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# Urban Water Reuse in Tourism Areas

António Albuquerque
*University of Beira Interior*

José Saldanha Matos
*University of Lisbon*



## 26.1 Introduction

Over the past decades, treated wastewater (reclaimed water) has been used as an alternative to potable water for a range of uses such as irrigation (landscapes, golf courses, and agricultural fields), aquifer recharge, industry applications, stream flow feeding, and nonpotable urban applications. In that period, there have been significant advances in reuse technologies, and an increase in the implementation of either rules or guidelines for water reuse.

The expected increase of population and changes in land use, sea level rise, and local climatic dynamics will continue demanding water supply challenges in many areas of the world, which can negatively affect the regions that have important economic benefits from tourism. These circumstances have forced planners to consider nontraditional water sources while maintaining environmental stewardship [8]. The water generated in tourist areas (namely stormwater and domestic wastewater), after treated and converted to reclaimed water, is seen as a valuable and alternative water resource to conventional water supplies for a range of applications.

According to the European Commission [12], droughts have increased in number and impact and in 2011 and 2012, water scarcity has affected large parts of Southern, Western, and even Northern Europe, with impact on economic activities connected with tourism. The number of areas and people affected is around 20% and the total costs of droughts amounted to 100 billion €. Tourism is a priority matter for the sustainable development in many countries and one of the concerns is the increase of water shortages as a consequence of the expected climate change [14,44].

Tourism generates one of the biggest pressures on water needs that coincides with the necessity to manage decreasing water resources more efficiently. Water consumption presents very atypical patterns compared with urban areas, which are related to seasonal people concentration (normally coincides with the period in which water resources are scarce), spatial concentration on coast areas (both urbanized and remote sites, normally presenting scarcity of local water resources and often located on sensitive natural sites), and use of facilities that consume large volumes of water (e.g., aquatic parks, swimming pools, golf courses, and spas). Additionally, the water and wastewater systems are designed for dealing with large variation of flow rate, which results in frequent problems for water management authorities.

As tourism areas continue to grow, pressure on local water sources will continue to increase and significant environmental, economic, and social impacts can arise where local freshwater supplies are limited or are available only with large capital investment. Mature tourist resorts over the world are developing activities that increase permanent water demand for facilities and leisure structures (e.g., golf courses, spas, aquatic parks, swimming pools, and gardens), as reported, for example, in Australia [21], French Polynesia [23], Portugal [42], Spain [18], Israel, Jordan, Morocco, and Tunisia [11].

The water-energy nexus points out that water and energy are mutually dependent [33]. This concept is also applied to water reuse because energy efficiency and sustainability are important keys for its application, which makes this type of water resource so essential to sustainable water management. The energy-water connection is particularly strong in regions with important water scarcity. Water reuse can significantly reduce energy consumption by eliminating some potable water treatment requirements and associated water conveyance (because reclaimed water can offset potable water use for some applications), protect dry areas from drought, lower consumers' utility bills, and reduce global warming pollution [36]. According to the California Energy Commission [5], approximately 20% of the electricity consumed in the state of California is associated with water-related energy use, including potable water conveyance, storage, treatment, distribution and wastewater collection, treatment, and discharge, and the energy required for treatment and transport of potable water is much greater than the amount required for polishing wastewater for reuse. Water reuse fits well the concept of sustainability because it allows other sources of water to remain in the environment and be preserved for future uses while satisfying some water demand of the present. The water-food nexus is also obvious in the face of the potential of reclaimed water to be used for farming purposes, increasing productivity, and contributing to employment and local economic development.

The integration of water reuse in water management strategies will contribute to reducing discharges to receiving waters and reducing reliance on natural water sources to meet water demands. In tourism areas, there are several opportunities for reusing reclaimed water produced from domestic wastewater, stormwater, and graywater. Reuse applications in tourist areas have been greatly developed over the past decade for landscape irrigation, urban applications (e.g., garden watering, car washing, and toilet flushing), wetland nature reserves, hydroponics applications, agricultural irrigation (e.g., turf farms, vineyards, and silviculture), and golf course irrigation [1,21]. Ecological treatment systems (e.g., constructed wetlands, sand filters, or rock filters) have been shown to be suitable for producing reclaimed water from domestic wastewater [25,30,38,51], stormwater [2,37,45] and graywater [31,34]. Therefore, the objective of this chapter is to address the potentialities and opportunities for reusing treated domestic wastewater, stormwater, and graywater in tourist areas, including aspects of risk control, regulation, and economical evaluation.

