International Water Management Institute

Water reuse in the Middle East and North Africa

A sourcebook

Edited by:
Javier Mateo-Sagasta (IWMI)
Mohamed Al-Hamdi (FAO)
Khaled AbuZeid (AWC)

Lien Arits / IWMI

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NOTE: This book has compiled data from 19 Arab countries of the MENA region (namely, Algeria, Bahrain, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, the United Arab Emirates and Yemen). Throughout this book the terms 'MENA region' and/or 'the Region' refer only to those 19 countries.

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Acronyms and abbreviations

AADC	Al Ain Distribution Company (UAE)
ABH	River Basin Agency (Morocco)
ACWUA	Arab Countries Water Utilities Association
ADC	Aqaba Development Corporation
ADDC	Abu Dhabi Distribution Company
ADSSC	Abu Dhabi Sewerage Services Company
AFD	Agençe Française de Développement
ANPE	National Agency of Environmental Protection (Tunisia)
APDN	Northern Development Agency (Morocco)
ASEZ	Aqaba Special Economic Zone
ASEZA	Aqaba Special Economic Zone Authority
AWC	Arab Water Council
BCM	billion cubic meters
BOD	biological oxygen demand
CAP	Common Agricultural Policy
CAPEX	capital expenditure
CDR	Council for Development and Reconstruction (Lebanon)
CE	circular economy
CEDARE	Centre for Environment and Development for the Arab Region and Europe
CFU	colony-forming unit
COD	chemical oxygen demand
CRA	Agricultural Outreach Unit
CRDA	Regional Commission for Agricultural Development (Tunisia)
CTV	Territorial Extension Unit (Tunisia)
DALY	disability adjusted life year
DGGREE	Directorate General of Rural Engineering and Water Management (Tunisia)
DHMPE	Directorate of Environmental Health and Environmental Protection
DO	dissolved oxygen
DOE	Department of Energy (UAE)
EAD	Environment Agency - Abu Dhabi
EC	electrical conductivity
EC	European Commission
ECRA	Electricity and Cogeneration Regulation Authority (Saudi Arabia)
EP	emerging pollutant
EPSS	Environment Protection and Safety Section (UAE)
EWRA	Egyptian Water Regulatory Authority
FAO	Food and Agriculture Organization of the United Nations
GASTAT	General Authority for Statistics of KSA
GCC	Gulf Cooperation Council
GDA	Agricultural Development Group (Tunisia)
GTA	gender transformative approaches
HACCP	Hazard Analysis Critical Control Point
HCWW	Holding Company for Water and Waste-water (Egypt)
ICARDA	International Center for Agricultural Research in the Dry Areas
IWMI	International Water Management Institute
IWPP	independent water and power project
JICA	Japanese International Cooperation Agency
JM	Jericho Municipality
JPTD	Jordan Projects for Tourism Development
JVA	Jordan Valley Authority
KSA	Kingdom of Saudi Arabia
LARI	Lebanese Agricultural Research Institute
MAHRP	Ministry of Agriculture and Hydraulic Resources and Fisheries (Tunisia)
MALE	Ministry of Local Affairs and the Environment
MARHP	Ministry of Agriculture, Water Resources and Fisheries
MENA	Middle East and North Africa
MEWA	Ministry of Environment Water and Agriculture (Saudi Arabia)
MHER	Ministry of Hydraulic and Electric Resources (Lebanon)
MHUUC	Ministry of Housing, Utilities and Urban Communities (Egypt)
MOA	Ministry of Agriculture (Palestine)
MoCI	Ministry of Commerce and Industry (Saudi Arabia)
MSP	multi-stakeholder platform
MSP	Ministry of Public Health
MWI	Ministry of Water and Irrigation (Jordan)
N	Nitrogen

NOPWASD	National Organization For Potable Water and Sanitary Drainage (Egypt)
OECD	Organisation for Economic Co-operation and Development
ONAS	National Sanitation Utility (Tunisia)
OPEX	operating expenditure
P	Phosphorus
PFU	Palestinian Farmers' Union
PNE	National Water Plan (Morocco)
PWA	Palestinian Water Authority
QMRA	Quantitative Microbial Risk Assessment
RADEEMA	Water and Electricity Distribution Authority of Marrakech (Morocco)
RSB	Regulation and Supervision Bureau (UAE)
RSS	Royal Scientific Society (Jordan)
RWE	regional water establishment
SCAD	Statistical Center – Abu Dhabi
SDG	United Nations Sustainable Development Goals
SIDA	Swedish International Development Cooperation Agency

