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Water Reuse in Arid Zones

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Preface

Water scarcity is the main driver for water recycling and reuse in countries located in arid zones. Despite multiple benefits from water recycling and reuse for the farmers and communities, there are several constraints to the collection, treatment, and safe and productive use of wastewater in agriculture. Apart from lack of supportive policies, unclear institutional arrangements, critical shortage of skilled human resources, and the public budgets in most countries for water recycling and reuse are inadequate. In addition, limited economic analysis, lack of reuse cost-recovery mechanisms, no or little value for treated wastewater, lack of awareness about the potential of water recycling and reuse, and inefficient irrigation and water management schemes are constraints to water recycling and reuse. Despite these constraints, some countries in arid zones have employed a range of conventional and nonconventional systems and have national standards and regulations in place for water recycling and reuse. Salient features of water recycling and reuse in Tunisia, Jordan, Israel, and Cyprus reveal that although each country has taken a slightly different path, policymakers in these countries consider reuse of reclaimed water an essential aspect of strategic planning and management of water and wastewater. Other countries in arid zones with similar situations can benefit from Tunisia, Jordan, Israel, and Cyprus by transforming wastewater from an environmental burden into an economic asset through aggressive implementation of water recycling and reuse programs.

66.1 Introduction

Given the current demographic trends and future growth projections, as much as 60% of the global population may suffer water scarcity by the year 2025 [9]. In addition to water scarcity, water quality deterioration is expected to intensify in resource-poor countries in dry areas, due to human activity and climate change. It is projected that water scarce countries will have to increasingly rely on alternative water resources such as wastewater to narrow the gap between water demand and supply for agriculture [16,18,19].

There are large gaps between developing and developed countries as well as low- and high-income countries for managing wastewater generated within their boundaries. High-income countries on average treat 70% of the generated wastewater, followed by upper-middle-income countries (38%), lower-middle-income countries (28%), and low-income countries, where only 8% of the wastewater generated is treated [31].

Wastewater treatment and use and/or disposal in the arid and semi-arid regions of developed countries, such as western North America, Australia, and southern Europe, are motivated by stringent effluent discharge regulations and public preferences regarding environmental quality [13]. Treated wastewater is primarily for irrigation, given the increasing competition for water between agriculture and other sectors [31,34]. In developing countries, wastewater treatment is limited, as investments in treatment facilities have not kept pace with persistent increases in population and the consequent increases in wastewater volume in many countries. Thus, much of the wastewater generated is not treated, and much of the untreated wastewater is used for irrigation by small-scale farmers with little ability to optimize the volume or quality of the wastewater they receive [29,32].

Many farmers in water-scarce developing countries irrigate with wastewater because: (1) it is the only water source available for irrigation throughout the year, (2) wastewater irrigation reduces the need for purchasing fertilizer as wastewater is rich in essential nutrients, (3) wastewater irrigation involves less energy cost if the alternative clean water source is deep groundwater, and (4) wastewater enables farmers in peri-urban areas to produce high-value vegetables for sale in local markets.

Irrigation with treated wastewater likely will expand in developed countries, particularly in arid and semi-arid areas, where competition for freshwater supplies will continue to increase [11,24]. Technical solutions and public policies generally are adequate in developed countries to accommodate increases in the treatment and use of wastewater. The same is not true for many developing countries, where treatment facilities already are inadequate, and much of the wastewater used by farmers is not treated.

This chapter provides an overview of the water and wastewater resources in arid zone countries, constraints in water reuse and recycling, and showcases examples from water-scarce countries that have progressed in implementing water recycling and reuse policies and practices. The aim is to provide a number of examples for countries with similar conditions for consideration and implementing water recycling and reuse projects and practices leading to safe and productive use of wastewater in different sectors, particularly in agriculture.