## 26.2 Urban Wastewater Characteristics and Challenges of Reuse

### 26.2.1 Urban Wastewater Characteristics

Urban waters produced at tourism areas are essentially composed of domestic wastewater and stormwater. These waters can be collected separately (by separate sewer systems) or jointly (by combined sewer systems). Older sewer systems typically constructed before the 1950s are combined, while more recent systems were designed as separate or partially separate systems. In many countries, for example, in Mediterranean countries, the tourism season occurs mainly during summer, with very low average precipitation. Impact of tourism can lead to triplicate the average flows and aggravate the hourly peak factor, affecting sewer performance (e.g., risks of overflows) and the efficiency of treatment plants. In any case, the wastewater presents a variety of substances (Table 26.1), populated by diversity of microorganisms, many of which are of fecal origin and some are pathogenic, which can be considerably removed through secondary and tertiary treatment. However, these treatment levels do not remove all the harmful compounds and pathogens, and a residual load is usually discharged into water resources. Therefore, surface water and groundwater abstraction for producing drinking water normally configures a case of indirect and not planned water reuse.

Urban waters can be treated through a variety of physical, chemical, and biological processes, as presented in References 46 and 1, in order to produce final reclaimed water for discharging into a water stream or for reuse. The typical quality of

**TABLE 26.1** Urban Water Characteristics

| Parameters | Domestic Wastewater + Stormwater[a,b,c] | Domestic Wastewater[b,c,d] | Stormwater[e,f,g] |
|---|---|---|---|
| pH | 6.9–8.8 | 6.7–8 | 5.2–8 |
| Conductivity (μS/cm) | 820–1 320 | 540–1100 | 12–1480 |
| TSS (mg/L) | 200–450 | 390–1230 | 35–90 |
| $NO_3$-N (mg/L) | 0–3.3 | 0–4 | 0.4–2.2 |
| $NH_4$-N (mg/L) | 12–40 | 20–80 | 0.4–2 |
| TN (mg/L) | 20–60 | 36–88 | 0.9–4.5 |
| TP (mg/L) | 4–13 | 4–15 | 0.2–0.9 |
| $BOD_5$ (mg/L) | 110–400 | 250–1100 | 8–30 |
| COD (mg/L) | 250–800 | 450–1900 | 40–175 |
| Oil and grease (mg/L) | 90–475 | 40–150 | 3–60 |
| Al (mg/L) | 0.1–1.1 | 0.3–1 | — |
| Cd (mg/L) | 0.01–0.1 | 0.001–0.004 | 0.05–0.3 |
| Cr (mg/L) | 0.01–0.1 | 0.01–0.04 | 0.05–0.14 |
| Cu (mg/L) | 0.02–0.2 | 0.03–0.08 | 0.05–0.8 |
| Fe (mg/L) | 0.6–8 | 0.2–4 | — |
| Ni (mg/L) | 0.02–0.1 | 0.01–0.04 | 0.3–0.6 |
| Pb (mg/L) | 0.01–0.2 | 0.02–0.08 | 0.05–0.9 |
| Zn (mg/L) | 0.1–0.2 | 0.1–0.3 | 0.3–1,2 |
| Total coliforms (MPN/100 mL) | $10^7$–$10^9$ | $10^{11}$–$10^{13}$ | $10^2$–$10^6$ |
| Fecal coliforms (MPN/100 mL) | $10^5$–$10^8$ | $10^9$–$10^{11}$ | $10^1$–$10^4$ |
| Fecal streptococci (MPN/100 mL) | $10^4$–$10^6$ | $10^6$–$10^8$ | $10^2$–$10^4$ |

[a] Marecos do Monte and Albuquerque [26].
[b] Asano et al. [1].
[c] Tchobanoglous et al. [46].
[d] von Sperling [48].
[e] EPA [6].
[f] Pitt [39].
[g] Hvitved-Jacobsen and Yousef [19].

Q5

Q6

**TABLE 26.2** Typical Characteristics of Reclaimed Water after Secondary Treatment of Urban Waters

| Parameters | Reclaimed Water[a,b,c] |
|---|---|
| pH | 7.2–8 |
| Conductivity (μS/cm) | 300–900 |
| TSS (mg/L) | 10–50 |
| $NO_3$-N (mg/L) | 0–3 |
| $NH_4$-N (mg/L) | 10–20 |
| TN (mg/L) | 5–15 |
| TP (mg/L) | 5–10 |
| $BOD_5$ (mg/L) | 20–40 |
| COD (mg/L) | 80–140 |
| Al (mg/L) | 0.04–1 |
| Cd (mg/L) | 0.003–0.14 |
| Cr (mg/L) | 0.02–0.1 |
| Cu (mg/L) | 0.01–0.25 |
| Fe (mg/L) | 0.5–3.5 |
| Ni (mg/L) | 0.01–0.15 |
| Pb (mg/L) | 0.01–0.1 |
| Zn (mg/L) | 0.1–0.2 |
| Total coliforms (MPN/100 mL) | $10^4$–$10^7$ |
| Fecal coliforms (MPN/100 mL) | $10^3$–$10^5$ |
| Fecal streptococci (MPN/100 mL) | $10^2$–$10^4$ |

