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Reclaimed water: a reliable resource for promoting self-sufficiency

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1. Introduction

The legal and practical status of the environment as a rightful user of water resources is bringing about a significant change in both the perception of and the traditional and anthropocentric management of our conventional water sources: rivers and aquifers. In order to ensure the chemical and sanitary quality of our supplies – begun in mid-19th century through drinking water treatment processes – it became subsequently necessary to treat our effluents in such a way as to ensure that the quality of river water flows was compatible with the needs of downstream users.

The opening years of the 21st century have signified the consolidation, not only of the maintenance of the quality of water in rivers and aquifers, but also of their streamflows at various points along their course and throughout the year. Integrated management at a river basin level is a legal requirement (Directive 2000/60/CE) and various instruments have been established to ensure that it is implemented, among them water use efficiency, water conservation, water storage, water use exchanges, water reclamation andreuse and desalination of brackish and salt water.

Water reuse is an intrinsic element in the natural water cycle. The discharge of treated effluent into water courses and its subsequent dilution withstreamflows have resulted in the downstream reuse of treated waste water for urban, agricultural and industrial purposes. The direct or planned reuse of water on a large scale is more recent in origin (dating from the mid-20th century) and entails the direct use of effluent, with some degree of reclamation, by transporting it to the point of use along a specific conduit, without prior discharge or dilution in a natural water course.

The considerable advances made in planned water reuse, especially in countries with adequate water resources, have been due to two main factors: the need to increase water supplies and the need to improve the methods of managing treated effluent discharges. The increase in water supply allocations and the rise in population of urban areas, together with a greater environmental awareness as regards natural water courses, have meant that traditional water supply sources are unable to meet current water demands. The ever longer distances between new water supply sources and urban population centres, the environmental constraints on building new reservoirs and the occurrence of multi-annual droughts have prompted numerous population centres to consider using reclaimed water as an additional water source for uses that do not require drinking water quality. Moreover, the increasing sanitary and environmental demands regarding the quality of inland and marine waters, together with location requisites and ever stricter levels of treatment imposed on treated effluent discharges, have made reclaimed water an alternative water supply source, that is cheap and safe from public health and environmental points of view.

The purpose of this article is to analyse the role of water reclamation and reuse in integrated management of water resources, especially in relation to their ability to promote self-sufficiency in water resources in semi-arid areas or places with chronic shortages, such as the inland basins of Catalonia and in particular the Barcelona Metropolitan Area. The specific aims of this article are to: describe the conceptual framework for planned water reuse; analyse the benefits and demands of planned water reuse; present the various uses of reclaimed water; assess the cost of planned water reuse in integrated management of water resources in Spain; analyse the socio-economic factors that have an impact on planned water reuse in Spain; describe groundbreaking and innovative initiatives on indirect potable water reuse; and formulate several practical applications that will increase the role of planned water reuse in the integrated management of water resources.

2. Planned water reuse

The treatment process required to allow reuse of treated effluent is generally termed “reclamation” and the result of this process, “reclaimed water”. In keeping with its etymological meaning, water reclamation involves restoring, either partially or totally, the quality level that water had before it was used, just as land and beach reclamation attempts to restore them to their earlier state and form (Asano et al., 2006; Mujeriego, 1990, 2007).

There are two essential and complementary requisites involved in setting up a water reclamation project: firstly, the quality standards appropriate for each of the possible uses of reclaimed water must be defined; and secondly, the recommended treatment processes to reach the quality standards of the reclaimed water intended for each of the expected uses must be identified.

Reuse of reclaimed water involves making it available to users, who can then use it for the intended purposes. In most cases, using reclaimed water entails transporting it from the reclamation plant to the place where it is to be used, storing it, or adapting the flows supplied by the reclamation plant to the flows requested by users, and lastly, establishing water use regulations (best management practices) that minimise any possible direct or indirect risk to the environment, the people using the water, the population living near the water reuse place and the consumers of any agricultural produce cultivated with reclaimed water. These three technical elements are the core of any planned water reuse programme.

3. The benefits of planned water reuse

The hydrological balance of a geographical area is the difference between the annual incoming water – consisting of rainfall and water from rivers, aquifers and transfers from other basins – and annual outgoing water or irrecoverable losses to the atmosphere or the sea. Any action intended to conserve water that succeeds in reducing these losses will improve the availability of water for use throughout the year. Consequently, water reclamation and reuse will only result in a net increase in water resources available for use in an area, if the waters are currently lost without the possibility of recovery, by runoff out to sea from a coastal town or through evapotranspiration in inland areas. (Pettygrove and Asano, 1984; Mujeriego, 1990).

