characteristics. Nowadays, due to over-exploitation of aquifers, most of these islands cannot meet their water demand with the traditional resources, forcing their water authorities to establish conservation measures, including water reuse. Several water reuse schemes operate in islands with severe water scarcity, their main applications being in landscape and crop irrigation. However, islands with abundant groundwater resources consider reuse and the advanced treatment it entails as an environmental protection measure, rather than as part of a water saving strategy. This article analyzes the role of water reuse in the management of water resources in the Canary Islands and the Region of Madeira.

Key words | islands, reclaimed water, water management, water reuse

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INTRODUCTION

The integrated management of water resources has been acquiring growing importance in recent years, since every phase of the water cycle has been found to be closely linked to others: water supply, water sanitation, and water reclamation and reuse (Bahri 1999; Lazarova *et al.* 2000; Friedler 2001; Okun 2002; Tsagarakis *et al.* 2004; Hochstrat *et al.* 2008). This is of particular relevance to insular environments like the Canary Islands and the Region of Madeira (Central Macaronesia). These regions present some specific problems concerning water supply, and, as a consequence of their isolation and distance from the mainland, integrated water resources management becomes more necessary than in other cases.

The Canary Islands and Madeira are two archipelagos situated in the Atlantic Ocean, off the north-west coast of Africa, sharing geological, environmental, and economic characteristics (Figure 1). The Canary Islands (Spain) comprise seven major inhabited islands, with a surface area of 7,447 km^2, and a population of 1,968,280 inhabitants in 2005. Eighty-five percent of their population is settled on only two islands: Tenerife and Gran Canaria, each with more than 800,000 inhabitants. The Region of Madeira (Portugal) is composed of two inhabited islands, Madeira and Porto Santo, with a population of 245,000 inhabitants in 2005, and a surface area of 796 km^2 including the Desertas and Selvagens islets. Madeira is the main island, with 241,000 inhabitants, 98% of the total population. The main economic activity of both regions is the tertiary sector, which provides more than 70% of the income of both archipelagos. However, water consumption by agriculture still consumes an important 50%, although it generates less than 5% of the regional income, in both regions (Delgado *et al.* 2001; Figure 2).

In Table 1 the distribution of water resources in each island is presented (AREAM 2001; Autonomous Government of the Canary Islands 2001). The traditional water

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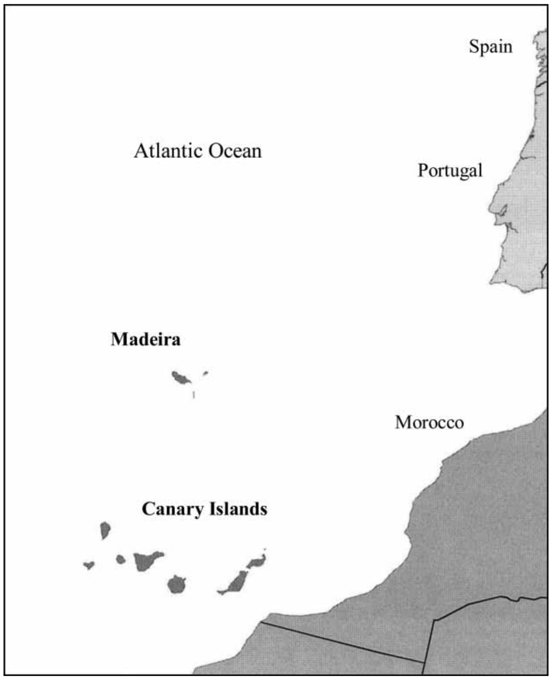

Figure 1 | Location of the Madeira and Canary archipelagos in the Atlantic Ocean.