SIO	Saudi Irrigation Organization
SONEDE	National Water Supply Utility (Tunisia)
SOP	standard operating procedure
TSS	total suspended solids
TWW	treated wastewater
UAE	United Arab Emirates
UN Water	United Nations Women
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNSTAT	United Nations Statistics Division
UN-Water	United Nations Water
US EPA	United States Environmental Protection Agency
USAID	United States Agency for International Development
USDA	United Sates Department of Agriculture
WAJ	Water Authority of Jordan
WHO	World Health Organization
WLE	CGIAR Research Program on Water, Land and Ecosystems
WWTP	wastewater treatment plant

Editors

Javier Mateo-Sagasta is a Senior Researcher at the International Water Management Institute (IWMI) where he works on water pollution control and safe water reuse and coordinates IWMI's work on water quality across research groups. He has led the ReWater MENA project, a major multi-partner initiative for more and safer water reuse in Middle East and North Africa, and undertakes regional and global assessments on wastewater, water pollution and resource recovery and reuse with UN partners. Javier is the co-chair of the technical advisory committee of the Global Water Quality Alliance and member of the steering committee of the Global Wastewater Initiative. Before joining IWMI, Javier worked as an agriculture engineer and environmental scientist for research centers in Jordan and the Netherlands, the private sector in Spain, the Food and Agriculture Organization of the United Nations (FAO) where he coordinated the water quality program of the Land and Water division for four years, and in multidisciplinary teams mainly in Middle East and North Africa, Latin America, Europe and South Asia.

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Foreword

The Middle East and North Africa (MENA) region[1] is considered the most water-scarce region in the world. Currently, average renewable water resources availability per capita is one-tenth of the worldwide average. Twelve of the world's 15 most water-stressed countries are in the MENA region. Increasing water scarcity and pollution is becoming a major concern. The water crisis is creating competition for water between sectors and countries with threats to social stability, peace, economic growth and ecosystems.

It is expected that water scarcity will be exacerbated as a result of population growth, changing lifestyles and the impacts of climate change in some regions, and governments and international organizations are all looking for solutions. Countries need to urgently adapt to this situation and one promising solution for increasing water supply is the smart reuse of treated water.

As this book highlights, the number of (direct) water reuse projects has doubled every decade since 1990, and there are more than 400 operational projects now in the MENA region. Nevertheless, the potential for resource recovery from municipal wastewater in the MENA region is still untapped. Despite the progress, only 10–11% of the municipal wastewater generated in the region is treated and reused directly, while 36% is reused indirectly, mostly in an informal and unsafe manner due to limited water treatment. Approximately 54% of the municipal wastewater is discharged into the ocean or evaporated with no productive use.

The region cannot afford this loss. The recovery of lost wastewater could, for example, irrigate and fertilize more than 1.4 million hectares. The recovery of carbon embedded in this wastewater, if recovered in the form of methane, could provide energy to millions of households.

MENA needs to overcome the barriers to more and safer water reuse and accelerate the replication of successful reuse cases. In this book, the most recent available data have been collected to review the state of water reuse in the region, and policy recommendations are made to address the challenges that obstruct the potential of water reuse. A number of successful water reuse cases have been selected and analyzed to encourage replication.

As highlighted in this book, the factors that will contribute positively to inclusive scaling and replication of safe water reuse projects are: participatory stakeholder processes and effective communication that improves acceptability; economic and finance models that improve cost recovery and sustainability; effective and harmonic policies that address institutional fragmentation; adequate regulations that are ambitious but affordable; safety measures from farm to fork; and gender mainstreaming in water reuse projects and policies that ensures equitable participation and benefit sharing.

[1]This book has compiled data from 19 Arab countries of the MENA region (namely, Algeria, Bahrain, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, the United Arab Emirates and Yemen). Throughout this book the terms 'MENA region' and/or 'the Region' refer only to those 19 countries.