There are many potential benefits to be gained from planned water reuse, notable among them are:

1. Provision of a new water supply source capable of contributing additional water resources, either in the form of net resources or alternative resources that will free up sources of fresh water of better quality and hence capable of being used for more demanding purposes, such as dringking water supply.
2. Reduction in the costs of treating and disposing treated effluents.
3. Reduction in the amount of pollutants discharged into natural watercourses, in particular when water reuse is achieved by agricultural, landscape or forestry irrigation.
4. Postponement, reduction and even elimination of additional facilities that may be necessary to produce drinking water.

5. Energy savings by avoiding the need to supply additional water from areas remote from the reclamation plant.
6. Reduction in carbon dioxide emissions as a result of lower energy consumption.
7. Use of the nutrients contained in reclaimed water, especially when it is used for agricultural and landscape irrigation.
8. Greater supply reliability. Treated effluents flows offer a much higher reliability than most natural water sources, in particular in semi-arid zones such as the Spanish Mediterranean coast.

In short, planned water reuse offers a supply reliability far greater than conventional sources by ensuring the availability of water flows, in particular during the summer, by enabling the use of the nutrients (nitrogen and phosphorus) contained in reclaimed water, while contributing to a more efficient management of water resources by facilitating the use of fresh waters for drinking water supply. The fact that reclaimed water supplies are located near urban population centres (at the door-step of our cities) offers a possibility of local and reliable supplies and hence raises the degree of water self-sufficiency of those populations.

Planned water reuse, together with water storage in diversion basins and aquifers, as well as water use efficiency, are the basic elements of integrated management of water resources in semi-arid areas such as southern California (Mujeriego, 2004).

4. Requirements of planned water reuse

One of the determining factors of the introduction and development of planned water reuse is the establishment of reclaimed water quality standards for each of the possible uses under consideration. The approval of Royal Decree 1620/2007, which establishes the regulations applicable to water reuse and the standards of quality applicable to reclaimed water, has been crucial for the promotion of this activity in Spain. Whereas the regulations applicable to management of reclaimed water are framed within the context of river basins, as required by the Water Framework Directive (Directive 2000/60/EC) – our existing Confederaciones Hidrográficas – the quality limits applicable to various possible usages of reclaimed water are based on the recommendations of the World Health

Organization and the criteria of the US Environmental Protection Agency, recommendations which had already been adopted and applied in a number of autonomous communities such as Catalonia, the Basque Country, the Balearic Islands and Andalusia during the implementation of water reuse projects over the course of the last two decades.

Transporting of reclaimed water from the treatment plant to the point of reuse is without doubt the main requirement of any water reuse project. Furthermore, the rules applicable to using reclaimed water are an essential component of any strategy aimed at protecting the quality of the environment and public health. In general, the higher the quality standards applicable to reclaimed water, the fewer the restrictions concerning its use due to its possible contact with people, animals or foodstuffs.

Health authorities have devoted particular attention to defining the rules applicable to the use of reclaimed water, such as: announcements consisting of visible posters indicating the type of water used; the standardised use of purple colour for pipes and control devices; the installation of cross-flow mechanisms; inspections of connections to the reclaimed water network; requirements for irrigation at certain times of the day and for using particular types of sprinklers; the banning of external taps; and the use of pipes and hose connectors of different sizes to those employed for drinking water supply.

The increasing number of quality controls on the production and the distribution of reclaimed water is fostering a change in legal strategies, which are moving towards a total water quality management approach: the introduction of successive and complementary processes (multiple barriers) that are extremely reliable and which are able to obtain a product (reclaimed water) of such a high quality as to ensure environmental and public health protection,regardless of the water use, while reducing financial costs and the need for staff to conduct analyses and monitoring.

The adoption of a total water quality management strategy for reclaimed water highlights the need to consider reclamation and reuse as a management element that is clearly different though complementary to effluent treatment and disposal, in particular as regards the allocation of infrastructure and the operation and maintenance costs of the projects: reclamation and reuse come under the strategy of developing new, additional or unconventional water resources, whereas treatment and effluent disposal come under the strategy of environmental protection of receiving waters, governed by specific technical and fiscal rules and regulations.