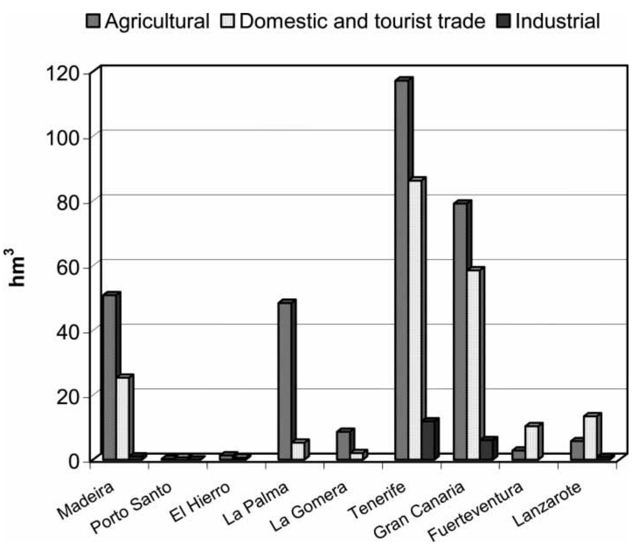

Figure 2 | Water consumption by sectors in the Region of Madeira and the Canary Islands in 2000 (AREAM 2001; Autonomous Government of the Canary Islands 2001).

supply in the Canary Islands and the Region of Madeira has been groundwater, provided mainly by horizontal water tunnels, named *galerías*, and vertical wells (Aguilera-Klink *et al.* 2000; Prada *et al.* 2005). Surface water has always been very limited in the Canaries, with no rivers as such, other than run-off along ravines during the occasional heavy rain. On the island of Madeira, surface water resources are much more abundant, but have been little utilized. Traditionally, groundwater has supplied the totality of water for agriculture and human consumption in both archipelagos. The development of modern irrigation systems in agriculture and horticulture and the accelerated population growth during the 20th century, together with the consolidation of the tourist trade in the last few decades, have led to the over-exploitation of aquifers in the most populated and economically active of the Canaries (Tenerife and Gran Canaria). Due to this over-use of groundwater, the supply from the catchment areas has decreased and water quality has become, in some cases, unsuitable for human consumption and even crop irrigation (Delgado *et al.* 2001). Other islands have been suffering from chronic water stress, such as Lanzarote and Fuerteventura among the Canary Islands, and Porto Santo in the Region of Madeira, where seawater desalination has been used for several decades to meet water needs (essentially for human consumption), becoming these islands' main water resource (Table 1). Later, in the last two decades of the 20th century, water reuse was incorporated as an alternative resource in those islands with limited conventional water resources (Table 1). In Figure 2, water consumption by sectors (agriculture, industry, domestic, and tourist trade) in each island of both archipelagos is presented.

Under these circumstances of water scarcity, conservation measures must be taken in order to preserve the available (high quality) groundwater for human consumption. Since many applications of water in urban areas and for irrigation do not require potable quality, water reuse appears as a key strategy in the sustainable management of water resources (Shelef & Azov 1996; Lazarova *et al.* 2000, 2001; Friedler 2001; Anderson 2003; Sala & Serra 2004; Angelakis & Durham 2006; Gikas & Tchobanoglous 2009), especially in insular environments. Planned water reuse for non-potable uses is a strategy that has been rapidly expanding in the last decades (Bixio *et al.* 2008). Other research has revealed that, in insular situations, water reclamation and reuse for crop irrigation is the most cost-effective solution to water shortages and the protection of the environment (Xu *et al.* 2001).

Table 1 | Water resources in the Canary Islands and the Region of Madeira (2001)

Resources (hm^3)	Madeira	Porto Santo	El Hierro	La Palma	La Gomera	Tenerife	Gran Canaria	Fuertev.	Lanzar.
Surface	431.9	0	0	4.2	3.4	1.0	11.0	0	0.1
Groundwater	315.0	0.8[a]	2.2	72.9	11.2	208.5	94.0	4.3	0.1
Desalination[b]	0	0.2	0.2	0	0	8.8	34.0	9.2	14.7
Reuse[c]	0	0.4	0	0	0	8.8	8.4	1.4	0.9
Total	746.9	1.4	2.4	77.1	14.6	227.1	147.4	14.9	15.8

[a]Groundwater unsuitable due to high salinity.
[b]Brackish water and seawater.
[c]Water reuse data corresponding to 2000.

The objective of this paper is to analyze the role of water reuse in the management of water resources in insular environments such as the Canary Islands and the Region of Madeira. The present status of water resources and consumption is discussed, as well as the situation and future of water reuse as part of the integrated water management.

