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Water reuse: Overview of current practices and trends in the world with emphasis on EU states

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Abstract: Water reuse has been practiced for over 5000 years; however, during the last 100 years efforts have been made in many regions of the world, for the production of high quality reused water, following strict quality guidelines. Technological advances are now permitting the production of reclaimed water suitable for direct potable pipe to pipe applications. In developed areas with intense water scarcity, water reuse is currently practiced in an efficient way. Such places include Southern USA (primarily, California, Florida, Texas and Arizona), Australia, Singapore, Israel and countries in the Persian Gulf. In Europe, there is a significant variation between the North and the South, with respect to water scarcity, and respectfully with water reuse applications. The states of Southern Europe (with the exception of Malta) have enforced regulations for safe water reuse, to encourage this practice. In some cases, however, (like in Italy and in Hellas), unjustifiable strict regulations may achieve the opposite, due to the difficulty and high cost in monitoring reused water quality. The EU Commission has recently organized a working group to assess the issue at the European level, aiming to establish European quality criteria for water reuse. It is expected that by the end of 2015, a uniform EU strategy on water reuse will be proposed. It is expected that water reuse may contribute in saving of over 30% of total water used, especially in some water deficient regions, with projection for further increase, as more and more wastewater is conveyed to wastewater treatment plants. The present article aims to present an overview on water reuse status worldwide, with emphasis on Europe. It is expected that controlled water reuse will prevail, as more countries will establish quality criteria.

Key words: Israel; California; EU states; Singapore; water reuse, water reclamation, water reuse regulations.

1. PROLEGOMENA

The first historical evidence of effluent reuse for irrigation goes back to the Minoan time (*ca.* 3200-1100 BC), in Crete, Hellas and to Mohenjo-Daro (*ca*. 2600-1900 BC), in Indus valley (Angelakis *et al*., 2005; Angelakis *et al*., 2014). Later on, in the Hellenistic Athens, Hellas, the drains and sewers conveyed storm water and wastewater to a collection basin outside the city, through Eridanos river (De Feo *et al*., 2014). From that basin, the effluents were transferred through ceramic-lined conduits to irrigate agricultural plains. A similar system had been in use at the area southeastern of Acropolis (Tzanakakis *et al*., 2014). In the more recent history, the first large-scale projects of unintended water reuse were set during the period 1500 to 1800 when "sewage farms" were developed near large cities in central Europe, as an attempt to protect public health and to control natural water-systems pollution (Tzanakakis *et al.*, 2014). The great epidemics of cholera and typhoid fever occurred in England during 1830-1850, and their association to the contamination of water sources with raw wastewater, made clear the need for sanitation and for protection of water resources. The latter motivated the health agencies to set sanitation rules and environmental policies to protect public health (Stanbridge, 1976; US EPA, 1979). However, sewage farms were operated in most cases as disposal sites aiming to maximize the volume of wastewater applied per surface area unit, rather than to recycle water efficiently for crop irrigation.

Even though water reuse has been practiced for over 5000 years (Tzanakakis *et al.,* 2007), it is considered as an innovative way to address water scarcity. Water reuse is thus a means for increasing water resources, particularly, but not exclusively, in water deficient areas. The first projects of the intended water reuse were implemented in California at the beginning of the twentieth century. The scarcity of water and the benefits of water recycling to crop yield were the main drivers which promoted the expansion of this practice. The State of California, recognizing the environmental and economic benefits, in line with the potential health risks, set in 1918 the first regulations worldwide governing water recycling in agriculture (California State Board of Health, 1918).

Treated wastewater has been increasingly used around the world for a number of applications, including irrigational, industrial, urban and in some rare cases, for direct potable use (Asano *et al.,* 2007; Paranychianakis *et al.,* 2011; Gikas and Tchobanoglous, 2009a). The major water reuse applications and the relative constrains that prevent expansion, are shown in Table 1. The principal causes preventing the expansion of effluent reuse worldwide are public health and environmental concerns (Marecos do Monte *et al.*, 1996). To reduce the potential risks to acceptable levels, many countries have set regulations or guidelines governing effluent reuse (Angelakis *et al.,* 1999).

Table 1. Major water reuse applications and constrains

Application	Major constrains
Irrigation (both agricultural and landscape)	- Seasonal demand - Usually away from the point of water reclamation
Industrial use	- Constant demand but site specific
Non-potable urban uses	- Limited demand - Requirement for dual piping systems
Recreation/environmental uses	- Site specific
Indirect potable use through groundwater recharge	- Requires suitable aquifer
Indirect potable use through surface water augmentation	- Requires available reservoir between the points of water reclamation and reuse
Direct potable use	- Public perception issues

The scope of this paper is to provide a general overview of the status of water reuse trends and practices. Although the background information on water reuse and the recommendation for further research identified in this study are applicable throughout the world, the primary focus is on the implementation of water reuse in Europe.

2. EMERGING TRENDS AND PERSPECTIVES

The mathematics of the future of the planet are highly troubling with respect to water for food, water for cities and water for energy. Under this frame, wastewater treatment and reuse is generally governed by the following macro drivers.