[a] Tchobanoglous et al. [46], EPA [7], WHO [50], Asano et al. [1], Marecos do Monte and Albuquerque [26].

reclaimed water after secondary treatment is presented in Table 26.2. Comparing Table 26.1 and Table 26.2, it can be noted that heavy metal and pathogen removal is not significant and polishing treatment may be needed (e.g., membrane technology and disinfection) if higher quality of reclaimed water is required. In remote resort areas, onsite wastewater treatment systems and ecological treatment processes are, in general, a more sustainable solution, using land treatment options, including wetlands and pond systems. Stormwater runoff presents higher quality than domestic wastewater or urban water, but can still need some treatment for removing trash racks, sediment traps, pathogens, and inorganic and organic compounds.

The wastewater produced by bathtubs, bathroom washbasins, clothes washing machines, and laundry tubs, known as graywater, presents advantages for reuse because it does not typically include kitchen and toilet wastewater, which have higher pollutant content and pathogens. Although feces and urine are not present, the quality of graywater is highly variable and can contain chemicals and pathogens that can be harmful for users and the environment (Table 26.3). Therefore, suitable treatment is also needed before its reuse.

According to Kavanagh [21], in Australian cities, stormwater runoff is equivalent to the amount of drinking water that is supplied. More than half of the drinking water is used for lower water quality purposes including garden watering and toilet flushing. Stormwater presents a high potential to be reused for non-drinking purposes and to markedly reduce the demand for drinking water [32].

**TABLE 26.3** Graywater Characteristics

| Parameters | Bathroom Water[a,b] | Laundry Water[a,b] | Graywater[c] |
|---|---|---|---|
| pH | 6.4–8.1 | 9.3–10 | 5–9.9 |
| Conductivity (μS/cm) | 82–250 | 190–1400 | 330–580 |
| Color (Pt/Co) | 60–100 | 50–70 | – |
| Turbidity (NTU) | 60–240 | 50–210 | 20–140 |
| TSS (mg/L) | 48–120 | 88–250 | 20–1500 |
| $NO_3$-N (mg/L) | 0.05–0.20 | 0.10–0.31 | 0–4.9 |
| $NH_4$-N (mg/L) | 0.1–15 | 0.1–1.9 | 0.1–8.1 |
| TKN (mg/L) | 4.6–20 | 1.0–40 | 0.6–50 |
| TP (mg/L) | 0.11–1.8 | 0.062–42 | 0.3–35 |
| $BOD_5$ (mg/L) | 76–200 | 48–290 | 33–620 |
| Oil and grease (mg/L) | 37–78 | 8.0–35 | – |
| Alkalinity (mg/L) | 24–43 | 83–200 | 125–382 |
| Ca (mg/L) | 3.5–7.9 | 3.9–12 | 4–824 |
| Mg (mg/L) | 1.4–2.3 | 1.1–2.9 | 1–15 |
| Na (mg/L) | 7.4–18 | 49–480 | 32–1090 |
| K (mg/L) | 1.5–5.2 | 1.1–17 | 4.5–13 |
| Al (mg/L) | <1.0 | <1.0–2.1 | 0.02–0.67 |
| As (mg/L) | 0.001 | 0.001–0.007 | – |
| B (mg/L) | <0.1 | <0.1–0.5 | – |
| Cd (mg/L) | <0.01 | <0.01 | <0.01 |
| Cl (mg/L) | 9.0–18 | 9.0–88 | 3.1–136 |
| Cu (mg/L) | 0.06–0.12 | <0.05–0.27 | 0.15 |
| Fe (mg/L) | 0.34–1.1 | 0.29–1.0 | 0.79–28 |
| Se (mg/L) | <0.001 | <0.001 | – |
| Zn (mg/L) | 0.2–6.3 | 0.09–0.35 | 0.38 |
| Total coliforms (MPN/100 mL) | $500–2.4 \times 10^7$ | $2.3 \times 10^3–3.3 \times 10^7$ | – |
| Fecal coliforms (MPN/100 mL) | $170–3.3 \times 10^3$ | $110–1.09 \times 10^3$ | $17–1.6 \times 10^5$ |
| Fecal streptococci (MPN/100 mL) | $79–2.4 \times 10^3$ | $23–2.4 \times 10^3$ | $19–1.51 \times 10^3$ |

[a] Boal et al. [4].
[b] Lechte et al. [24].
[c] Jeppesen [20].