METHODS

As part of this study, a participatory seminar was organized on reclaimed water reuse in the Canary Islands and the Region of Madeira, based on the methods used in the EASW (European Awareness Scenario Workshop). This methodology aims to promote democratic participation in decisions related to the impact of science and technology on society. It allows participants to exchange views and debate on issues and processes that affect technological development and its impact on the natural and social environment, so as to identify and plan specific solutions to existing problems. Participants in this workshop were members of organizations involved in the treatment, reuse, distribution, and research of reclaimed water in the Canarian and Madeira archipelagos.

RESULTS AND DISCUSSION

Present situation of water reuse in the Canary Islands and Madeira

At present, there are water reuse schemes in the islands with acute water shortages: Tenerife, Gran Canaria, Fuerteventura, and Lanzarote (Canary Islands), and in Porto Santo (Region of Madeira). The main and almost sole destination of the reclaimed water is agricultural and landscape irrigation, as seen in Table 2. Agriculture is an important water consumer in the islands of Tenerife and Gran Canaria, accounting for 66 and 43% of this water, respectively. In the islands with an economy based almost exclusively on tourism, the main use is irrigating golf courses, parks and gardens, especially in tourist areas (e.g., Lanzarote and Fuerteventura). It should be noted that the spread and continuance of many of these new green areas depend on the supplementation of scarce conventional resources with reclaimed water, as a new alternative resource. Indeed, water reuse now plays a key role in the economic development of these islands. In all cases, reclaimed water is produced using some type of tertiary treatment. As in 2005 Spain

Table 2 | Applications and volumes of reclaimed water reused in the Canary Islands and the Region of Madeira (2005)

Use (hm^3)	Porto Santo	Tenerife	Gran Canaria	Fuertev.	Lanzarote[a]	Total
Agriculture	0	5.85	4.00	0	0.55	10.40
Parks and gardens/golf courses	0.43	2.92	5.34	5.63	1.30	15.62
Others	–	0.04	–	–	–	0.04
Total	0.43	8.81	9.34	5.63	1.85	26.06

[a]Figures corresponding to 2006.

and Portugal did not yet have national regulatory standards on water reuse, most reuse projects used the World Health Organization guidelines (WHO 1989) in order to minimize sanitary risks.

Two islands have centralized water reuse schemes, in which several treatment plants (Tenerife, two, and Lanzarote, three) supply reclaimed water to their reuse systems. Both schemes include water transportation systems, storage reservoirs, advanced treatment facilities (desalination and disinfection), and distribution networks.

Tenerife's water reuse scheme came into operation in 1993. Eighty-five percent of the reclaimed water from treatment plants of the metropolitan capital area (Santa Cruz-La Laguna) and the main tourist resort area (Adeje-Arona) is reused in the south of the island, in crop and golf-course irrigation. Reclaimed water is tertiary treated by sand filtration, desalination (reverse electrodialysis), and final chlorination. Of the 8.81 hm^3 of water reused in 2005, most was applied to the irrigation of banana plantations (66%) and golf courses (22%) in the south, and a small fraction to maintaining parks and gardens in the capital city of Santa Cruz (11%). A very small percentage (0.5%) was reused in the construction industry.

Lanzarote has been forced to desalinate seawater for several decades to meet the water demand. It has one of the highest water sanitation rates of all the Canary Islands, above 80%. Water reclamation includes a membrane treatment (ultrafiltration or a combination of microfiltration and reverse osmosis) before final disinfection. Currently, most of it is reused in green areas (30% golf courses and 40% parks and gardens) and only 30% in agricultural irrigation, of a total of 1.85 hm^3 of reclaimed water reused in 2006. The amount of water reused in the island doubled in 2000–2006, from 0.9 to 1.85 hm^3.

Gran Canaria has 19 water reclamation plants, where water is generally reused in the surrounding area of each plant, in crop and landscape irrigation. Nevertheless, it must be noted that 83% of the water reused is produced by only four treatment plants located along the east and south sides of the island, where the main cities and tourist resorts are situated. In most of the Gran Canaria treatment plants, water reclamation includes advanced treatments, such as microfiltration or reverse osmosis, and disinfection (chlorination). There are two main reclaimed water transportation networks, on the north and south-east sides of the island.