2.1 Population Growth

It is estimated that by 2050 the world population will increase by an additional 2 billion people (Reiter, 2012). This, inevitably will put pressure to natural water resources, and will trigger the need for exploitation of additional water sources. Sewerage and drainage systems, and especially water reuse, will thus play a vital role in future urban planning and should be reconsidered and redesigned, with emphasis on decentralized wastewater treatment systems, which will allow efficient on-site water reuse (Gikas and Tchobanoglous, 2009a).

2.2 Urbanization

It is estimated that approximately 155,000 inh./d will be added to the Planet between now and 2050. Experts predict that 90% of an additional 1,000,000 inh./wk will live in what are today classified as developing countries, and 90% of the above will live in cities (Reiter, 2012). In most of the cases, it will not be possible to simply extend existing centralized water and wastewater systems to cope with the extra water demand and waste loads. The increasing volume of wastewater and the inadequate infrastructure and management systems are expected to be in the heart of the wastewater crisis (UN, 2010). The expected increase in urbanization will have a series of impacts to the future wastewater management and, especially, to water reuse (Gikas and Tchobanoglous, 2019a). The optimal scenario for municipal wastewater management is the construction of satellite wastewater treatment systems, where reclaimed water will be reused near the point of reclamation (thus, minimizing pumping costs). Reclaimed water will be beneficially used in a number of applications (e.g., for urban non-potable uses, for industrial areas, and for landscape irrigation) (Gikas and Tchobanoglous, 2009a). A satellite wastewater management and water reuse scheme is shown in Figure 1.

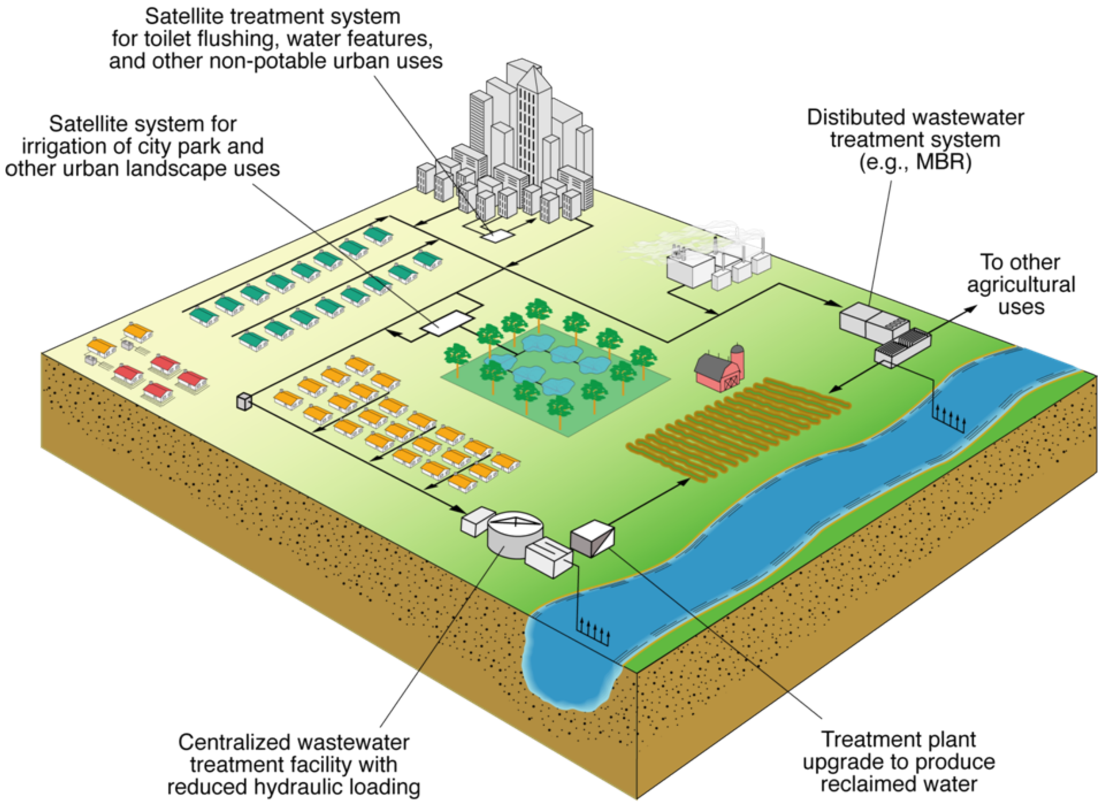

Figure 1. Satellite systems for wastewater treatment and water reuse (courtesy of Prof. George Tchobanoglous).