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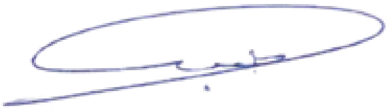

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Section 1
Evolution, state and prospects for water reuse in MENA

Introduction

Javier Mateo-Sagasta

Section 1 summarizes the best available data on water reuse in the Middle East and North Africa region.[1] The chapters of this section review the challenges and opportunities to untap the reuse potential in MENA. It is aimed at a broad audience, including public officers, academics, students and the media.

Chapter 1 covers the context and drivers of water reuse in MENA. The MENA region is considered the most water-scarce region in the world. The significant population growth, high urbanization rate, migration, irrigation expansion and agricultural intensification have created an increased water demand in the region. On the supply side, available water resources are diminishing due to decreasing precipitation and runoff and increased evapotranspiration because of climate change. The chapter analyzes how these drivers are aggravating the already existing regional water crises. It also shows how water reuse is being adopted formally and informally as part of the solution. It concludes by calling for an accelerated change toward more and safer water reuse.

Chapter 2 explores the untapped opportunities for wastewater production, treatment and reuse in MENA. The chapter offers a systematic and synthesized review of municipal wastewater generation, composition and fate in MENA countries based on the best available data from hundreds of sources. The chapter provides definitions and key figures to better understand the subsequent chapters of this book. It looks at the dimension of valuable resources embedded in wastewater streams and the extent to which these resources are so far being recovered for beneficial uses. The chapter provides some explanations for situations where the data are weak or scarce.

Chapter 3 presents case studies from five MENA countries to illustrate the water reuse policy and institutional landscape development in the region. The chapter explores the policy and

[1]This book has compiled data from 19 Arab countries of the MENA region (namely, Algeria, Bahrain, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, the United Arab Emirates and Yemen). Throughout this book the terms 'the MENA region' and 'MENA' refer only to those 19 countries.

institutional landscape of wastewater treatment and reuse in Egypt, Jordan, Lebanon, Tunisia and Saudi Arabia. It analyzes the key elements that contribute to, or hinder, the development of water reuse policies and institutional arrangements in the selected countries. It does so by observing the different trajectories each country has followed in developing its water and sanitation sector over the years. The chapter analyzes the key policy and institutional milestones as well as the bottlenecks that shaped this development throughout the years. It starts by identifying the most important policies and institutional reforms (milestones) that shaped the current water reuse institutions and arrangements, then analyzes the current interactions and de facto functioning of the different governmental institutions that operate in the sector.

Chapter 4 explores the cost recovery mechanisms of water reuse in the MENA region. It assesses several wastewater treatment and reuse projects in the MENA region by focusing on indicators such as their costs and cost recovery or revenue generation mechanisms and the associated technologies. The chapter draws on primary and secondary data collected from existing wastewater treatment plants (WWTPs) in the region with varying value propositions to estimate the investment and operational cost of WWTPs per volume of wastewater treated and operational cost recovery from water reuse.

Chapter 5 examines how water quality standards and regulations for agricultural water reuse in the MENA region evolve from international guidelines to country practices. The chapter analyzes national regulations and guidelines for irrigation water reuse in the MENA region with a focus on five countries: Egypt, Lebanon, Morocco, Jordan and Tunisia. It introduces the main regulatory approaches adopted worldwide with a focus on the WHO and FAO guidelines that proved influential in the region. The second part of the chapter reviews the historical development of countries' regulations within the larger development of water reuse policies. The third part compares the health-based, agronomic and physicochemical standards against different international guidelines and other MENA country regulations, with a particular interest in human-health standards and restrictions imposed on agricultural practices. The fourth part of the chapter questions the adoption (or lack thereof) of the internationally promoted risk management approaches and unpacks some challenges preventing their translation into national policies and practices. The chapter concludes with common trends in designing qualitative regulations for agricultural water reuse in the MENA region and draws recommendations for future policy and research activities.