Therefore, domestic wastewater, stormwater, and graywater are urban waters with potential to be reused after treatment in the form of reclaimed water.

## 26.2.2 Challenges of Reuse

The main constraints of water reuse in densely populated tourist areas are the greater probability of unknowingly exposing the public to reclaimed water and the lack of adequate regulations for allowing application in uses such as urban applications and golf course and landscape irrigation [23]. Many resorts will have to cope with increasing water demand and tourist flows, changing in climatic variables, and more droughts [18].

The Mediterranean region is one of the world's top tourism destinations and tourist flows to this region are constantly increasing (4% of the world total in 1990 and 6% in 2005, according to the European Commission [11]. Water resources are limited and unequally distributed in space and time, thus exacerbating the pressures. Water consumption and water reuse by the tourism sector is not well documented by statistics and, therefore, it is difficult to assess the impact it has on water resources. Nevertheless, several water reservoirs are already under pressure and water supply increasingly relies on reclaimed water reuse or desalinized water, being necessary new tools and water management strategies for the tourism sector [11,14]. The expected trend for the near future is an increase in water consumption to satisfy the growth of tourists (396 million persons are expected in 2025 compared to 166 million in 1995), which look at comfort requirements and water consuming facilities such as swimming pools, aquatic sports, spas, and golf courses.

The residential sector has been grown around the tourist centers, with most houses having been built as second homes, often with high water needs for garden watering and swimming pools, which creates an increase in water consumption in the season of low rainfall and high evapotranspiration [9,44]. Additionally, the changes in garden design, using imported garden plants, and some garden irrigation practices are leading to significant differences in water consumption of tourist landscapes differentiated by land use pattern [18].

Remote tourist resorts normally are not connected to public water supply networks or sewer networks and wastewater treatment solutions normally involve natural systems such as septic tanks and filtration devices (typically filtration trenches or soak ways) or constructed wetlands, sometimes coupled with a disinfection system (e.g., UV or maturation ponds). This association of technology is normally sufficient for getting reclaimed water with the minimal quality for garden watering, toilet flushing, and car and boat washing.

Wastewater treatment technologies are now advanced enough to mitigate pathogens and chemical contaminants in reclaimed water, offering a multitude of process combinations that can be tailored to meet specific water quality objectives. Therefore, the concept of "fit for purpose" is highlighted to emphasize the efficiencies realized by designing reuse for specific end applications [35].

Health safety and economic viability are essential for some water reuse practices and can be achieved through suitable combinations of wastewater treatment technologies and best practices in the application sites. Two good examples are agricultural irrigation, which demands food security, and golf course and landscape irrigation, which allows contact between reclaimed water and users.

The public education and acceptance is essential for the success of setting up wastewater reuse projects in tourist areas. Periodic public presentations and discussion of projects should be organized with municipalities, professional organizations, end-users associations, consultants, public health authorities, and public representatives in order to evaluate the expected economic, social, and environmental benefits.

## 26.3 Potentialities and Opportunities for Reusing Reclaimed Water

Domestic wastewater, stormwater, and graywater produced at tourist areas, after converted in reclaimed water, are suitable for the irrigation of public parks, lawns and landscape, urban nonpotable applications (e.g., toilet flushing, washing of cars, municipal equipment, roads and pavements, and garden watering), and filling water nature reserves as well as for some agricultural activities.

According to Kavanagh [21], sustainable water management at tourist resorts should incorporate water reuse measures associated with water saving measures such as

- Rainwater should be reused as a water source.
- Extracted water should be returned to the source with no loss in quality.
- Treated wastewater should be reused for all nonpotable purposes.
- If possible, graywater should be kept separate from blackwater.
- Water saving devices should be used where possible.
- Dry composting toilets should be used.
- Xeriscape (low water) gardens should be employed.
- Wastewater should be treated according to the standards for the defined uses, utilizing a minimum of chemicals and energy.

Irrigation may use direct reuse, normally involving a reclaimed water distribution network, or indirect reuse, normally involving the discharge of reclaimed water into a water stream and then retrieved to be used again, providing additional benefits such as wildlife and wildfowl habitat, water quality improvement, flood diminishment, and fisheries breeding grounds. Indirect reuse also provides a polishing treatment because it allows an additional removal of residual pollutant load and pathogens elimination.