66.2 Water and Wastewater Resources in Arid Zone Countries

Looking at the natural global water cycle that yields an annual renewable water supply of about 7000 m^3 per capita, it is evident that there is enough freshwater available every year to fulfill the needs of the present population of this planet. However, in certain regions and countries, the annual renewable supply of water is less than 500 m^3 per capita. In addition, the availability of water varies greatly over time in these areas, which results in extreme events. Floods and droughts, for example, occur frequently, sometimes in the same area or neighboring regions. What this contrast illustrates is that freshwater resources and population densities are unevenly distributed across the globe.

Among the arid zones of the world, the Middle East and North Africa (MENA) region is the driest region of the world. The region is home to about 5% of the existing global population, but with only 1% of the world's freshwater resources. The MENA countries depend on seasonal rainfall, have very few rivers—most of them originate in other countries—and often rely on fragile, and sometimes nonrenewable, aquifers. There is already an increasing competition for high-quality water among different water-use sectors. Although agriculture is the dominant user of freshwater in these countries, it has been yielding its share gradually to nonagricultural uses, that is, household, municipal, and industrial activities. Since the use of freshwater for these activities generates wastewater, the volume of wastewater has been increasing commensurate with rapidly growing population, urbanization, improved living conditions, and economic development.

The phenomenon—less freshwater allocation to agriculture, more freshwater allocation to nonagricultural sectors vis-à-vis increasing volumes of wastewater—is expected to continue and intensify in the countries in the arid zones in the foreseeable future. Most small-scale farmers in urban and peri-urban areas of these countries already depend on wastewater to irrigate a range of crops, often as they have no alternative sources of reliable irrigation water.

In addition to the MENA region, several countries in other regions also encounter a water deficit. The datasets and maps published in recent years show that more and more countries will become water-stressed because of increased water scarcity. In arid zones, water scarcity remains the main driver for water recycling and reuse.

66.3 Constraints to Water Recycling and Reuse

Considering the acute problem of water scarcity and emerging problem of water quality deterioration amid climate change events, the developing countries located in dry areas have an opportunity in terms of planned and beneficial water recycling and reuse. The rate of wastewater treatment is still low in most of these countries while many wastewater treatment plants are plagued by poor operation and maintenance, and if operational, they are operated well beyond their design capacity [2]. These conditions eventually question wastewater treatment processes, quality of treated wastewater, and safety of practices aimed at using wastewater in agriculture [12]. In addition, the regulations prohibiting the agricultural use of untreated or partly treated wastewater exist, but their implementation is not strictly enforced [28].

The major constraints leading to low percentage of water recycling and reuse in countries in dry areas can be: (1) inadequate public budgets in most countries to collect domestic and industrial wastewater separately for treatment per reuse or disposal options; (2) inadequate information on the status of water recycling and reuse or disposal of different forms of wastewater and associated impacts on environmental and human health; (3) incomplete economic analysis of the wastewater treatment and reuse options, usually restricted to financial feasibility analysis rather than a complete financial and cost and benefit evaluation; (4) perceived high cost of developing wastewater collection networks and wastewater treatment plants and low returns without sound assessment and feasibility studies; (5) lack of wastewater treatment and reuse cost-recovery mechanisms including commitment in most countries to support comprehensive wastewater treatment programs; (6) mismatch between water pricing and regional water scarcity with no or little value for treated wastewater resulting in closure of wastewater treatment plants or substantial subsidies to keep the treatment plants in operation; (7) lack of awareness about the potential of water recycling and reuse; (8) general preference for freshwater over wastewater; (9) overall inefficient irrigation and water management schemes undermining the potential of water reuse; (10) lack of supportive policies to promote water recycling and reuse; (11) unclear institutional arrangements and lack of coordination between national agencies and local institutions for wastewater management; and (12) critical shortage of skilled human resources to address the complex issues resulting from wastewater collection, treatment, and reuse systems.