5. Reliability of water reclamation process

One characteristic requirement of water reclamation projects is the need to ensure very high standards of reliability in the treatment process and a satisfactory management of the reuse system. The fact that reclaimed water is usually the only alternative source for the purpose under consideration, without the protection that dilution with better quality water may offer, and above all the fact that water reuse often gives rise to the possibility of direct contact with people, animal and plants – the health or development of which may be affected – mean that the reliability of reclamation plants must be extremely high, to the point of becoming an essential element of their design, operation and maintenance.

In short, reclamation is currently regarded as a process intended to provide a quality product in a manner very similar to that adopted in drinking water treatment plants. This new approach to water reclamation and reuse has meant that planned water reuse has become an essential element of integrated management of water resources.

Increasing environmental awareness and above all health concerns from people in potential contact with reclaimed water has had the effect of improving its sanitary quality, bringing it ever closer, especially in developed areas, to the "analytical quality" of drinking water, though this does not imply that reclaimed water is used for human consumption. This quality change is especially evident in demonstration projects on indirect potable reuse, in which reclaimed water is disposed in the natural environment (all the while preserving its quality levels) so that it can later be used as raw water for drinking water production.

6. Types of water reuse

There are many possible uses for reclaimed water, notable among which are urban uses (landscaping, fire-fighting, street cleaning and car washing); industrial uses (refrigeration as well as train wagon and carriage cleaning); agricultural, landscape and forest irrigation; ornamental and recreational uses; enhancement and preservation of the natural environment; and recharge of

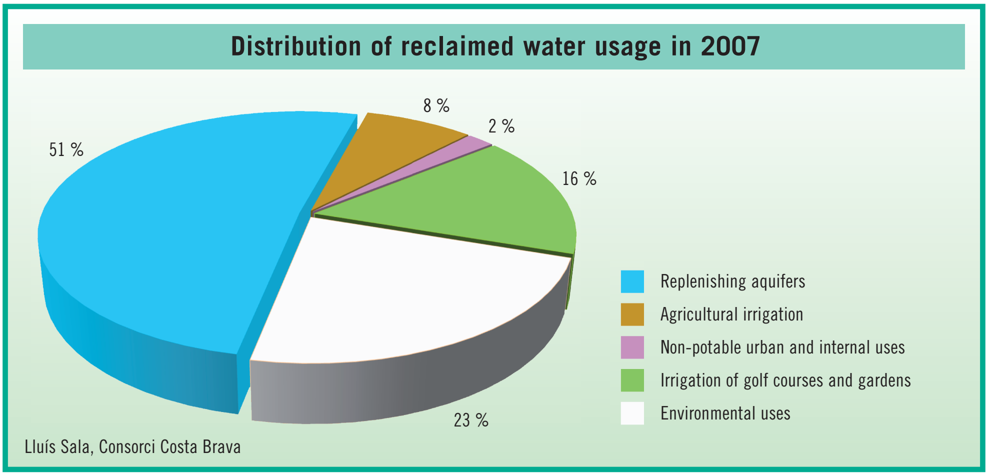

Figure 1

aquifers. The most widespread type of reuse is agricultural and landscape irrigation for growing horticultural produce (direct consumption) and irrigation of crops that will subsequently be processed, cereals, citrus fruits and vineyards. Iirrigation is conducted by sprinklers, micro-sprinklers, drip systems or flooding (see figure 1.)

Given the possibility that people may have contact with or consume reclaimed water, reuse is classified as: potable reuse and non-potable reuse. The first category includes uses in which reclaimed water may be injested by people at some time, while the second encompasses all other usages. It is important to note that to date reclamation projects for non-potable reuse are those most widely adopted in many parts of the world, where thay have achieved high standards of reliability and acceptance among users and the general public. This is especially true of developed semi-arid areas, where water resources are becoming ever more limited and irregular, and where environmental protection is an increasingly pressing priority.

As an example of the reclamation capacity and volumes (absolute and relative) currently reclaimed in various areas of the world, planned reuse by Consorci of Costa Brava during 2007 was 5.5 hm^3/year, amounting to 18% of the 30 hm^3 of treated effluent produced in its plants. Figure 2 shows the evolution over time of water reuse by Consorci of Costa Brava since 1989, when it was included for the first time as an element of the Consorci's water resource management. As a further example, planned reuse in California by June 2003 reached a volume of 670 hm^3/year (compared with 495 hm^3/year in 2000 and 330 hm^3/year in 1987).