Golf courses represent another opportunity for water reuse. In many ways, it can be seen as agricultural fields, having a soil/plant/atmosphere consortium that is linked by the water needed for the plants to grow and presenting high evapotranspiration rates. The water consumption can rise up to 2500 $m^3$/day in a dry, hot season, depending on its dimension, local climate, water retention properties of substrata, and water requirements of turf [42]. A standard 18-hole golf course has an irrigated surface of 54 ha, and the annual average water consumption is approximately 0.3 $Hm^3$. Presently, water authorities in several countries (e.g., France, Spain, Portugal, and the United States) are already imposing the use of reclaimed water for the irrigation of golf courses and several projects submitted to environmental impact assessment evaluation have been approved conditionally to the use of reclaimed water.

The combination of water with low salinity and a high concentration of exchangeable sodium (which is common in desalinated regenerated water) can have a negative impact on the structural stability of soil, which loses fertility over the medium term because of losing its capacity to drain away water. Estévez et al. [10] have analyzed data and practices of reclaimed water reuse in golf courses of Canary Islands (Spain) for over 25 years, having concluded that is better to adapt the local plant species and varieties watered, instead of choosing species that are more tolerant of salinity. This practice would reduce the polishing requirements for high-quality reclaimed water producing. Other measures for getting water savings would include the adjustment of the volume and frequency of watering according to plant needs and evapotranspiration.

Other projects have considered the production of high-quality reclaimed water for several applications. The island of Bora Bora has implemented a reuse project [23], which has involved the upgrading of the wastewater treatment plant (WWTP) of Povai with an advanced membrane treatment to produce high-quality reclaimed water for toilet flushing in hotels, public spaces cleaning and landscape irrigation, boat and sea plane washing, filling of fire reservoirs of fire protection boats, washing of construction engines and pressure tests of concrete, and fire protection in buildings. The project has generated a good cooperation between the stakeholders, which was essential for the success of the project.

A study set up in the Llobregat Delta in Spain [16] has shown how water reuse and exchange can be a cost-effective approach to managing water scarcity at the basin level. The cost-benefit analysis has pointed out a total water-exchange cost of 5.2 million € per year, with an annual benefit of 14.4 million € from an additional 13 million $m^3$ of freshwater released from agricultural use. Farmers would save about 351,000 € per year due to the reduction of costs with water pumping systems and fertilizer use. The annual global savings would be approximately 9.5 million €.

## 26.4 Regulation and Risk Control

Water reuse practices require strict control, which can be set up through the quality control of the reclaimed water or the risk management of the reuse procedures. Before reusing reclaimed water, it is necessary to evaluate if that water resource is safe for reuse, which can be done by applying traditional methods of comparing it with standards or using hazard/risk assessment tools as mentioned by Salgot et al. [42].

Regulations have been created for helping the control of reclaimed water quality and the reuse procedures. However, their efficiency depends on economic and social circumstances, legal capacitation by implicated entities and administrative bodies, human health/hygiene level (endemic illnesses, parasitism), technological capacity, previously existing rules and/or criteria, analytical capacity, risk groups possibly affected, and technical and scientific opinions [41]. Therefore, three groups of factors can be considered: technical and technological issues (e.g., analytical, treatment methods, capacity, and knowledge), legislative and economic issues (e.g., criteria, socio-economic, and legal competence), and health-related issues (e.g., sanitary state, diseases, and risk groups).

Regulations have been based traditionally on microbiological quality considerations [42]. More recently, chemical and toxicological considerations have been integrated, but qualitative aspects still need to be adjusted, not necessarily by increasing the number of analyses or adopting more restricted values, but rather by appropriately implementing complementary tools, such as risk assessment or good reuse practices.

Although most of the world regulations on water reuse are concerning agricultural applications, several experts and international entities have published standards for urban applications, and golf course and landscape irrigation [1,3,7,8,26,46,50], which can be used in tourist areas.

Reclaimed water that complies with reuse standards for a given use should have enough quality to reduce risks to an acceptable level. Nevertheless, as standards change for different countries, it is not generally feasible to apply uniform methodologies and analytical control worldwide or even at a regional level, and risk-related tools are recommended to apply for risk control. According to Salgot et al. [42], management systems based on the hazards/risks associated with wastewater treatment practices, recycling, and application are being developed for some reuse applications such as irrigation. The in situ risk evaluation normally follows a specified pattern, which can include real site observations, interpretation of quality analysis, and health risk assessment, including the hazard analysis and critical control points (HACCP).