Most developing countries in dry areas are generally characterized by increased population growth and urbanization, improved living conditions, and economic development; all are drivers of increased volumes of wastewater emanating from the domestic and industrial sectors. While these changes are rapid, there is inadequate information on the status of collection and reuse and/or disposal of different forms of wastewater (untreated, partly treated, diluted, and treated) and associated environmental and health impacts [28]. Even in cases where such information is available, there are large differences in the qualitative and quantitative assessment of wastewater because of the different criteria used.

Although the economic impacts of reusing wastewater largely depend on the degree of treatment and the nature of the water reuse options, economic assessments of wastewater treatment and reuse options in the arid region countries are usually restricted to financial feasibility analysis [19,27]. In fact, there are costs and benefits associated with the specific wastewater treatment and reuse systems. There is a need to consider other factors such as centralized and decentralized treatment options, levels of treatment (primary, secondary, and tertiary), intended reuse options, wastewater collection and conveyance infrastructure leading to wastewater treatment plant in locations where such infrastructure does not exist, and transportation options for treated effluent to specific locations for intended reuse. In addition, the opportunity cost of water reuse should be considered under conditions where new uses and moving a given supply of water from one place to another specific location are anticipated. In doing so, the economic analysis therefore needs to consider the implications of wastewater distribution as well as certain restrictions on crop choices based on the quality and quantity of reclaimed water in the anticipated reuse projects.

The perceived high cost of establishing wastewater collection networks and treatment plants capable of satisfactory wastewater treatment is another major constraint leading to uncertainty in terms of adopting comprehensive wastewater treatment and reuse programs. Wastewater treatment facilities and costs vary from location to location and are based on the infrastructure needed, the quality of the wastewater collected and the anticipated quality of the treated wastewater,which may be the result of primary, secondary, and tertiary treatment. Lee et al. reported that the cost of wastewater treatment may range from 0.46 to 0.74 US$ m^{-3}, with an average of 0.53 US$ m^{-3} [21]. The major components of the cost based on these estimates in 2001 include capital (0.10–0.16 US$ m^{-3}), operation (0.25–0.40 US$ m^{-3}), maintenance (0.08–0.15 US$ m^{-3}), and miscellaneous (0.03 US$ m^{-3}). Estimates from Middle Eastern countries reveal wastewater treatment cost in Saudi Arabia for tertiary treated wastewater at $ 0.30 m^{-3}, in United Arab Emirates for tertiary treated wastewater at $0.43 m^{-3}, and in Kuwait for secondary treated wastewater at $0.18 m^{-3} [15]. These cost calculations are based on projected plant life, interest rate, plant availability, and production capacity around the mid-1990s.

While considering the cost of wastewater and stormwater collection, customer service and billing, stormwater treatment and drainage, property taxes, capital and rehabilitation, corporate services, and planning and engineering aspects of overall wastewater treatment process, the cost could be much higher than reported by Lee et al. [21]. For example, based on the estimates of treating wastewater from Ottawa (Robert O. Pickard Environmental Centre—Wastewater Treatment Plant), the overall wastewater treatment cost may reach CAD$1.64 per m^3 (1.00 CAD$ = 0.97 US$). The cost components consist of wastewater treatment (24.4¢), wastewater and stormwater collection (26.1¢), customer service and billing (7.9¢), stormwater treatment and drainage (6.1¢), property taxes (1.4¢), capital and rehabilitation (75.5¢), corporate services (17.4¢), and planning and engineering (5.0¢) [8]. Based on the analysis of 338 treatment plants in Spain for technical efficiency and cost analysis in wastewater treatment processes, Hernández-Sancho et al. estimated the cost of secondary treatment of wastewater in the range of € 0.40–€ 0.77 m^{-3} (1.00 € = 1.33 US$ in 2010) [14]. The above estimates reveal that there are differences in the approaches used to calculate the overall cost of wastewater treatment. These range from only considering the cost of reclaimed water recycling (additional treatment, storage, and distribution) to adjusting for other associated costs such as that of the wastewater collection and treatment [20].