2.3 Tourist Industry

Mass tourism is a phenomenon developing during the last 50 years. Extensive pressure on water resources is applied in places visited by tourists, thus there is continuous need for the exploitation of additional water sources. Tourists are particularly attracted by insular areas with limited water resources, where, during the tourist season, the population may expand even more than 30 times the permanent population (Dedian et al., 2000). Water reuse from wastewater can be a sustainable solution (Gikas and Angelakis, 2009), as opposed to water importation or water desalination, both of which require large quantities of energy (Gikas and Tchobanoglous, 2009b). Reclaimed water may be used to cover non-potable needs, in applications where potable water is currently used (Gikas et al., 2013)

2.4 Climate Variability

Under the global warming scenario, it is predicted that the world will experience more extreme climatic conditions (more severe floods and droughts) (Aerts, 2009). According to UN (2011), *there* *are also cities that are on sites that are or were relatively safe without climate change, but that now face new levels of risk.* Specifically, an increase in heavy rainfalls may affect the capacity and maintenance of storm water, drainage, and sewerage infrastructure (Douglas, 2008). In some regions of the world the problems of floods and droughts will be more pronounced than in others. For example, the geographical distribution of flood risk is heavily concentrated, regarding Asia, in India, Bangladesh and China, causing high human and material losses (De Feo *et al.,* 2014). Concerning Europe, the region's most prone to a rise in flood frequencies are northern to northeastern Europe (Sweden, Finland and northern Russia), while southern and southeastern Europe (Portugal, Spain, southern France, Italy) show significant increases in drought frequencies (Lehner *et al.*, 2006).

Many of the structures, water supply sources, water and wastewater management facilities and wastewater discharge infrastructure are vulnerable to adverse impacts from climate variability and uncertainty (Case, 2008). The future collecting and conveying sewage as well the sewage disposal systems should be able to adapt in the new urban environment, especially in the coastal areas.

2.5 Water Energy Nexus

With existing sewerage and drainage systems, the search for new ideas is forcing wastewater utilities across the globe to use a range of alternative solutions, which usually demand higher energy consumption (such as long distance networks and sewage pumping). Such practises are expected to further increase the carbon footprint, thus contributing to the climate change problem (Apostolidis, 2010). The primary question many water managers are now asking is: Have we solved one problem and unintentionally created another one? There is a strong correlation between energy and wastewater collection, treatment and reuse. It is, thus, important in delivering solutions in a variable climate world, to consider properly the relationship between water and wastewater management and energy use. In the case of wastewater collection and conveyance, there are novel concepts in recovering energy, and thus, reducing the overall energy footprint (e.g., sewers may be adapted to recover heat from wastewater with heat pumps).

3. WATER REUSE IN EUROPE

3.1 Status of Water Reuse

In EU, more than 84% of the population is connected to wastewater collection services and of this later figure, more than 94% is also connected to one of the 70,000 existing wastewater treatment plants (WWTPs) (Paranychianakis and Angelakis, 2009). The effluent qualities from most of the EU operating WWTPs have been found to comply with the EC Directive 91/271 (Mamais *et al.*, 2002; Raso, 2013). The effluent produced from such WWTPs often has been found to improve the water quality of the receiving rivers (Ilias *et al.*, 2014). The major problem, regarding WWTP effluents, apart of the spontaneous high BOD values, is the increased salts level. Salinity problems are more frequent in WWTPs located in coastal areas, most likely due to seawater intrusion, or intrusion from shallow saline aquifers into the municipal sewerage systems (Ilias *et al.*, 2014). Water with high salt concentrations may result to reduced agricultural productivity and to deterioration of agricultural land quality.

In general, the potential for water reuse in Europe is very high. The percentage of water stress index (WSI, abstraction/availability ratio) is above "moderate" levels in 50% of the EU states, while in 25% of the EU states the WSI is above "high" (Raso, 2013) (Figure 2). More than 200 water reuse projects have been implemented in the EU with an estimated volume of 750 Mm^3/yr (the relative value for USA is 3,850 Mm^3/yr). Also a significant number of water reuse projects are in an advanced planning phase. The water reuse status is quite different between northern and southern

Europe. In southern Europe, water is reused predominantly for agricultural irrigation and for urban or environmental applications, while in northern Europe water is reused mainly for urban, environmental or industrial applications. Water reuse volume at the EU level in 2025 is estimated to about 3,222 Mm^3/yr (Raso, 2013) (Figure 3), which is estimated to save 0,9% of the total water abstraction in year 2025. However, in southern states, e.g., Malta, Cyprus, Hellas and Spain, reused water may cover up to 26%, 7.6%, 5%, and 3%, respectively, of their future water demand.

3.2 Water Reuse Criteria in the EU States

A number of EU states have established their own water recycling regulations in the last few years. Currently, all the Mediterranean states in the EU, except Malta, have established new criteria or have revised the existing ones (Kellis *et al.*, 2013). The water reuse criteria have been issued as regulations. They focus mainly on agricultural and landscape applications, but additional uses, such as recharge for aquifers (not used for potable supply), and environmental uses are also covered in the cases of Hellas, Italy and Spain. Also health criteria for aquifers recharged with reused water have been recommended by WHO (Aertgeerts and Angelakis, 2003). Overall, based on the parameters' thresholds defined, water reuse criteria can be separated into three major categories:
(a) French criteria, which are based on the revised WHO criteria (WHO, 2014) and Australian guidelines.
(b) The Cyprus, Hellas, and Italy regulations, which are more or less based on the Californian regulations.
(c) The Portugal and Spain criteria, which compared to the previous two types, follow an intermediate line.