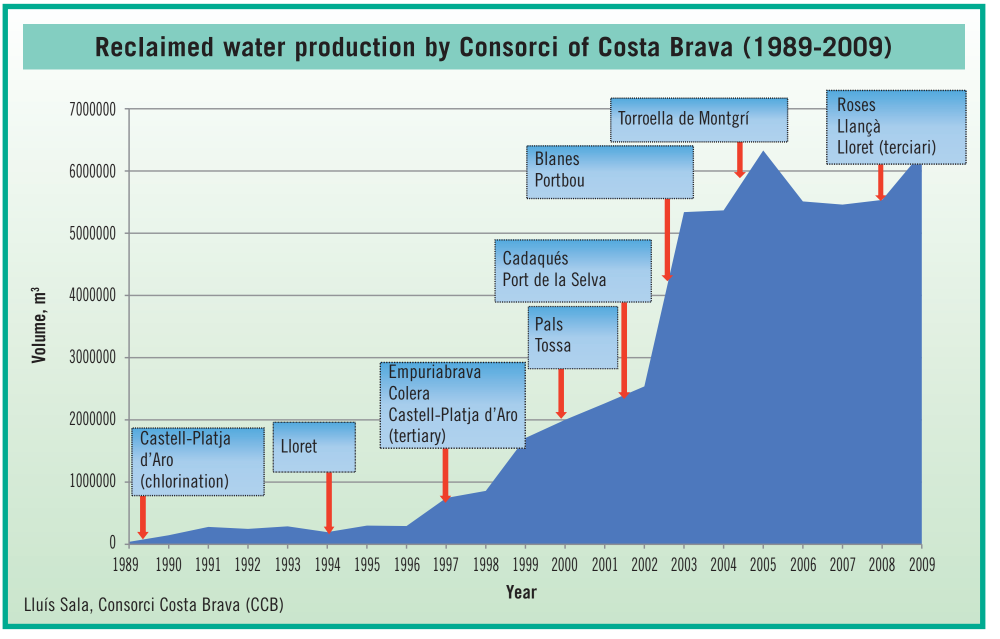

Figure 2

Florida has a water reclamation capacity of 1,900 hm³/year and in 2006 achieved a reuse flow of 915 hm³/year (compared with 810 hm³/year in 2001).

Those figures illustrate the considerable volumes of reclaimed water that are reused each year in these geographical areas. Even though water reuse for the whole of California stands at around 10%, the figures for more restricted areas of the state can exceed 30%, especially in the semi-arid zones of the south. In this context, the figure of 18% achieved by Consorci of Costa Brava between 2007 and 2009 is quite considerable, as it ranks in the upper half of that range.

7. Cost of planned water reuse in Spain

The first ten years of the process to introduce planned water reuse in Spain saw various projects come on-line for agricultural and landscape irrigation in Costa Brava, financed by Consorci of Costa Brava from 1985, and the Vitoria-Gasteiz water reclamation plant in 1995, sponsored by the Arrato Irrigation District and financed by Álava Provincial Council. The main achievement of this phase was to document the ability of the human resources and technology of those facilities to produce reclaimed water of a quality comparable to that achieved in other pioneering countries, and to use it efficiently for landscape and crop irrigation by individuals or large agricultural projects.

The completion of the first reclaimed water regulating reservoir in 2004, as part of the integrated management project of Vitoria-Gasteiz, and the expansion of various reuse projects in Costa Brava and elsewhere in Spain marked the second ten-year period of the process to develop planned water reuse. The most important achievement of this second phase was to document the real cost of water reclamation and reuse at a quality level and with a degree of integrated management comparable to that of countries leaders in the field. The most recent data supplied by those in charge of running the Vitoria-Gasteiz water reclamation plant (Julio López, personal communication, 2006) confirm the initial benchmark figure of 0.06 euro/m^3 as the cost of reclaimed water in Spain. Moreover, the Vitoria-Gasteiz regulating reservoir, with a capacity of 7 hm^3, represents an investment by the Álava Provincial Council of 11.8 million euros, equivalent to 1.7 euros/m^3 (Mujeriego and López, 2008).

The figures above show that the greatest financial burden is associated with water reuse (distribution to the user), whereas the cost of the reclamation plant and above all the operational and maintenance costs are comparatively much lower.

The limiting factor for the expansion of water reclamation projects in Spain has been precisely the lack of a framework for integrated management that allows for a join consideration of the costs of the process and the direct benefits and indirect benefits (externalities) arising from it. There can be no doubt that many of these projects have been very positively received by users and that public perception is very favourable, especially as regards garden and golf course irrigation and environmental protection. It is evident that the objective to be achieved in the third ten-year period, which began in 2005, is for planned water reuse to truly become yet another element of integrated management of water resources through agreements between urban, agricultural and leisure users.