The lack of wastewater treatment cost-recovery mechanisms has led to low demand for cost-based reclaimed water when compared with treated or untreated wastewater supplied free of charge to the farmers. The reasons are that both farmers and households have skepticism about the quality of the reclaimed water as they do not have access or means to monitor and verify the quality of water they use. In addition, the availability of untreated wastewater free of charge adds to the complexity of the whole issue and makes it difficult to convince farmers to pay anything for reclaimed water that is not of high quality. For example, despite low prices charged to Tunisian farmers for reclaimed water (0.02 US$ m^{-3}) compared to approximately fourfold higher conventional water supply costs (0.08 US$ m^{-3}), the demand for reclaimed water was lower than other water supplies [19]. In most countries, there are no or few farmers or water users associations that can help farmers make use of wastewater in a safe and productive manner.

The mismatch between water pricing and water scarcity is another important constraint affecting the whole process of wastewater treatment in most arid regions in developing countries where water pricing should also consider its scarcity value. This aspect has particular importance in the agricultural sector. According to Kfouri et al., the price of freshwater delivered to irrigators does not reflect even the cost of water supply. At best, some countries, such as Tunisia, charge sufficient rates to cover operation and maintenance costs [5,6]. In general, most arid regions in developing countries do not charge or control groundwater abstractions other than the private cost of pumping and the permitting process.

In general, the lack of commitment on the part of several developing-country governments to advocate and support comprehensive wastewater treatment programs has led to the lack of understanding among farmers and households about the perceived environmental benefits of wastewater treatment and reuse of reclaimed water. Because of the collection and conveyance of wastewater away from urban areas, households do not recognize the benefits of wastewater treatment and reuse amid extreme water scarcity. The governments therefore find it easier to collect fees for connection and wastewater service than for eventual treatment of wastewater. In addition, they do not take into consideration regulatory and monitoring costs. In most arid region developing countries, irrigation and water management schemes are inefficient and do not pay due attention to the potential of reclaimed water as a resource that can be used for irrigation, environment conservation, and other purposes such as groundwater recharge, municipal, recreational, or industrial uses.

66.4 Opportunities for Water Recycling and Reuse

Despite these constraints, some countries in arid zones have employed a range of conventional and nonconventional systems and have national standards and regulations for reuse. Although each country has taken a slightly different path, they also are similar in important ways. Policymakers in these countries consider reuse of reclaimed water an essential aspect of strategic water and wastewater sector planning and management. Salient features of water recycling and reuse in Tunisia, Jordan, Israel, and Cyprus are presented in the following sections.

66.4.1 Tunisia

With actual renewable water resources (ARWR) of 432 m^3 per capita in 2010, water recycling and reuse has been a priority of Tunisia since the early 1980s, when Tunisia launched a nationwide water reuse program to increase the country's usable water resources. Most municipal wastewater receives secondary biological treatment generally through activated sludge and, in some cases, there is tertiary treatment of wastewater in place. In order to promote tourism and protect the environment for tourists, several treatment plants are located along the coast to protect coastal resorts and prevent marine pollution.

Reusing reclaimed water for irrigation in Tunisia is viewed as a method to increase water resources, provide supplemental nutrients, and enhance wastewater treatment in a way that protects coastal areas, water resources, and water receiving bodies sensitive to water quality. Restrictions for water reuse designed to protect public health have received considerable attention in Tunisia and are in line with recommendations of the World Health Organization [35]. The government also supports research studies investigating the use of treated wastewater for groundwater recharge, irrigation of forests and highways, wetlands development, and industrial use.

Tunisian regulations allow the use of secondary treated effluent on all crops except vegetables, whether eaten raw or cooked. Regional agricultural departments supervise the treated wastewater reuse and collect charges from the farmers. In Tunisia, farmers pay for irrigation water on the basis of the volume of water required and the area to be irrigated, and the number of hours corresponding to the contract, at a rate of TND 0.02–0.03 per m^3 (1 TND = US $0.61 in 2013).