Hellenic regulations, for example, distinguish three basic effluent qualities (Ilias *et al.*, 2014):
(a) The highest quality refers to urban uses and groundwater recharge (for non-potable aquifers only) with direct injection, and defines a threshold of 2 cfu/100 mL for TC.
(b) The intermediate quality refers to unrestricted irrigation and to industrial uses, except that of cooling water, and defines a threshold of 5 cfu/100 mL for *E. coli*.
(c) The lowest quality refers to restricted irrigation, aquifer recharge through basins and to industrial cooling, and defines the threshold of 200 cfu/100 mL for *E. coli.*

In addition to the effluent quality limits and treatment processes, Hellenic regulations include several barriers for each application. For example, monitoring of several heavy metals and metalloids is required and varies with the capacity of the WWTP from 2 (<10,000 p.e.) to 12 (>200,000 p.e.) times per year. In addition, a set of 40 organic compounds should be monitored two times per year in WWTPs serving more than 100,000 p.e. In conclusion, the Hellenic criteria as well as the Italian ones (which are similar to the Hellenic), impose a number of difficulties to the particularly strict limits and to the high number of parameters considered (74 and 62, respectively, for large WWTP) (Ilias *et al.*, 2014).

3.3 The EU Commission Initiative for Water Reuse at the EU level

A recent initiative of the EU Commission has been undertaken towards the establishment of EU regulations on water reuse. The EU Commission has assigned to the working group "Program of Measures" the development of a strategy for the maximization of water reuse in EU. The relative actions are described below:

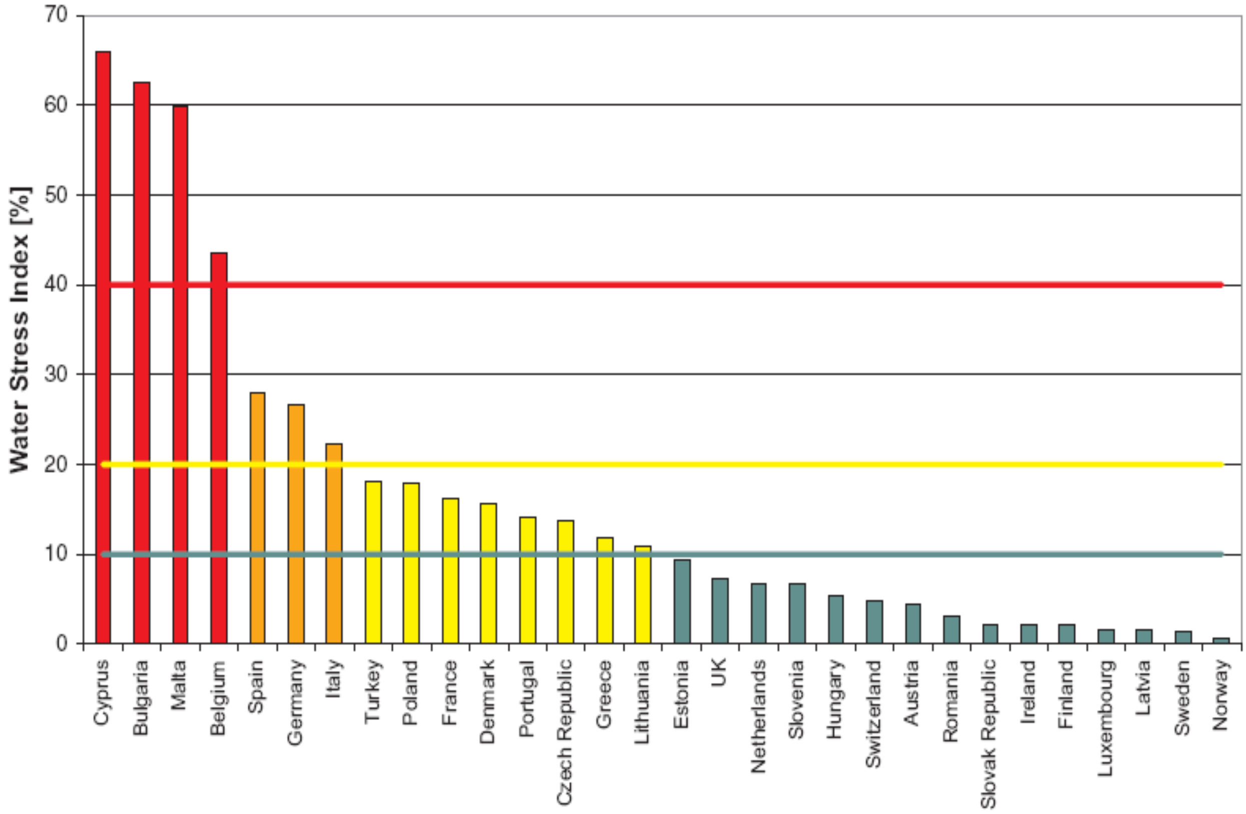

Figure 2. WSI % (abstraction/availability ratio): WSI below 10%, low; WSI from 10% to 20%, moderate; WSI from 20% to 40%, high and WSI above 40%, severe (from Raso, 2013 (with permission)).