Chapter 1

Context and drivers of water reuse in MENA

Nisreen Lahham, Javier Mateo-Sagasta, Mohamed O.M. Orabi and Youssef Brouziyne

Key messages

- In recent decades, the Middle East and North Africa (MENA) region has experienced the fastest global decline in available water resources in the world and, currently, the average per capita renewable water resources availability is 10 times less than the global average.
- This situation has been aggravated locally and millions of people that have been internally displaced now require increased domestic water supply in a context of already stressed water resources.
- MENA's population is expected to grow rapidly from 381 in 2015 to 680 million in 2050. Such population growth, together with a rapid urbanization, agricultural expansion and intensification and changing consumption patterns is forecast to drive the increase of water demand by 50% in 2050.
- Much of the MENA region is forecast to experience more warming than the global average, with average temperatures expected to rise by at least 4°C by 2050, even if global warming is limited to a 2°C increase. Precipitation is also forecast to decrease in most of the MENA region by mid-century.
- Demographic growth and urbanization have also translated into greater wastewater production. The capacity for sanitation and wastewater treatment is not growing at the same rate and therefore the amount of wastewater discharged untreated into the environment keeps growing in some countries. An increasing amount of water pollution further aggravates the situation and makes less water safe for use.
- Water scarcity and pollution are driving thousands of farmers in the region to use marginal quality water to irrigate, posing potential health, agronomic and environmental risks. These risks need to be assessed and mitigated.
- Despite increasing water scarcity, substantial amounts of wastewater (treated or untreated) are still lost in the sea or evaporated on land or across rivers with no beneficial use, missing opportunities for resource recovery.

1.1. Introduction

The MENA region[1] occupies an approximate territory of 12.5 million square kilometers (km^2), which is about 9.5% of the planet's land area (FAO 2022a).[2] Home to 5.4% of the world's population (World Bank 2022a), the region contains only 1% of the world's renewable freshwater (Kandeel 2019). The MENA region is considered the most water-scarce region in the world, with average water resources per capita at 550 cubic meters (m^3)/capita/year (FAO

[1]This book has compiled data from 19 Arab countries of the MENA region (namely, Algeria, Bahrain, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, the United Arab Emirates and Yemen). Throughout this book the terms 'MENA region' and/or 'the Region' refer only to those 19 countries.

[2]As the rest of the regional figures in this chapter, these figures have been calculated based on data from the 19 analyzed countries.

2022b). That amount is half the 1,000 m^3/capita threshold for water scarcity and just above the 500 m^3/capita threshold for absolute water scarcity, according to the UN Water Stress Index (Frascari et al. 2018).

The significant population growth, high urbanization rate, migration, irrigation expansion and agricultural intensification have created an increased water demand in the region. On the supply side, available water resources are diminishing due to decreasing precipitation and runoff and increased evapotranspiration, as a result of climate change (IPCC 2021).

This chapter analyzes how these drivers are aggravating the already existing regional water crises. It also shows how water reuse is being adopted formally and informally as part of the solution. It concludes by calling for an accelerated change toward more and safer water reuse.

1.2. Population growth, urbanization, migration and agriculture intensification

Since 2000, the MENA region has experienced an average population growth of 1.8% annually (World Bank 2022b). The total population has increased from around 70 million in 1950 to around 418 million in 2020 (World Bank 2022a). MENA's population is expected to keep growing, in part because of its young age structure, with one-third of the region's population aged under 15. As a result, the population of MENA is projected to more than double between 2000 and 2050.

Population growth is coupled with increasing trends in urbanization. About 73% of the MENA population (305 million) lived in cities in 2020, doubling since 1960 and exceeding the global average of 56% (UN 2018). Table 1.1 shows the relationship between population growth and urbanization in the countries of the MENA region, from 1970 to 2050. In countries such as Algeria, Jordan, Iraq and Morocco more than 60% of people already live in cities. Except for some countries, such as Sudan and Yemen, most countries in MENA have experienced extensive urbanization over the past 30 years, even in countries where population growth has been low or moderate. Urbanization growth is expected to accelerate, and the region's urban population is expected to increase by 10% in 2050, reaching nearly 560 million (UN 2018).