Table 1 sums up the current investment and energy costs arising from reclamation, storage in diversion basins and desalination of brackish and sea water. The figures given for water reclamation are for levels of quality suitable for reuse in agricultural and landscape irrigation and sufficient to ensure standards of environmental protection and public health comparable to those associated with the

Investment and energy costs of various management alternatives, Consorci of Costa Brava, Vitoria, Aigües Ter Llobregat (ATLL), Palma de Mallorca, Taibilla, Malaga, Belgium, California / Orange County Water District (OCWD).			
Alternative	**Investment, euros/m³ – annual**	**Depreciation, years**	**Energy, kWh/m³**
Reclamation (irrigation without restriction)	0.26 (Vitoria, 1995)	15-25	0.001-0.73 (Sala and Serra, 2004)
Storage (in diversion basins) (in aquifers)	1.7 (Vitoria, 2004) $ 2.0 (California, 2000) $ 0.86 (California, 2005)	> 100 > 100 25	—
Rhone river transfer (ATLL, 1999) (2009 estimate)	2.8 (€900 M, 325 hm³) 3.9 (€1,270 M, 325 hm³)	50	1,7-2,0
Brackish water desalination Potable reclamation Potable reclamation	0.9 (Málaga, 2005-06) €2.4 (Belgium) €3.4 (€2.6) (OCWD, 2008)	5 (membranes) 15-20 (works and equipment)	0,8 — —
Seawater desalination (Blanes, Barcelona, Mallorca, Taibilla)	3,0-4,0	5 (membranes)	3,5-4,0

Table 1

use of drinking water. This level of quality, therefore, allows reclaimed water to be reused without any restriction regarding possible contact with the public and the crops. The figures for demineralisation of brackish water correspond to the costs associated with advanced water reclamation processes for indirect potable reuse.

Table 1 shows the increase in investment costs as treatment levels move from water reclamation to water storage and to water demineralisation. If we add to this the depreciation period, it becomes evident that the unit costs of water storage are the lowest of all, followed by water reclamation and lastly by water desalination. A full cost evaluation of wate reuse obviously requires taking into account the investment costs of any distribution network that may be necessary. For this reason, water reuse projects are generally designed to expand progressively, initially serving groups of users with the highest usage capacity or those closest to the water reclamation plant.

There is also a clear difference in energy consumption by these three alternatives. Whereas basic water reclamation involves unit consumptions of less than 1 kWh/m³, the demineralisation of brackish water and of sea water normally reaches values close to 1 and 4 kWh/m^3 respectively. Aside from the financial cost, it is also important to consider the environmental impact of such levels of electricity consumption. Bearing in mind that average carbon dioxide emissions in Spain stand at around 460 g/kWh and that emission rights are some 20 euros per tonne, each kilowatt hour adds an additional environmental cost of up to 0.01 euro per cubic metre to reclaimed water (basic and advanced) and 0.04 euro per cubic metre to desalinated seawater.

8. Socio-economic management of water reuse

Periods of drought are frequently the cause of severe tension between the various water resources user groups. At the same time, they raise everyone's interest in finding unconventional sources of water capable of providing much more reliable solutions to the lack of conventional resources. The priority accorded by Spanish legislation to human consumers over and above any other use meant that the management of measures to mitigate the effects of the droughts recorded from 2005 to 2008 in Spain – particularly in certain autonomous communities such as Catalonia, Valencia, Murcia, Andalusia and Madrid – stirred heated debate between urban and agricultural users, prompting renewed interest in planned water reuse as a way to resolve short-term or permanent water shortages.

Establishing the price and the cost of reclaimed water is crucial to the effectiveness, efficiency and success of any planned water reuse programme. Determining this price and cost is a complex process, mainly because it is usually more costly to supply reclaimed water than to maintain a supply of drinking water, even though reclaimed water essentially is of lower quality than drinking water (Cuthbert and Hajnosz, 1999). Whereas the costs of supplying drinking water are usually based on past investments, projects to supply reclaimed water require investments and a system of operations and maintenance which, in accordance with traditional cost allocation methods, make the cost of reclaimed water equal to or even higher than that of drinking water supply obtained from existing sources.

The dilemma in these cases is evident: if reclaimed water is billed at its real cost price, users will generally not have sufficient incentive to use it; however, if reclaimed water is billed at a cost lower than its production cost, compensation from other sources of revenue will have to be found. The question that arises in this situation is to determine who should be responsible for these costs and what the amount should be. Nevertheless, the benefits to be obtained in the long term from the use of reclaimed water are such that numerous public water and irrigation water supply services are promoting its use.