The island of Fuerteventura is notable for its large number of water treatment plants (75), most of which (56) are private, located in tourist resorts. Eighty percent of the water reclaimed in the island is currently reused. This reclaimed water comes from both public treatment facilities (3.46 hm^3/year from 12 plants) and private (2.17 hm^3/year, 42 plants) and its main use is in parks and gardens (93% of a total of 5.63 hm^3/year), especially in tourist areas. The remaining 7% is used to irrigate two golf courses located in the south of the island. At present, there is no reuse in agriculture on the island due to the small share of the agricultural sector in the economy of the island, which is almost completely based on the tourist trade.

In Porto Santo, in the Portuguese Autonomous Region of Madeira, infrastructure for reclaimed water reuse has also been established, including advanced treatment (microsieving), disinfection (ultraviolet light application and chlorination), reclaimed water storage, and distribution networks. However, due to the limited agricultural activity in the island, just a few farmers are presently using the reclaimed water from the reuse system. Consequently, the most appropriate application in Porto Santo is landscape irrigation in parks and gardens and a golf course.

Although water reuse has been considered in the water plans of all the islands, in the cases of Madeira, La Palma, La Gomera, and El Hierro, it has not yet been put into practice, for two main reasons. In the first place, the first three islands have traditionally had an abundance of water resources. Their water consumption is still far below their conventional water reserves (groundwater). Even the island of Madeira has plenty of surface resources which have not yet been utilized (Table 1). In many places, the lack of water resources is what has led to the implementation of water reuse systems, as in the islands of Tenerife, Gran Canaria, Fuerteventura, Lanzarote, and Porto Santo, where water reuse began as a necessary alternative water resource. The environmental consideration of water reuse has become a more recent concern. The second reason for the minor role of water reuse in these islands (especially Madeira itself, La Palma, and La Gomera) is their steep orography, with a large proportion of their populations living in small villages, only some with small-scale poorly developed water sanitation systems, providing small amounts of available water for reuse. Nevertheless, water reuse should still be considered as part of their water management, e.g., by using decentralized reclamation systems (Gikas & Angelakis 2009).

Table 3 shows the growth in reuse of reclaimed water in the Canary Islands and Madeira in the period 2000–2005. In the islands with greater technical experience in the field (Tenerife and Gran Canaria), the volume of water reused has grown only moderately in recent years. Stagnation of the growth in reuse at only 0.7% can be seen in the case of Tenerife, which can be attributed to a combination of factors. These include limitations in transport, storage, and tertiary treatment systems, which in some cases have reached their maximum capacity, and second, competition from desalination, due to its decreasing costs in recent years. Lanzarote and Fuerteventura, which recently started reusing water, have undergone spectacular growth in reuse, owing particularly to the very low volumes reused in 2000.

Obstacles faced by water reuse in the Canary Islands and Madeira

The reclaimed water suitable for reuse (of adequate quality and reliable supply) is usually produced in large centralized treatment plants, usually away from water demanding areas (mostly for agricultural purposes). This involves the construction of complex transport and storage infrastructures. The steep orography makes difficult the transportation of both raw wastewater for treatment and reclaimed water for reuse. Furthermore, reclaimed water sometimes has a poor agronomic quality (high content of dissolved salts) which requires water desalination, increasing the treatment costs. In a study carried out in the Island of Gran Canaria it has been found that the average cost of production of 0.20 €/m^3 for water reclamation increases up to 0.42 €/m^3 when water reclamation includes desalination by reverse electrodialysis (Palacios *et al.* 2008). In the water reuse projects of the Canary Islands, the reclamation process often includes desalination, especially in agricultural applications, due to the frequent high salinity of reclaimed water. In Tenerife's water reuse scheme the tertiary treatment (sand filtration, desalination by reverse electrodialysis, and disinfection) accounts for 35% of the exploitation cost of water reuse (total exploitation cost approximately 0.50 €/m^3). The exploitation cost breakdown is completed as follows: 15% reuse scheme personnel, 25% reclaimed water pumping, 25% infrastructure maintenance and water quality control and monitoring. In addition to this, the spread of reuse is also hindered by the decreasing cost of seawater desalination (average cost production of 0.59 €/m^3 by reverse osmosis in the study performed in Gran Canaria by Palacios *et al.* 2008). With the latest technological advances, this alternative is becoming more economically viable, moreover, because in some cases it is even subsidized. In their study carried out in the island of Gran Canaria, Palacios *et al.* (2008) used energy needs of 2.5 kWh/m^3 for reverse osmosis (seawater desalination) and 1.1 kWh/m^3 for reverse electrodialysis (reclaimed water desalination), which are data previously proposed by Fernández (2007) from the Consejo Insular de Aguas de Gran Canaria (Gran Canaria Water Council). These data are similar to those found in the literature for medium–high capacity seawater reverse osmosis plants, between 2.2 and 2.5 kWh/m^3 (Ludwig 2010). Nevertheless, recent studies comparing water reuse to seawater desalination show that reuse is still an economically viable solution to overcome water scarcity (Xu *et al.* 2003; Gikas & Tchobanoglous 2009). On the other hand, water management projects regarded as having less economic benefit in the short term may become competitive in the future, as a result of the