The HACCP system allows the evaluation of hazards associated with all the steps in the water reuse system, its control, and the identification of the critical points. It can help the water authorities to undertake water-related inspections, while promoting self-control activities, and requires a compromise and involvement of stakeholders. It involves the following steps [49,50]: conduction of hazard analysis, identification of the critical control points (CCP; Figure 26.1), establishment of target and tolerance levels (e.g., identification of hazards that must be controlled), setting up a monitoring system (e.g., controls, critical limits, and procedures for monitoring), definition of corrective actions and verification procedures (validation of the HACCP plan), and production of documentation.

## 26.5 Economical Evaluation and Justification of Reuse Options

The economics of water reuse normally involve calculations based on different approaches, but consider the key variables, such as the cost of wastewater treatment, storage, and transport (investment and operational and maintenance costs). However, most focus on cost-benefit tools as presented in the works of Heinz et al. [15] and Hernández-Sancho et al. [17]. Costs for reclaimed water production from domestic wastewater are normally higher than the costs associated with stormwater recycling, rainwater collection, and treated graywater [43]. Costs

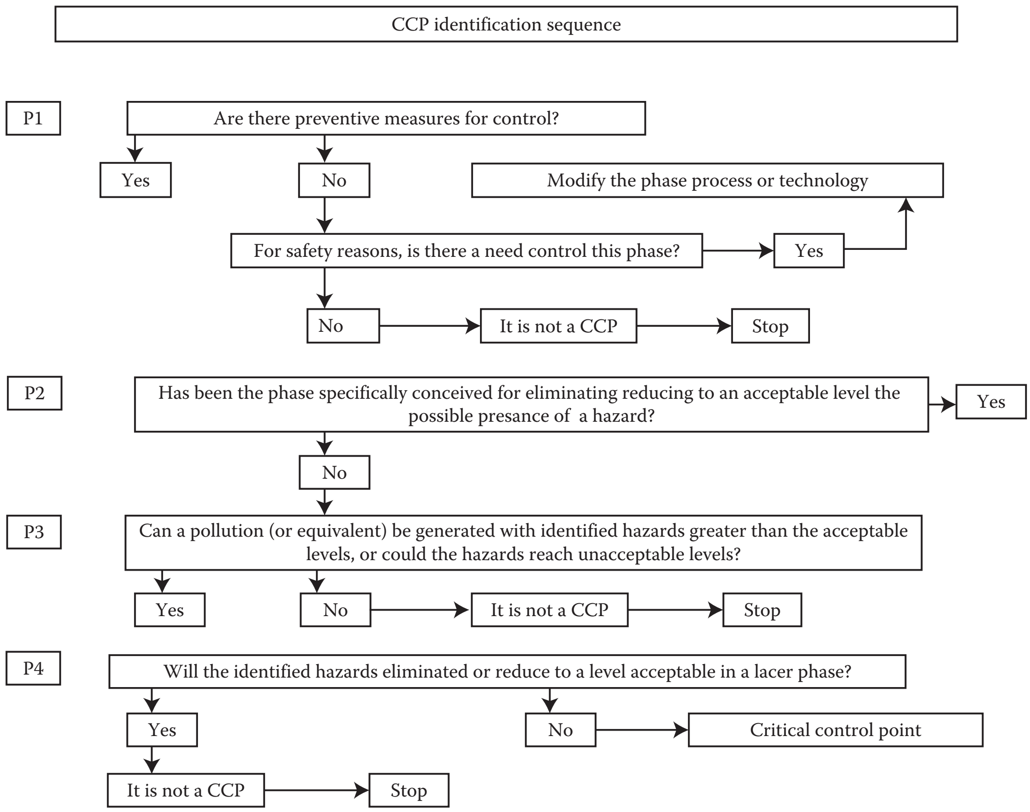


**FIGURE 26.1** Procedure for the identification of Critical Control Points. (From Salgot, M., Priestley, G. and Folch, M. 2012. Golf course irrigation with reclaimed water in the Mediterranean: A risk management matter. *Water*, 4, 389–429.)

differ considerably, according to the size and sophistication of the reuse options and the seasonality of its use. For example, the costs of water reuse in golf courses can range from several cents to over 1 € per cubic meter, including analytical costs and mortgage of the treatment facilities [40].

Economic instruments, policy on water management, clearer regulations, and financial incentives are essential for enrolling stakeholders and the viability and cost competitiveness of water reuse projects. Water reuse is still suffering from the under-evaluated and subsidized conventional water resources and constraints for the application of "full-cost recovery" and "polluter-pays" principles.