Population growth in some of the MENA countries was not limited to natural demographic increases but was also affected by an influx of cross border displacement of people, due to the turmoil and series of conflicts and economic crises in countries such as Syria, Iraq, Yemen or Lebanon. Not only were citizens moving from rural to urban areas, but refugees from other countries were also relocating to cities. About 2.7 million refugees are hosted in different MENA countries, with an additional 12.4 million people internally displaced. Abrupt relocations of population further increase water demand and impact water quality in host communities. Migration puts increased pressure on municipal water resources for both migrant and host communities. The Syrian refugees in Jordan, for instance, have contributed to a 40%

increase in the demand for water in the northern governorates (Borgomeo et al. 2021). In Lebanon, 25% of the population are refugees who require an increased domestic water supply in a context where local authorities already struggle to provide water for its population.

Urbanization and income growth are some of the key drivers of the changing lifestyle and diets in the MENA region, which in turn contribute to increased water demand. Even though poverty persists, and about 20% of the population lives on less than USD 2 a day (World Bank 2022c), average income per capita has increased. This rise in income has transformed consumption patterns and diets toward water-intensive products such as meat and dairy (Mateo-Sagasta et al. 2018). The growing demand for water-intensive products, as seen in other parts of the world, has increased the demand for irrigation in many MENA countries such as Tunisia, Egypt and Morocco, as these countries are major exporters of many fruits and vegetables.

TABLE 1.1 Population growth and urbanization for MENA countries.

Country/Region	Population (millions)[a]					Urban population (%)[b]	
	1970	2001	2015	2020 (estimated)	2050 (forecast)	2015	2050 (forecast)
Algeria	14.5	31.5	39.7	43.9	66.6	70.8	84.5
Bahrain	0.2	0.7	1.4	1.7	2.4	89.0	93.2
Egypt	34.5	70.2	92.4	102.3	174.1	42.8	55.6
Iraq	9.9	24.2	35.6	40.2	79.2	69.9	80.5
Jordan	1.7	5.2	9.3	10.2	14.2	90.3	95.3
Kuwait	0.7	2.1	3.8	4.3	5.4	100	100
Lebanon	2.3	4.0	6.5	6.8	6.6	88.1	93.4
Libya	2.1	5.4	6.4	6.9	8.8	79.3	88.4
Mauritania	1.1	2.7	4.0	4.6	9.0	51.1	72.9
Morocco	16.0	29.1	34.7	36.9	47.5	60.8	77.2
Oman	0.7	2.3	4.3	5.1	7.6	81.4	94.9
Palestine	1.1	3.3	4.5	4.8	10.1	75.4	85.5
Qatar	0.1	0.6	2.6	2.9	3.9	98.9	99.7
Saudi Arabia	5.8	21.2	31.7	34.8	46.7	83.2	90.4
Sudan	10.3	28.0	38.9	43.8	81.2	33.9	52.6
Syria	6.4	16.8	18.0	17.5	34.6	52.2	71.9
Tunisia	5.1	9.8	11.2	11.8	13.9	68.1	80.2
UAE	0.2	3.3	9.3	9.9	10.3	85.7	92.4
Yemen	6.2	17.9	26.5	29.8	57.9	34.8	57.2
TOTAL	**119.1**	**278.3**	**380.8**	**418.3**	**680.0**	**71.3**	82.4

SOURCES: [a]UN 2019; [b]UN 2018.

The agricultural sector is the largest user of water in MENA (FAO 2022c). By 2050, the agricultural sector is expected to produce about 100% more food to ensure food security, which will require substantial and additional amounts of water.

Forecasts suggest that these drivers will continue into the next decades, increasing the demand for water resources. It is anticipated that these trends in population growth combined with economic growth will result in a 50% increase in water demand by 2050 (Mualla 2018).

1.3. Water scarcity and water stress

Water stress in the MENA region, measured as water withdrawals as a percentage of total renewable surface freshwater availability,[3] is greater than in any other region in the world. Currently, the average per capita renewable water resources availability is 10 times less than the worldwide average (Table 1.2) (FAO 2022b). Eight countries in the region (Kuwait, United Arab Emirates, Saudi Arabia, Libya, Qatar, Yemen, Algeria and Bahrain), hosting 60% of the regional population, are in the global top 10 highest levels of water stress (World Bank 2018). MENA water resources have experienced the fastest global rates of decline, decreasing by about two thirds over the last 40 years (World Bank 2018). The surface water resources of the region are not only the scarcest, but they are also the most variable and unpredictable in the world. Surface freshwater availability varies greatly from year to year (World Bank 2018).