Planned water reuse acquires a new dimension when it is considered from a broader perspective than the traditional point of view (different bodies that manage a part of the water cycle), revealing its potential to avoid the greater costs entailed by new sources of drinking water, even when such a supply is really possible, and to avoid the higher costs that could arise from improvements in treatment and disposal required by new health and environmental limits.

Water resources management in the context of a river basin, as has traditionally been implemented in Spain and as the Water Framework Directive (Directive 2000/60/EC) requires in Europe, offers an excellent framework that is far more favourable for carrying out the integrated or systemic management of water resources, a method in which the economic and financial requirements of planned water reuse become just another element in the overall balance sheet of the costs and profits of the river basin.

Implementing river basin agencies, as responsible entities for integrated management of water resources, means that planned water reuse projects can benefit from savings and even from the benefits of not having necessarily to resort to new and costly sources of drinking water, such as desalination, transfers from distant areas or emergency supplies delivered by tankers. The development of regulations governing the water public domain and the introduction of management instruments governing the exchange of water rights offer enormous possibilities for improved resource management, whileenabling reclaimed water to be considered a new element that strengthens the whole water system.

The most notable benefits arising from water reuse include the greater availability of fresh raw water when this is replaced by reclaimed water, and the improved reliability of reclaimed water supplies, thereby palliating or lifting restrictions that must be applied during dry spells and preventing the enormous losses that periods of drought normally entail. By adding the possibilities of integrating surface and groundwater resources – especially due to the storage possibilities that aquifers offer – plus water conservation and water use efficiency in agriculture, integrated management provides substantial improvements to be made in the availability of water resources for different user groups, as well as a more reliable supply of those resources.

9. Indirect potable water reuse

The debate among specialists on the scope and future of planned water reuse – and consequently of the technical means for reclaiming water in countries that have made notable achievements in this field – is currently focused on the conflict between the appropriateness of promoting indirect water reuse for drinking purposes and the more cautious approach of restricting water reuse to the non-potable uses that have been pursued for several decades. This specific – and, in many practical instances, political – debate usually eclipses an indisputable state of affairs: the enormous success achieved by water reuse for non-potable uses in many countries around the world, in particular in states with a large and diverse number of projects, such as California and Florida, and in areas such as Costa Brava (Girona), the city of Vitoria (Álava), the Balearic and the Canary Islands, Costa del Sol and many other resort areas on the Spanish Mediterranean coast, where planned water reuse has made remarkable progress since the 1980s.

The growing need for water resources to supply urban populations, together with the physical and administrative availability of increasing flows of treated effluents in urban areas very close to the points of use, allied to the availability of water treatment processes with a proven ability to eliminate practically all known and detectable contaminants in water supplies, have resulted in treated effluents being considered as a raw material for producing reclaimed water of a quality virtually similar to the best surface or ground water available and at a cost comparable to that of conventional water sources. The use of advanced water reclamation processes, involving filtration with water demineralisation membranes and combined disinfection processes using efficient biocides – such as UV light, chlorine, oxygen peroxide and ozone – offers the possibility to obtain a water of excellent chemical and sanitary quality that in many cases is higher than the best surface water available in those areas.

The two fundamental strategies adopted to promote indirect potable water reuse are information and public participation, implemented through well-organised, systemic and long-term processes, as well as the use of the natural environment as an essential element in the re-use of reclaimed water. The ultimate aim is to give water “a natural touch” that will contribute to improving its quality, regulating its flows and reinforcing a positive public perception about reclaimed water in comparison with traditional sources of public water supply.

The innovative concept of indirect potable water reuse has been applied for a number of years in several pioneering projects, among them the Ground water Replenishment System in Orange County in southern California (www.gwrsystem.com), which begun in January 2008 after more than 30 years of prior studies and demonstrations; the coastal dune groundwater replenishment project in Wulpen, Belgium (http://www.iwva.be/docs/torreele_en.pdf); the NEWater project in Singapore (www.pub.gov.sg/newater/Pages/default.aspx); and the Western Corridor project in the south-east of Queensland, Australia (www.westerncorridor.com.au).

The Metropolitan Area of Barcelona has set up a demonstration project on advanced water reclamation with the aim of producing water to supplu a sewater intrusion barrier in the Llobregat River delta (Mujeriego et al., 2008). This project is one component of a much larger basic water reclamation system (with a capacity of 100 hm^3/year) intended to supply wetlands, agricultural irrigation and environmental flows of the Llobregat River. The indirect potable reuse demonstration project has a capacity of 5,000 m^3/day and is being expanded to produce up to 15,000 m^3/day in order to supply water to the additional injection wells of the seawater intrusion barrier. The advanced reclamation processes adopted are the same used in the projects mentioned above: ultra-filtration, reverse osmosis and disinfection using UV light.