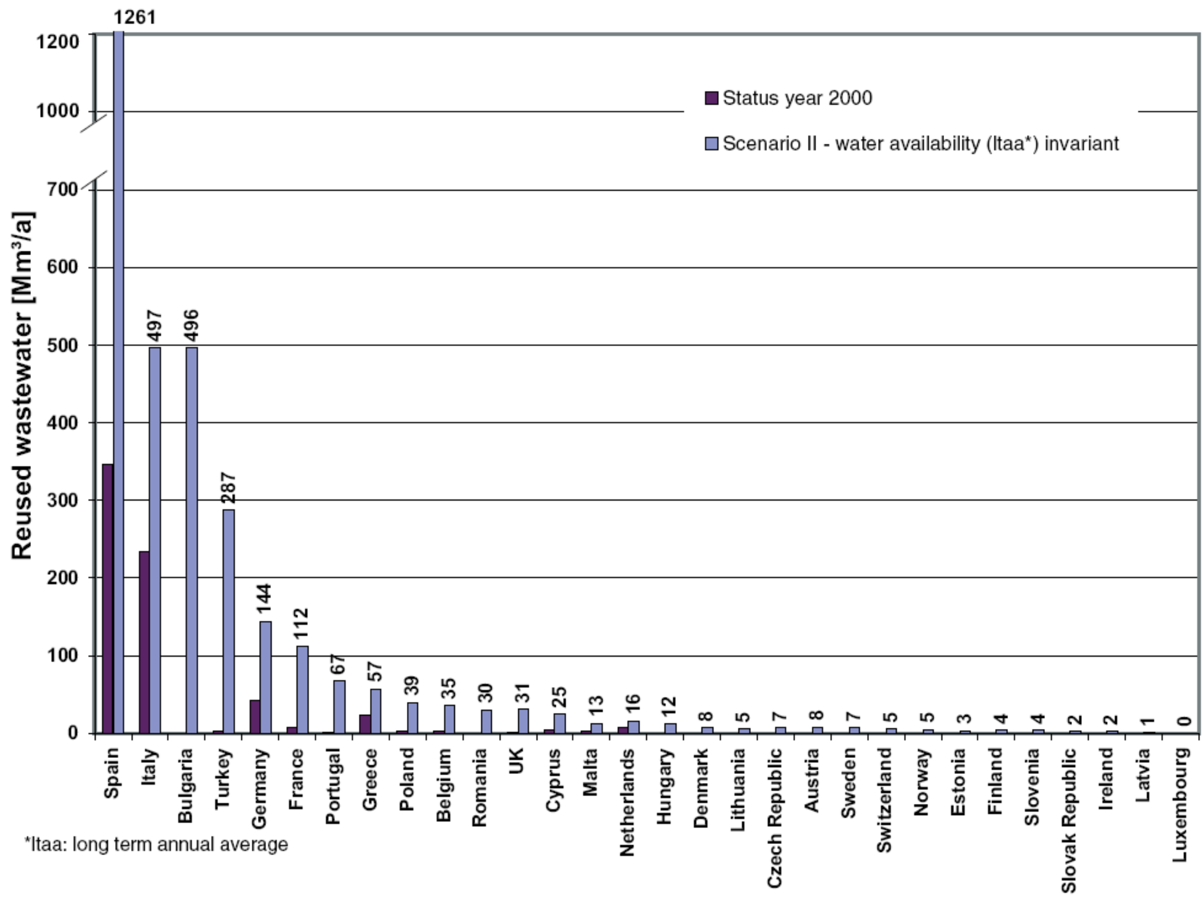

Figure 3. Water reuse in Europe (from Raso, 2013 (with permission)).

(a) DG ENV had tendered a study on "Maximization of water reuse in the EU" in 2013. The objective was to further analyze the possibilities for the maximization of water reuse in the EU, and to assess the environmental, economic and social impacts of the proposed measures/combination of measures, and to elaborate those that could bring the most benefit in terms of water availability, as well as to provide support for the stakeholders/public consultations. A contract on the above matter was awarded to a consortium led by Bio-Intelligence, which was initiated in September 2013. The CIS WG "Program of Measures" dedicated a session to Water Reuse during the meeting in March 2014.
(b) The scheduled public consultations are planned to start during summer 2014, by the distribution of a questionnaire. The results will be finalized by the end of 2014.
(c) A stakeholders meeting has been scheduled for December 2014 and an EC Impact Assessment Board meeting for March 2015.
(d) Finally, following the conclusion of the impact assessment, expected by the end of 2014, the Commission intends to submit the most suitable measure/s on water reuse to the Impact Assessment Board for an opinion in the 1st half of 2015. In case of a positive opinion on the proposed measure/s, the adoption of the EU-level instrument on water reuse by the Commission is envisaged by the end of 2015 (http://ec.europa.eu/environment/water/blueprint/follow_up_en.htm).

It is expected that the EU will follow the trends of the rest of the developed world. The Commission aims to look into the most suitable EU-level instrument to encourage water reuse, including the possibility of establishing a regulation with common standards. More on this and the status of water reuse in EU states are given by Paranychianakis *et al*. (2014). The Commission intends to make a proposal in 2015, subject to an appropriate impact assessment, to ensure the maintenance of a high level of public health and environmental protection in the EU (http://ec.europa.eu/environment/water/blueprint/follow_up_en.htm).