Of the annual volume of wastewater generated in Tunisia (0.246 km^3 in 2010), 0.226 km^3 are treated [30,31]. The annual volume of treated wastewater in Tunisia is expected to reach 0.290 km^3 by 2020 [3]. At that point, the expected amount of treated wastewater will be around 18% of the available groundwater resources and could be used where excessive groundwater mining is causing seawater intrusion in coastal aquifers.

In general, there is a strong government support for wastewater reclamation and reuse [4,30]. However, this support has yet to trigger wastewater use at a large scale as groundwater is preferred and being used even though large efforts have been made to provide reclaimed water to the farmers using groundwater. There are a number of issues related to social acceptance, regulations concerning crop choices, and other agronomic considerations that affect these decisions. Farmers in the arid south have expressed their concerns about the long-term impacts of saline wastewater on their crops and soils. In addition, farmers also consider crop restrictions as an impediment as they cannot grow high-value crops such as vegetables with reclaimed water.

Considering these challenges, the Tunisian policy makers have started to pay greater attention through better coordination and demand driven approaches to better plan wastewater reclamation and irrigation with treated effluent in Tunisia. To bridge the gap between the needs of different parties, ensure the achievement of development objects, and preserve the human and natural environment, interdepartmental coordination and follow-up commissions with representatives from the different ministries and their respective departments or agencies, the municipalities and representatives of the water users associations have been set up at national and regional levels [2].

66.4.2 Jordan

With ARWR of 145 m^3 per capita in 2010, Jordan is one of the most water-scarce countries of the world. In terms of establishing wastewater collection networks, treatment of collected wastewater, and use of treated wastewater in agriculture, Jordan is one of the countries where relevant wastewater policy framework and institutional structure exist [23]. The wastewater policy "Jordanian National Wastewater Management Policy," developed more than 15 years ago in 1998, has three major considerations: (1) reclaimed water is to be considered a part of the water budget in the country with no consideration of disposal; (2) water reuse is to be planned on a basin scale; and (3) fees for wastewater treatment may be collected from the water users [25]. The Jordanian wastewater policy is unique and innovative and although the government has not achieved full success in implementing the policy, it represents a different way of thinking about water recycling and reuse [19].

Jordan has implemented an aggressive campaign to rehabilitate and improve wastewater treatment plants. In addition, enforceable standards have been introduced to protect the health of fieldworkers and consumers. In addition, Jordan has extensive research studies on water recycling and reuse. The share of reclaimed water in the total water supply in Jordan is about 13%. There are three categories of water reuse in Jordan: (1) planned direct use within or adjacent to wastewater treatment plants; (2) unplanned reuse of reclaimed water in *wadis*; and (3) indirect reuse after mixing with surface water supplies, which is mainly practiced in the Jordan Valley where reclaimed wastewater provides about half of the irrigation water in the valley.

The planned direct use of reclaimed water is administrated by the Water Authority of Jordan, which has special contracts with the farmers formalizing their rights to use reclaimed water directly at 20 fils per m^3 (1000 fils = 1 Jordanian Dinar = US $1.4 in 2014). At the policy level, the Jordanian National Wastewater Management Policy requires that the reclaimed water supply prices cover at least oil and maintenance of the reclaimed water delivery to the farmers [22]. However, reclaimed water supply prices do not include costs incurred on wastewater collection and treatment. Other planned direct reclaimed water users are some private enterprises and experimental pilot projects cosponsored by international donors.

Phase 1 of the As-Samra Wastewater Treatment Plant, the major wastewater treatment facility located 50 km north of Amman, was designed to handle annual wastewater volume of 25 million m^3; however, it used to process at least double the amount of wastewater. The cost incurred on Phase 1 was US$ 169 million. Implementing Phase 2 with an estimated cost of US$ 223 million, the treatment plant has been upgraded recently to handle wastewater at a daily volume of 267,000 m^3 and an annual volume of 97 million m^3. A Private Public Partnership (PPP) model has been used to finance the construction and operation of the treatment plant, with major funding provided by the United States Agency for International Development (USAID). The model is based on a 25-year build-operate-transfer (BOT) approach. Treated wastewater flows into the King Talal Dam, where it is mixed with freshwater from the King Abdullah Canal before being discharged into the Jordan Valley to be used for irrigation.