Table 3 | Growth in water reuse in the Canary Islands and the Region of Madeira in the period 2000–2005

	Porto Santo (hm^3)	Tenerife (hm^3)	Gran Canaria (hm^3)	Fuertev. (hm^3)	Lanzarote (hm^3)	Total (hm^3)
2000	0.40	8.75	8.40	1.40	0.93	19.88
2005	0.43	8.81	9.34	5.63	1.85[a]	26.06
% increase	8.5	0.7	11.2	302	99	31.1

[a]Figure corresponding to 2006.

application of tightened environmental policies and advanced water treatment technologies (Xu *et al.* 2001).

Finally, another obstacle faced by water reuse projects was the absence of legislation that regulated and minimized the associated risks until 2006 (in Portugal) and 2007 (in Spain). Maintaining standards (quality, safety, etc.) for water reuse is essential (Marecos do Monte *et al.* 1996; Salgot & Pascual 1996; Angelakis *et al.* 1999; Bixio *et al.* 2008). The implementation of the recently approved Portuguese standard NP 4434 with guidelines for reclaimed urban water reuse for irrigation (Instituto Português da Qualidade 2006) and the Spanish Royal Decree 1620/2007 on the reuse of reclaimed water (Ministry of the Presidency 2007) will undoubtedly lead to greater safety guarantees and a much wider acceptance of reclaimed water reuse in the Canaries and the Region of Madeira.

Water reuse management

Water reuse has recently begun to be considered a part of water resources management, and responsibility for its development lies with the corresponding water management authorities (Bixio *et al.* 2008). Each Canary Island has its own water council (*Consejo Insular de Agua*) in charge of water management. This authority develops the island's water plan, which takes into account the specific hydrological characteristics of each island. Hence, water reuse is considered differently depending on the island's water availability. Islands are very limited territories where all phases of the water cycle must be taken into account in order to efficiently manage water resources (Xu *et al.* 2001; Tsagarakis *et al.* 2004). Traditionally, water supply and sewerage systems have been separately managed by different authorities. With the incorporation of water reuse, a new link must be taken into account, since reclaimed water supplied for crop irrigation (managed by the water supply authority) comes from a reclamation plant, often managed by the sewerage authority. Water supply, water sanitation, water reuse, and environmental protection should be managed by a single water agency.

In the case of most of the Canary Islands the respective island water councils are generally in charge of the management of reclaimed water reuse. In Tenerife, however, a third ad hoc water-related utility was created to manage the reclaimed water reuse (transportation, storage, advanced treatment, disinfection, and distribution). In the region of Madeira, water resources are managed by similar organizations: in Madeira, the water supply is managed by IGA *(Investimentos e Gestão da Água, S.A.)* and water sanitation by the regional sewerage authority DRSB *(Direcção Regional do Saneamento Básico);* in Porto Santo, both water supply and water reclamation and reuse are managed by IGA.