4. WATER REUSE PARADIGMS AROUND THE WORLD

There are at least over 60 countries around the world practicing various types of water reuse. It is difficult to conclude which countries are reusing the largest volumes of wastewater due to the lack of international standardized databases. It is also difficult to compare the intensity of reuse in countries with different population and area size. With respect to total annual volume, China, Mexico and the United States (mainly California, Texas, Arizona, and Florida) are the countries with the largest quantities of water reused. However, in the first two cases, reused water is mostly poorly-treated wastewater. When considering the intensity of reuse per inhabitant, Qatar, Israel and Kuwait are the countries first ranked, while when considering the percentage of reuse related to the total volume of fresh water used, Kuwait, Israel and Singapore become the first ones (Jiménez Cisneros, 2014). When the technological achievements are considered California, Singapore and Japan are probably pioneers.

4.1. Singapore

Treated wastewater has been reused for indirect potable uses (primarily through the recharge of the potable aquifers); however, despite the technological progress, public opinion tends to view potable uses of reused water with scepticism. Singapore is an island with an area of 699 km^2 and a population density of about 6,200 inh./km^2. It has developed all possible water sources, while water is also imported through a pipe, from neighbouring Malaysia. The government has launched a program for the reduction of water consumption per capita, which was reduced from 165 L/inh.d in 2003 to 155 L/inh.d in 2009, and it is expected to further drop to about 147 L/inh.d by 2020 (http://www.globalwaterintel.com/archive/11/7/general/singapore-aims-1-million-m3d-desal.html).

In an effort to explore the possibility of reusing wastewater for industrial and potable uses, the government of Singapore (through the Public Utilities Board) launched in 2000 a wastewater recycling demonstration project with an initial capacity of 10,000 m^3/d. Thus, a portion of the treated effluent from the Bedok Sewage Treatment Plant was diverted to the water purification plant (called the *NEWater Factory*) which included microfiltration (MF), reverse osmosis (RO) and ultraviolet radiation (UV) disinfection units (Giap, 2005; Law, 2003; Singh, 2005). The quality of reused water (called NEWater) was assessed using a number of analytical methods, including toxicity tests in fish and mice (Ong *et al.*, 2004; Singapore Public Utilities Board, 2002). Initially, the production of NEWater was at 72,000 m^3/d, but now it has been considerably expanded. NEWater is primarily used in industrial applications and in cooling towers, however, a small amount is injected to the potable water reservoirs (accounting for less than 2.5% of the total water supply) (Singapore Public Utilities Board, 2002). As the contract with Malaysia for water importation will expire in 2061, Singapore is preparing to increase the use of NEWater to 50%, in case that the contract will not be renewed (Figure 4). Water reuse project in Singapore has been well accepted by the public, as a result of a systematic governmental promotion program.

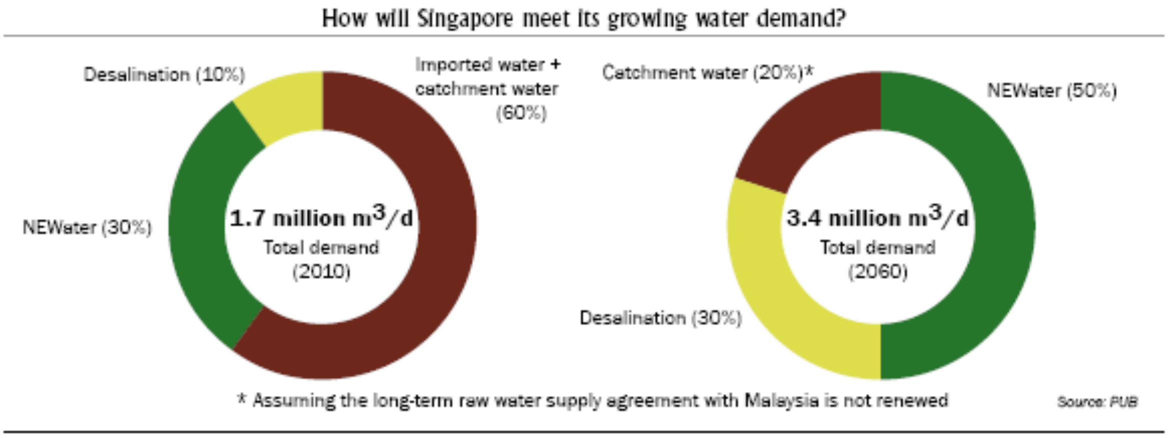

Figure 4. Water sources in Singapore in 2010, and projection for 2060 (in case that water importation from Malaysia is terminated) (Source: http://www.globalwaterintel.com/archive/11/7/general/singapore-aims-1-million-m3d-desal.html, accessed June 29, 2014)

4.2. Israel

A significant fraction of Israel's agricultural goods is produced in Negev desert (about 100 km south of Tel Aviv), using reclaimed water, which is conveyed from Tel Aviv. The bulk volume of wastewater from greater Tel Aviv (approximately 350,000 m^3/d) is treated at the Dan wastewater treatment and reclamation plant. The Dan wastewater treatment plant comprises pre-treatment processes, anaerobic selectors (for phosphorus removal), activated sludge with anoxic and aerobic zones, and secondary clarification (Idelovitch and Michail, 1984). Secondary treated effluent is then pumped to four recharge basins covering a total area of 80 ha, where the water initially percolates vertically into the aquifer for 15-30 m, and then spreads horizontally. The infiltration capacity is maintained by alternate flooding and drying. The relative conceptual diagram of wastewater treatment and water reclamation is shown in Figure 5.