Treated wastewater constitutes 13% of the ARWR and its contribution is set to rise as conventional wet sanitation and wastewater collection is expected to increase in the coming decades [7]. Jordan has taken the lead in terms of treating part of the domestic wastewater, generally known as greywater, at the household level and making use of it in home gardens to irrigate a range of plant species. It comprises 55%–75% of residential wastewater. The greywater reuse projects have revealed considerable potential of greywater reuse in irrigation at the household level in poor communities. In addition to increasing yields of high-value crops and economical returns, greywater reuse has increased community participation in the national efforts to conserve limited water resources onsite and low-cost greywater treatment and reuse systems [1].

More recently, on February 20, 2014, Jordan launched its first wastewater master plan to help the government determine investment priorities in wastewater services across the country through the year 2035. Referred to as the National Strategic Wastewater Master Plan, it identifies investment needs and priorities for wastewater collection and treatment in every governorate to enable the Ministry of Water and Irrigation to better direct donor and government resources to areas with limited wastewater services or overloaded capacities. The USAID-funded Jordan Institutional Support and Strengthening Programme prepared the plan upon a request from the Ministry of Water and Irrigation.

The master plan will aim at providing wastewater services to all areas with more than 5000 residents as an action plan for investment, development, and donor support through 2035. This will help the water and wastewater sectors as they are under increasing pressure due to massive population growth, high energy costs, and climate change impacts, among other challenges. To move forward with the plan, the Water Authority of Jordan has prepared an accurate and up-to-date map for wastewater information using Geographic Information Systems tools. While this information will allow new projects to save months of time in the planning stage, this will also help in identifying priority areas for wastewater projects.

66.4.3 Israel

Israel is another water-scarce country with ARWR of 240 m^3 per capita in 2010. As early as 1953, Israel drafted the standards for water reuse, which have continued to evolve to reflect the latest scientific findings on microbiological and chemical risks [33]. The Water Law of 1959 and policy enacted by the administration up until today define sewage as a "water resource" and an integral part of the water resources of the country and its water budget.

Most of Israel's farmers using reclaimed water are organized into different types of communities and cooperatives. The Ministry of Agriculture provides professional guidance through an efficient extension service. Part of the success of the practice of water reuse in Israel is due to the capacity of the well-organized and informed farmers to adapt quickly to the switch to reclaimed water from other water resources [17]. The reuse of reclaimed water has provided an attractive means of increasing water supply in the country.

On the water reuse front, the institutional set-up of the water sector in Israel has played a pivotal role in facilitating the reuse of reclaimed water in agriculture. The cost of reclaimed water paid by the farmers is about 20% lower than that of the equivalent volume of freshwater. With no provision of private wells, the farmers have no alternate sources of water for irrigation within the zones where treated wastewater is available. This governance structure largely solves problems of reduced reclaimed water demand while ensuring a regular supply of water for irrigation [19].

Israel is a country that has practiced massive water reuse for decades. Most reclaimed water is still dedicated to restricted irrigation, which helps liberate freshwater resources for unrestricted irrigation. However, with long-term use of wastewater, Israel has a substantial risk of salinization of groundwater in the wastewater-irrigated areas. Wastewater produced by the domestic, municipal, and industrial sectors becomes more saline than the water used in these sectors and there are no inexpensive ways to remove salts once they enter sewage. This concern has led to expanding research on developing crops that can withstand higher levels of salts in the growth medium. The Ministry of the Environment has been engaged in a campaign to reduce the addition of salts to sewage since the early 1990s. The country has one of the best-documented and analyzed experiences of water reuse demonstrating much innovation, particularly over the past three decades.