The advanced reclamation facilities of the Metropolitan Area of Barcelona offer an unparalleled benchmark for implementing an ambitious demonstration programme to monitor and research the technical ability of the water supply system to respond to health, environmental and social concerns that may be raised by the health authorities and the public at large. The results of such a programme would provide not only information, education and public and social groups participation campaigns to be run, but also the consolidation of a solid referent for developing indirect potable reuse on a large scale in the Metropolitan Area of Barcelona, while generating international scientific and technical competence in a field of such importance as integrated management of water resources.

Secondary effluent from the wastewater treatment plants of El Prat de Llobregat (100 hm^3/year) and Besòs (160 hm^3/year) offers a raw material that can be used to obtain some 210 hm^3/year of high quality water (using filtration with reverse osmosis membranes and disinfection with UV light and hypochlorite) that could be added to surface and ground water masses in the Metropolitan Area, thereby becoming part of the future supply sources and freeing up similar water flows from current water supply sources. A project of this nature would contribute considerably to improving the reliability of the water supply in the area served by Aigües Ter Llobregat (ATLL) (a public wholesaler company) and would place Barcelona and Catalonia at the forefront of new ways of managing water resources that are better suited to the droughts that are anticipated and which are far more respectful of the environment and the users in the Ter River basin, which currently supplies a significant portion of the water resources used in the Metropolitan Area of Barcelona. The Groundwater Replenishment System in Orange County is unquestionably the most iconic benchmark, both technically and sociologically, that could be used to promote a groundbreaking initiative in the integrated management of water resources in Catalonia.

10. Practical uses of reclaimed water

The water reuse projects implemented in Spain have provided an accurate assessment of the costs of water reclamation and reuse. This assessment has been based on essentially two aspects: the cost of producing reclaimed water and the cost of making it available to users, both of which are fundamental elements for apportioning costs to future beneficiaries of this resource. However, this purely financial approach is to a large extent in keeping with the views of societies in which resources are generally privately owned or managed by two different bodies, one which deals with water supply and the other which deals with sanitation. In a European context, however, in which water is a public resource managed by state and regional authoritieswithin a river basin system, the proper apportioning of water costs must be considered within the framework of integrated or systemic management, in a similar manner to that applied to new supplies obtained by extractions from aquifers, transfers from other river basins or seawater desalination. The experience acquired in various reclamation and reuse projects in Spain clearly shows the emergence of environmental and economic benefits that are not obvious and which must be taken into account due to their great importance.

Article 7 of Royal Decree 1620/2007 establishes a procedure for reusing water through initiatives or plans put in place by authorities. It also offers the possibility for different authorities (central government, autonomous community or municipalities) to carry out, within the realm of their respective powers and responsibilities, plans and programmes on water reuse with a view to encouraging water reuse and more efficient use of water resources. The Water Reuse Programme of Catalonia, currently under approval by the Catalan Water Agency (2009), contains a similar provision, by including the possibility of 'public' promotion of this new or additional water resource through public funding, similar to those considered when a water transfer or a desalination plant is proposed.

The various practical applications in which water reuse can help to improve integrated management of water resources, offering users a better supply reliability, lower overall costs and greater environmental protection, include (Mujeriego, 2009):

1. Replacing fresh water used for irrigation with reclaimed water;

2. Using reclaimed water for under-supplied irrigated land, or for new agricultural and landscape irrigation projects;

3. Replacing instream water flows with high-quality reclaimed water just downstream from where the extraction for supply takes place, especially if this point of extraction is a storage reservoir;

4. Supplying reclaimed water to maintain instream water flows when the supply source must simultaneously meet the needs of urban users and a natural aquatic ecosystem;

5. Producing reclaimed water, rather than treated effluent that is discharged into surface water, in order to reduce the surface water flows released from storage reservoirs, whose main purpose is to dilute those discharges;

6. Supplying reclaimed water as an alternative to extracting groundwater from over-exploited aquifers;

7. Artificial groundwater recharge with reclaimed waters.

Achieving a major framework agreement between urban and agricultural, industrial and leisure users in the context of integrated management of water resources conducted by river basin agencies, by using current management instruments for exchange of water use rights, or other methods that may be established, constitutes a very positive way to meet the fresh water needs for public supplies and water for agriculture and landscape irrigation.