Future perspectives

A preliminary comparison between agricultural water demand and reclaimed water availability in each island could be useful in order to make an initial approach to the possibilities of water reuse in the different islands under study. In Table 4 the production of raw wastewater, treated wastewater (secondary treatment), reclaimed water, and agricultural water demand in every island is presented (AREAM 2001; Autonomous Government of the Canary Islands 2001; Delgado *et al.* 2001).

Depending on the agricultural water demand and wastewater production, there are three different scenarios in the

Table 4 | Agricultural water demand, and annual volume of raw wastewater, secondarily treated wastewater, and reclaimed water produced in the Canary Islands and the Region of Madeira (2001)

Volume (hm^3)	Madeira	Porto Santo	El Hierro	La Palma	La Gomera	Tenerife	Gran Canaria	Fuertev.	Lanzar.
Agricultural demand	50.8	0.2	1.3	48.4	8.6	117.1	79.1	2.8	1.0
Raw wastewater	20.2	0.7	0.5	4.4	1.4	57.1	45.9	6.2	9.0
Treated wastewater[a]	0.1	0.6	0.1	1.9	0.4	15.5	21.8	4.5	5.0
Reclaimed water[b]	0	0.4	0	0	0	8.8	8.4	1.4	0.9

[a]Secondary treatment.

[b]Reclaimed water data corresponding to 2000.

archipelagos studied: (1) Tenerife and Gran Canaria, characterized by a high agricultural demand and a substantial localized urban wastewater production; (2) Porto Santo, Fuerteventura, and Lanzarote, with a low agricultural water demand and a higher wastewater production; and (3) Madeira island, La Palma, and La Gomera, with a fairly low wastewater production and both considerably high agricultural water demand and groundwater resources. El Hierro does not fit into any of these categories, since in spite of lacking water resources it has a low wastewater production due to a small and scattered population.

Scenario 1: Tenerife and Gran Canaria

Here, more than 60% of the wastewater is produced in urban areas, with water sanitation facilities that are already in operation (Delgado *et al.* 2001). Taking into account the water demand for crop irrigation, it can be inferred that a significant proportion of groundwater still destined for agriculture could be preserved by taking full advantage of treated water from urban areas, provided that it is adequately reclaimed. In these two islands, if all wastewater from urban and tourist areas were reclaimed and reused, a great part of the traditional resources (groundwater) would then be conserved. However, it is necessary to highlight the uneven geographic distribution of water reclamation sites, and the agricultural areas where water would be reused (complex transportation and distribution systems would be necessary). At the same time, the agronomic quality of the reclaimed water obtained must be assessed, since it may require additional advanced treatments (e.g., desalination). In this case, the amount of reclaimed water that could be feasibly and cost-effectively reused in crop and landscape irrigation is the concept to bear in mind.

In the tourist areas of these islands, more than half the wastewater is produced in the seaside resorts themselves, so other non-potable reuse applications must be examined (Delgado *et al.* 2001). Reclaimed water from tourist areas has several drawbacks for crop and landscape irrigation, due to the often unsuitable quality levels (high salinity) caused by the additives typically used by some tourist resort activities (such as laundries, swimming-pool water treatment, etc.). Taking this into account, the less centralized gray water reuse and dual systems should be implemented in the future (Al-Jayyousi 2003; Lazarova *et al.* 2003), since adaptation to these in newly developed resorts and urbanizations is much easier than in traditional inhabited areas.

Scenario 2: Lanzarote, Fuerteventura, and Porto Santo

The production of wastewater is higher than the agricultural water demand of these more arid islands. This is due to the minor role of agriculture in their economies, which have become almost entirely tertiary (tourist-trade dependent) in recent decades. Provided that the reclaimed water is of suitable quality for irrigation, their present agricultural water demand could easily be met with the reuse of reclaimed water. Given the relative importance of their tourism sector, as occurs in Scenario 1, gray water reuse and dual systems are an even more practical option where new urban developments like tourist resorts and residential areas are still developing. While dual distribution systems might seem at first glance to be costly, several factors common to many cities have made them economically attractive (Okun 2002).

Scenario 3: Madeira Island, La Palma, and La Gomera

On these islands, an increase in the coverage of water sanitation is expected in the future. In any case, since the amount of groundwater saved by the application of reclaimed water in agriculture would be low, in these islands advanced water treatment and reuse should be considered more as an environmental protection measure than just in terms of the obvious economy of water conservation (Anderson 2003).