66.4.4 Cyprus

Cyprus is the third largest island in the Mediterranean region and has always been confronted with inadequate volumes of water to meet its agricultural and domestic needs. Its geographical location, semi-arid climate with frequent droughts, economy, and political situation exacerbate its water problems. Cyprus had ARWR of 707 m^3 per capita in 2010. Over 87% of the island's water extractions, 96% of which are coming from groundwater, are for agricultural purposes. The salinization of the groundwater resources by overexploitation of the aquifers has led to the development of alternative water supplies. With desalination as an alternative to meet the water needs, the country has steadily been increasing the use of desalinized water, reaching an annual volume of 49 km^3 [10]. Wastewater reuse is another alternate option with most of the 25 million m^3 of treated wastewater used for agricultural and landscape irrigation [36].

The Sewage Boards at the municipality level are responsible for the collection, treatment, and disposal of wastewater while the Water Development Department undertakes the management and distribution of recycled water. Cyprus has followed effective strategies toward improving the efficient use of water such as improvement in irrigation systems, conservation of groundwater, water pricing, campaigns of water awareness, and reuse of treated wastewater and greywater effluent, among others. This has resulted in a very efficient system of irrigation, with closed systems, and an overall conveyance efficiency averaging 90%–95%.

In terms of groundwater conservation with treated wastewater for later recovery and reuse, Cyprus has taken several steps. For example, the entire quantity of treated wastewater produced in Paphos, the fourth largest city located in southwest Cyprus, is used for Ezousa aquifer recharge, which is subsequently pumped for irrigation through diversion in an irrigation channel. The Code of Good Agricultural Practice regulates irrigation with reclaimed water. The treated effluent can be applied to all kinds of crops except leafy vegetables, bulbs, and corn eaten raw. The major crops irrigated with treated effluent are citrus trees, olive trees, fodder crops, industrial crops, and cereals. In addition, it is used for landscape and football field irrigation [26].

In the case of Limassol, the largest municipality of Cyprus, there are multiple uses of wastewater generated by the city and subsequently treated. During winter months when the demand for water in agriculture decreases, treated wastewater is pumped to an irrigation dam for irrigation or subject to aquifer recharge. In 2010, about 15% of treated wastewater was used for recharge of the Akrotiri aquifer. The government's long-term plan and water policy aim at fully utilizing reclaimed water and incorporating it into the country's water balance [26]. There are considerations to increase the volume of treated wastewater for aquifer recharge to replenish this depleting aquifer. The implementation of the plan would yield a welfare improvement that would not only increase the economic benefits to all stakeholders in both the short- and long-term, it would also help Cyprus in its efforts to meet the European Union's (EU) Water Framework Directive, WFD (2000/60/EC), requirements by 2015. In compliance with Article 9 of the WFD (2000/60/EC), Cyprus has launched a new water pricing policy to recover the cost of water services. To encourage the use of treated wastewater, it is supplied to the potential users without full cost recovery for different uses at a cost lower than freshwater.

66.5 Summary and Conclusions

Amid water scarcity, the volumes of wastewater generated by the domestic and industrial sectors in countries located in arid zones are increasing due to increased population growth and rapid urbanization, improved living conditions, and economic development. These countries will have to increasingly rely on alternative water resources such as wastewater to narrow the gap between water demand and supply for agriculture or afforestation.

The issues regarding wastewater generation, treatment, and use will intensify in the future, with increasing water scarcity and economic growth. The implementation of research-based technical options for wastewater treatment and reuse in developing countries located in dry areas, supported by flexible policy level interventions and pertinent institutions with skilled human resources, offers great promise for environment and health protection as well as livelihood resilience through agricultural productivity enhancement. This may not be achieved in the next few years. Therefore, interim measures would be needed to address water recycling and reuse to gradually reach a level when most wastewater in these countries would be collected, treated, and used in treated form safely and productively.

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