Operation and maintenance costs of recycling facilities normally include costs with treatment technology (e.g., replacement of membranes and/or UV lamps) and of equipment of reservoirs, pumping systems, and distribution networks), being labor, chemicals, and energy. A project developed in Bora Bora [23] has shown that the main components of operation costs were labor (46%), repair and maintenance (21%, including membrane replacement), energy consumption (14%), chemicals (12%), and water quality monitoring (4%). The average energy consumption was 0.3 kWh/m$^3$ at nominal flow and 0.95 kWh/m$^3$ at 30% of the hydraulic capacity of membrane treatment. Labor costs were close to the typical values in conventional activated sludge systems (45 ± 5%) and energy costs were lower compared to typical values of secondary treatment 25 ± 5% and ~~tertiary MF/RO~~ treatment 26–32% [22]. This project has brought economic Q1 benefits for maintaining a number of economic activities such as construction, boat cleaning, and pleasant landscape in conditions of severe drought with strong restrictions on potable water consumption. For luxury hotels, the unit cost of high-quality reclaimed water was 2.5–3 times less expensive than the drinking potable water.

## 26.6 Case Studies in a Mediterranean Country

### 26.6.1 Overview

In this section, adapted from Viegas et al. [47], some reflections are presented about water reuse in Portugal, a Mediterranean country with a significant tourism industry, focusing on two representative case studies in water stressed regions: the Algarve, a very popular tourist destination principally during summertime, densely populated with urban and rural parishes, and Lisbon, the capital of the Portugal with tourism spread throughout the year.

Portugal has abundant potential freshwater resources. However, there is a shortage of its availability given the irregularity of their occurrence, both along the territory and over the year. The climate variability along the Portuguese territory is the first reason for the pronounced spatial differences that are observed in the freshwater availability. In a great part of the country, the water balance is deficient with the evapotranspiration exceeding the sum of infiltration and runoff. Moreover, the consequences of the climate diversity on freshwater availability are greatly amplified by other factors including the demographic characteristics and the pressure of some important economic activities, namely tourism.

Considering the population distribution along Portugal, a high density in major urban coastal areas is observed. The high potential for water reuse in large urban systems, namely for urban nonpotable uses, is then clear.

Tourism has been increasing heavily its weight in the economy of Portugal. With a high concentration during the summer, it significantly contributes to the seasonal stress of water scarcity, in particular in the Great Lisbon coastal area and in the Algarve. Also, the development of the golf industry, demonstrated by the growing number of golf courses being created, in addition to the high water needs for their maintenance and the current environmental policy, make golf course irrigation with treated wastewater a strategic goal relating resource sustainability. Actually, the Environmental Impact Declarations of new golf courses often impose its irrigation with treated wastewater. The case studies of these two Portuguese regions are given as examples.

### 26.6.2 Algarve Region Case Study

The Algarve region is a paradigmatic example in Portugal because tourism and golf are the structural basis of its economy while it suffers severe or extreme droughts from time to time. The wastewater utility for the region (Águas do Algarve, S.A.) explores 58 WWTPs, accounting for the treatment of 26 $hm^3$ in 2007, 24 $hm^3$ with secondary treatment and 2 $hm^3$ with tertiary treatment [27,13]. With a total of 31 golf courses in operation and 52 foreseen in the near future, the maintenance of the Algarve as a golf destination struggles with the high water consumption of this activity. However, the current environmental policy of treated wastewater use and the vicinity of 15 WWTPs to the golf courses open the opportunity of supplying the irrigation demand with treated wastewater, which proves to be sufficient except for the months of April, May, and October [28]. Studies performed [13,27–29] show that the available technology (traditional biological treatment) is able to provide the quality needed, except for a couple of wastewater systems with salt intrusion, which can increase the water salinity to 3 dS/m, cases for which desalination post-treatment is needed. The bulk supply of treated wastewater for golf course and landscape irrigation in the Algarve region is still not fully implemented mainly due to economic reasons [13].

### 26.6.3 Lisbon Region Case Study

Lisbon is the largest and most populated city in Portugal, with a territory of 84 $km^2$, about 600,000 inhabitants and a fluctuating population of about 1.2 million people. SimTejo, S.A. is the wastewater utility responsible for the collection, treatment, and disposal of urban wastewater from six municipalities of the Lisbon region: Lisbon, Loures, Vila Franca de Xira, Amadora, Mafra, and Odivelas, covering approximately 1000 $km^2$. Today, SimTejo serves a population of about 1.5 million inhabitants, and operates 29 WWTPs, 74 pumping stations, and 245 km of sewerage systems, treating an average flow rate of 110 $hm^3$/yr.