The water is recovered by approximately 100 wells, located 300 to 1,500 m from the recharge basins, and then it is piped about 100 km south, where it is distributed for unrestricted agricultural irrigation. A fraction of the water is temporarily stored in a number of local storage tanks, with a combined volume of approximately 10 Mm^3. The quality of reused water is significantly improved during percolation through the aquifer, thus BOD, COD, TN and TP are further reduced by more than 75 percent (Idelovitch *et al.*, 2002), while total and faecal coliforms, faecal streptococcus and enteroviruses are non-detectable after water recovery. Biofouling in the conveyance piping system is controlled by a combination of mechanical cleaning (pigging) and chloride dosing (Icecton Tal *et al.*, 2002).

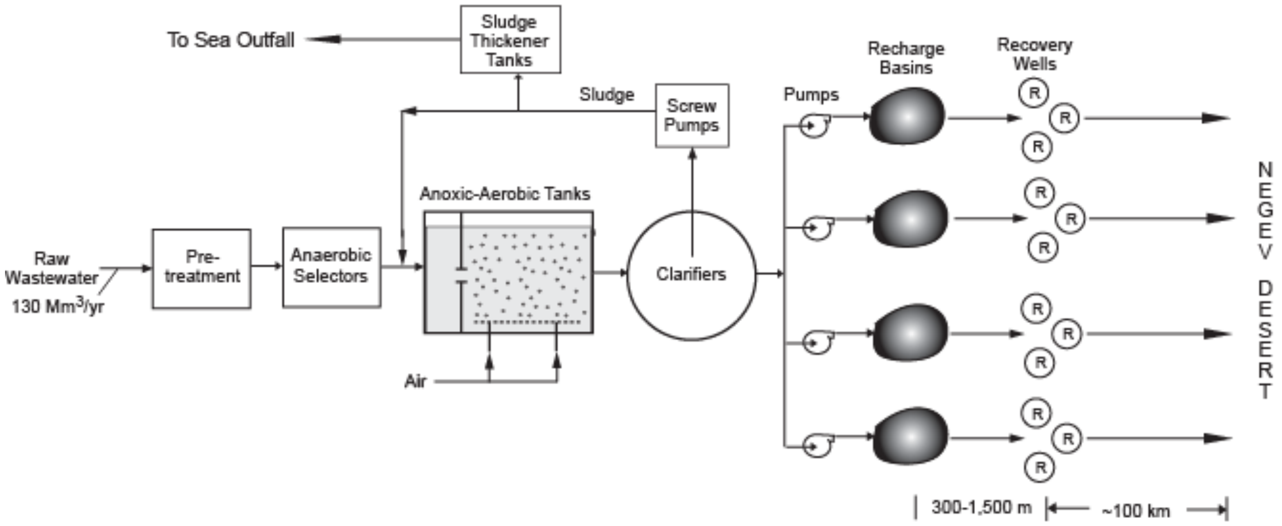

Figure 5. Schematic diagram of the wastewater treatment plant of Tel Aviv in Dan region and recharge basins (Adapted from Icecton Tal et al., 2002)

4.3 California

The state of California is a pioneer regarding water reuse, as it has introduced regulations since 1918 (California State Board of Health, 1918), and since then, they have been revised a number of times, to account for the mew findings and the new technological advances. Treated wastewater, which complies with the current water reuse quality criteria is of high quality and safe if used according to the regulations (California Department of Public Health, 2014).

California is a state with high variability of water availability between North and South. Northern California is rich in water resources and sparsely populated, while Southern California is densely populated and has limited water resources. The major strategy for water supply in Southern California, and more specifically in the Grater Los Angeles and Greater San Diego areas, was by water conveyance from the North, via a system of channels and pumping stations, and the utilization of Colorado River water. However, the main constrain for water conveyance from the North to the South is the Tehachapi Mountains, located between Fresno and Los Angeles, which impose the use of pumping stations, thus increasing the energy requirements. An analysis of the power consumption for water supply and wastewater treatment in Northern and Southern California is shown in Table 2. Also from Table 2, it is obvious that the energy requirements for water supply and wastewater treatment in Southern California is over three times that of Northern California, while the cost of water supply (excluding local distribution) is approximately 60 times higher, respectively. On the other hand, just the city of Los Angeles is currently discharging treated wastewater into the ocean at a rate of about 1.5 Mm^3/d (Leverenz *et al*., 2011).

Table 2. Typical electrical power consumption for urban water supply and wastewater treatment in Northern and Southern California (George Tchobanoglous, personal communication).

System	Power consumption (GWh/Bm^3)	
	Northern California	**Southern California**
Supply and conveyance	0.57	33.69
Water treatment	0.38	0.38
Distribution	4.54	4.54
Wastewater treatment	9.46	9.46
Total	**14.95**	**48.07**

The energy required for water supply to the Orange County water system is significantly higher, compared to the energy required for the reuse of high quality water. Based on a recent study (Tchobanoglous *et al*., 2011), the relative energy requirements for supplying 1 m^3 to the above system are 3.00 kWh for desalinated seawater, 2.83 kWh for State Project water, 2.03 kWh for Colorado River water and 0.65-1.22 kWh for the high quality reclaimed water from treated wastewater. However, water reuse in agricultural or landscape applications or even for indirect potable reuse through storage in appropriate aquifers is generally restricted due to various factors, which are summarized in Table 3.