The introduction of contractual agreements on the use of reclaimed water that answer the concerns regarding the quality and the reliability of supply for irrigation and industrial water, as well as the financial interests of concessionaires, offers agriculture, landscape and industry a practical alternative of great value for resolving the challenges that will arise from shortage of water resources, especially in coastal areas, while at the same time ensuring regulatory backing over the quality requirements of crops cultivated with reclaimed water.

All these considerations should drive the qualitative leap that must be part of the debate when it comes to analysing the economic aspects of reclaimed water. We should not only quantify its cost but above all we should be estimating its value. The real costs of alternatives, such as water transfers and water desalination, and particularly the emergency measures put in place to palliate the effects of droughts, such as those adopted in Catalonia in 2008, clearly demonstrate the enormous financial benefit to be derived from reclaiming and reusing water. Recent initiatives on the recovery of environmental water volumes and, above all, the mitigation of rainfall patterns due to meteorological disturbances, intended to aid both the supply of drinking water and water for environmental preservation, show that reclaimed water and water reuse are determining factors in raising the value of water in all its numerous aspects and uses.

The current economic and financial state of affairs, at the opening decade of the 21st century, and the increasing environmental awareness in recent decades will probably foster new ways of approaching reclamation and reuse projects by instigating a more detailed and critical assessment of the financial costs of other sources – which, though higher, seemed justified in the past – and by highlighting the economic benefits and greater value of water that accrue from water reclamation and reuse.

The knowledge and experience acquired over the last 25 years in places such as Costa Brava and elsewhere in Catalonia and Spain clearly demonstrate that we know how to reclaim and reuse water, and that we know how to quantify the associated financial investment, operation and maintenance costs. The most pressing challenge now is to turn water reclamation and reuse into yet another element of integrated management of water resources, particularly bearing in mind the value of water and not just the cost of producing and using it. A value that is without doubt usually far greater than the cost of reclaiming and reusing it.

11. Conclusions

The analysis presented above allows us to draw the following conclusions:

1. Planned water reuse is an essential component of integrated management of water resources, especially in coastal areas, where it can make a significant contribution to a net increase in those resources.

2. Progress in water reclamation and reuse does not depend solely on technological advances. The existence of a solid legal and regulatory framework plus a political commitment to implement water reclamation and reuse are determining factors for its development.

3. Water reclamation and reuse are management elements clearly different from effluent treatment and disposal, especially as regards the apportioning of implementation, operation and maintenance costs of the projects: water reclamation and reuse come under the strategy of developing new water resources, whereas effluent treatment and disposal come under the strategy of environmental protection, with its own rules and regulations.

4. Planned water reuse offers a better supply reliability than that of conventional water sources by ensuring the availability of water, especially in summer, and by allowing fresh water to be used for public supply and environmental enhancement.

5. A river basin system provides an excellent framework for implementing integrated water resources management, in which the economic and financial requisites of water reuse are additional elements in the basin's cost and profit balance sheet.

6. Indirect potable water reuse has been applied for some years as an innovative concept in a number of places around the world, notably in southern California, Belgium, Singapore and eastern Australia. These projects all share a common goal: to generate a new water source for public supply that can be dependable, in contrast with weather changes, by using virtually identical advanced reclamation processes and employing one of the two possible 'naturalisation' options: a coastal aquifer or a storage reservoir.

7. The advanced reclamation facilities available in the Metropolitan Area of Barcelona are an unsurpassed benchmark for introducing an ambitious demostration programme to monitor and research the technical ability to respond to health, environmental and social concerns that may be raised by the health authorities and the general public. This demostration programme could offer a solid reference for promoting self-sufficiency in the Metropolitan Area of Barcelona while generating international scientific and technical competence in managing water resources, a field of considerable importance.

8. Achieving a major framework agreement between urban, agricultural, industrial and leisure users in the context of integrated management of water resources conducted by river basin agencies constitutes a very positive way to meet the fresh water needs of public supplies and water for environmental enhancement, agricultural irrigation and industrial uses.

9. Time has come to consider a qualitative leap in the economics of reclaimed water by estimating its value rather than simply quantifying its cost. The real costs of alternatives such as water transfers and water desalination and particularly of the emergency measures put in place to palliate the effects of droughts, such as those adopted in Catalonia in 2008, clearly demonstrate the enormous financial benefit to be derived from reclaiming and reusing water in comparison with more traditional resource management options.

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