Given its urban and peri-urban profile, there are many potential applications for water reuse in the region, namely: (a) agricultural irrigation: nurseries and crop irrigation; (b) landscape irrigation: golf courses, industrial parks, public parks, cemeteries, and roadside plantings; (c) industrial: cooling water, fire protection, heavy construction, and process water; (d) nonpotable urban uses: air conditioning, car wash and laundries, decorative fountains, municipal urban services, toilet flushing, and sewer flushing; and (e) recreational/environmental uses: artificial lakes, fisheries, and wetlands. The company started using reclaimed water in 2001, first for internal use (e.g., polymer dilution, facilities cleaning, small gardens, scum and foam control in most WWTPs) and later for street cleaning. Today, SimTejo provides water reuse to three municipalities and the goal is to extend this practice to all the municipalities served.

In Lisbon (Chelas WWTP), besides internal use, treated wastewater is delivered to the municipality for landscape irrigation and street cleaning. Mafra municipality uses treated wastewater for landscape irrigation. In Loures, the vicinity of Frielas WWTP to a big commercial area (IKEA Loures) has created the opportunity to supply treated wastewater for cooling purposes in the air conditioning system (3200 $m^3$/day in the summer and 1280 $m^3$/day in the winter), representing the most impacting case of water reuse in the Lisbon area thus far.

The complete rehabilitation and upgrading of Alcântara WWTP, which now includes filtration and UV disinfection, together with the rehabilitation and expansion of the trunk sewer network allowed, through a cost synergy, the installation of a water reuse supply system to Lisbon downtown (Figure 26.2). This system offers new possibilities for treated wastewater use, namely for landscape irrigation, street cleaning, combined sewer flushing, and service water in wastewater pumping stations.

Next to Beirolas WWTP is the renovated east part of Lisbon—the Parque Expo area. When the renovation works took place, a dual plumbing system was installed, already prepared for landscape irrigation using treated wastewater from Beirolas WWTP, planned for the near future.

There is a growing trend toward the use of treated wastewaters in different countries of the world, with the major drivers being water scarcity and seasonal stress, in part due to tourism,

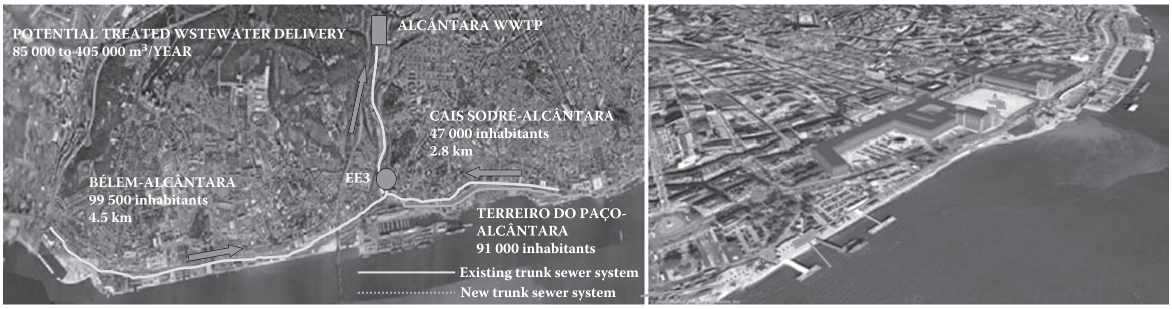


**FIGURE 26.2** Alcântara WWTP and the treated wastewater supply system to Lisbon downtown.

and one of the major barriers is the economical feasibility of the projects.

## 26.7 Summary and Conclusions

Weather changes and population increases in touristic regions clearly dictate higher demands for water, which in arid and semi-arid regions may be considered a limited resource, usually with groundwater resources under heavy pressure. In most of those zones, future demands are not expected to be met by traditional water resources like surface and groundwater. In order to handle increased water demand, the treated wastewater originating from municipal WWTPs should be studied and developed, to be available to farmers and other end-users, for agricultural irrigation and for other compatible uses.

A significant number of tourist regions regularly experience severe water supply and demand imbalances, particularly in the summer months. Tourism is a very important economic activity and is pushing water demand particularly in regions suffering occasional water deficit, like the southern half of Portugal's mainland, namely the Algarve and Lisbon regions, which are presented in this chapter as case studies. Water reuse should be assumed an important management strategy in situations of water scarcity, being that there is a growing trend toward the use of treated wastewaters in different parts of the world, with the major drivers being water scarcity and seasonal stress, in part due to the tourism industry, and probably one of the major barriers is the economical feasibility and sustainability of the projects.

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