Table 3. Main constrains for various water reuse applications in Southern California

Application	Main constrains
Agricultural irrigation	Large distance between recycled water and agricultural demand Need to provide winter storage
Landscape Irrigation	Dispersed nature of landscape irrigation Cost of parallel distribution system
Indirect Potable Reuse	Most communities lack suitable hydrology for groundwater recharge Availability of nearby suitable surface storage

Based on the above, it looks that the most favorable option is the reclamation of high quality water at the wastewater treatment plants of Southern California, and reuse it for direct potable applications (Figure 6). Figure 6 also depicts the elevations that water has to be lifted during conveyance from Northern to Southern California, and the obstacle of Tehachapi Mountains. By reclaiming water in Southern California, not only the water scarcity problem of this area will be ameliorated (at low energy expenses), but will also release water for beneficial uses in Northern and Central California (right map in Figure 6).

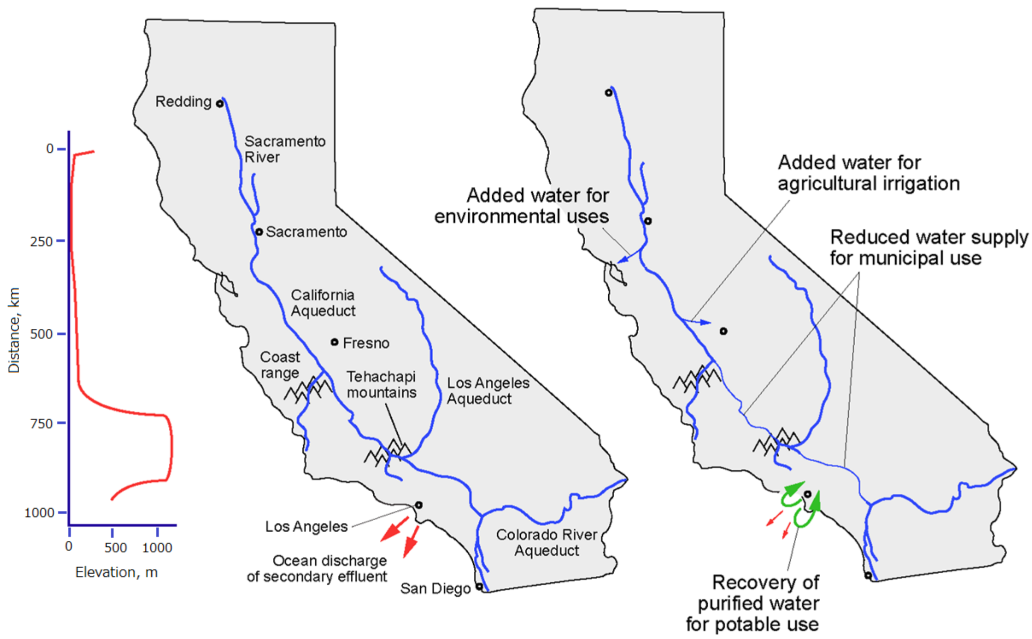

Figure 6. Current (left map) and proposed (right map) situation for water supply to Southern California. Water reuse for direct potable applications seems the most favourable solution to the water sacristy of the South. The diagram at the far right shows the elevations that water has to be lifted during conveyance from Northern to Southern California (Courtesy of Prof. George Tchobanoglous).

5. CONCLUSIONS AND RECOMMENDATIONS

Water reuse is practiced in several regions of the world. In most of the developed world, water reuse is practiced in a controlled way, as strict quality criteria are enforced. In Europe, a common strategy on water reuse does not exist, however, the EU Commission has recently organized a working group to assess the issue at European level. It is expected that by the end of 2015, a uniform EU strategy on water reuse will be proposed.

Nowadays, the European South is leading on water reuse in the European continent. Water reuse quality criteria in South European states are either derived from the California guidelines (e.g., Hellas, Cyprus and Italy) or from the Australian guidelines (e.g., France), or from a combination of the above (e.g. Spain and Portugal). However, water reuse may be discouraged in cases that the states enforce unjustifiably strict water quality criteria (such as in Italy and Hellas, where over 60 parameters have to be monitored in large WWTPs.

Singapore, California and Israel, are leading in wastewater treatment and reuse, as they use high technological processes for the production of superior quality reused water.

Water reuse will be a critical element in the development of sustainable strategies for water resources management. Technology is now available to produce water for any use, including direct potable pipe to pipe reuse. A saving of up to 30% in total water use may be achievable in some regions by proper water recourses management, including the production of high quality water from WWTPs, for reuse. The aforementioned percentage may increase further in the near future as the percentage of wastewater conveyed to WWTPs for treatment increases, and as WWTPs are upgraded to produce effluent complying with the reuse guidelines. In order to achieve this, national water policy should be improved and extended to encourage the safe use of recycled water for various applications. It is expected that controlled water reuse will prevail, as more countries will establish quality criteria.

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