This aspect, which comes to the fore regarding these less urbanized islands, must also be borne in mind when developing water strategies for the other islands. Preservation of the coastal and marine environment should become a key issue (Angelakis & Bontoux 2001; Lazarova *et al.* 2001) considering the importance of the tourist trade in the economy of both archipelagos, located on the coastline where an unspoilt natural environment is an integral part of the attraction.

Conclusions from the water reuse in the Canary Islands and the Region of Madeira seminar

As part of this study, a participatory seminar was held on the reuse of reclaimed water in the Canary Islands and Madeira based on the methodology of EASW. In this seminar, the current and future situation of water reuse in these archipelagos was analyzed by various experts involved in the fields of water treatment, reuse, distribution, and research. This section summarizes the main conclusions reached. It should be taken into account that some of the proposed measures (those requiring additional funding) may be difficult to implement in certain countries or regions in the short or medium term, depending on the current economic climate.

1. The reuse of reclaimed water in the Canaries and Madeira will certainly contribute significantly to alleviate the water deficit and to the environmental conservation in the region. Hence, when economically possible, an effort should be made in all the islands to extend and complete the water sanitation, reclamation and reuse infrastructure, to allow the maximum use of this resource. Also, the installation of decentralized water reclamation systems based on low-cost technologies is an option to be assessed where suitable.
2. Reclamation processes should be mainly selected based on their removal performance and operating reliability. Increasing monitoring and analytical controls are already reaching unpractical levels, due to cost implications.
3. Confidence in the use of reclaimed water, and thus its acceptance by stakeholders, is linked to a wide and complex range of socio-economic factors. Hence, priority must be given to sanitary and physico-chemical reclaimed water quality, cost minimizing, reliability of supply, and the efficiency of the authorities or companies responsible for its management.
4. Included among the actions to be taken in the short to medium term to achieve the widest development of the reclaimed water reuse schemes in the Canaries and the Region of Madeira are the following.

(a) The establishment of information programs for reclaimed water users, on topics such as the basic processes in water reclamation (acceptable quality, quality indicators, and sanitary risks), interpretation of water quality analysis and best reuse practices (crop selection, irrigation techniques, fertilizing adjustments, etc.).

(b) The application of financial incentives for users of reclaimed water, in order to increase its acceptance and use. The implementation of this measure may be subject to economic considerations.

(c) The creation of a regional organization in each archipelago, authorized to take decisions, to bring together all sectors involved with reclaimed water reuse. This organization would have the following aims: to ensure compliance with regulations governing the reuse of reclaimed water, to improve the public perception of water reuse, and to propose actions to promote and create trust among stakeholders in the reuse of reclaimed water. This new organization should be created by a restructuring of the present regional and insular water management agencies (water councils in the case of the Canary Islands).

5. The following measures are recommended with regard to establishing training programs and possible Research, Development, and Innovation (RDI) lines. The implementation of these measures may be subject to funding availability. In any case, these measures should be applied in the framework of cooperation programs between the Water Management Agencies and the Research and Educational Institutions in order to minimize the implementation cost.

(a) Establishment of measures to coordinate and to structure research efforts in the area of water reclamation and reuse technology, which can incorporate the concerns and needs of all stakeholders in water reuse.

(b) Periodical organization of training courses for professionals to attain optimal performance in operating plants using new water reclamation technologies.

(c) Promotion of reuse demonstration projects, including different reclamation technologies and reuse applications which comply with the established guidelines or regulations.

CONCLUSIONS

The integrated management of water resources is of major importance in insular environments, where, due to the limited territory, every phase of the water cycle, water supply, water sanitation, and water reclamation and reuse, is closely linked to the others.

In insular environments it becomes necessary to reuse water in those applications where it is appropriate as a conservation action to preserve the available high quality groundwater for human supply. Even in islands with a surplus of water resources, water reuse should be considered as an environmental protection measure.

Although water reuse for crop irrigation has been found the most cost-effective solution to water shortages in insular environments, other uses of non-potable supplies such as gray water reuse by the adoption of dual distribution systems, are an option to be considered where new tourist areas are being developed.

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