Demographic growth and urbanization have also led to greater wastewater production. The capacity for sanitation and wastewater treatment is not growing at the same rate in many countries and therefore the amount of wastewater discharged untreated into the environment keeps growing (WHO 2021).

Climate change profoundly affects the availability and quality of water resources in the region, further worsening the vulnerability of the region's water security (IPCC 2021). Increased temperatures and evapotranspiration and reduced precipitation and runoff commencing from climate change pose additional pressures on water resources (World Bank 2018).

Since the 1960s, temperatures in the MENA region have increased by about 0.3°C per decade (Waha et al. 2017). In general, the hotspots of temperature increase are in Southern Egypt, Eastern Turkey and most of the Saharan desert, where temperatures increased up to 4°C per decade (ESCWA 2019). Even if global warming is limited to a 2°C increase by 2050, the MENA region is set to experience temperatures well beyond this projection because of the desert warming amplification phenomenon. Temperatures are expected to rise in the region by at least 4°C by 2050 (Wehrey et al. 2022).

[3]Physical water scarcity is measured in terms of water usage relative to the natural endowment of surface freshwater resources, so it does not capture the contribution of non-conventional water supplies or groundwater resources that may have been developed to relieve water stress.

Precipitation levels in the MENA region have also fallen and most of the countries have become drier, with an annual average precipitation below 350 millimeters (ESCWA 2019). Whereas average global precipitation has risen since 1950, with a faster rate of increase since the 1980s (IPCC 2021), precipitation in the MENA region is forecast to decrease. Significant declines are forecast around the Mediterranean region of North Africa (Morocco, Algeria, Tunisia and Northern Egypt) and the Levant (Lebanon, Jordan and Syria) (ESCWA 2019). Rainfall in Jordan, for example, is forecast to decrease by 30% by the end of this century (Wehrey et al. 2022).

The MENA region is expected to become a global hotspot for droughts (Driouech et al. 2020) with declining precipitation, declining runoff and increasing evaporation by 2050 (IPCC 2021). These trends suggest interrelated implications leading to intensifying the region's current water scarcity.

Increased water scarcity is forecast to make gross domestic product drop between 6 to 14% yearly by 2050, reduce labor demand by up to 12% and lead to significant land-use changes, including the loss of beneficial hydrological services (World Bank 2018; Taheripour et al. 2020).

TABLE 1.2 Per capita water resources in MENA countries.

Country/Region	Per capita annual renewable fresh water (m³)			
	1970	2000	2015	2020
Algeria	763	366	282	276
Bahrain	506	158	78	74
Egypt	1,593	804	596	584
Iraq	8,478	3,604	2,393	2338
Jordan	497	176	96	94
Kuwait	23	9	4.931	5
Lebanon	1,862	1,077	660	657
Libya	301	127	106	105
Mauritania	9,364	4,104	2,662	2589
Morocco	1,737	985	815	805
Oman	1,803	600	300	290
Palestine	708	248	176	172
Qatar	444	905	21	21
Saudi Arabia	375	110	73	71
Sudan	708	NA	926	904
Syria	2,471	983	982	992
Tunisia	872	468	404	399
UAE	453	43	16	16
Yemen	329	114	75	74
MENA	1,752	827	561	551

NOTES: NA=data not available. *SOURCE*: FAO 2022b.

By 2041–2070, groundwater recharge could tumble 30 to 70% (relative to 1961–1990). Morocco and Tunisia are especially vulnerable due to their preexisting water scarcity and heavy reliance on groundwater sources (World Bank 2018). Climate change could also degrade important coastal groundwater sources as sea level rise drives saltwater intrusions into freshwater aquifers (IPCC 2021).

1.4. Water reuse as a response to the MENA water crisis

Water scarcity and pollution are forcing thousands of farmers in the MENA region to use raw or diluted wastewater to irrigate. The use of raw wastewater in agriculture has been reported in different countries of the region although the total extent of the practice is unknown. The lack of data is due partly to the informal character of most of the wastewater irrigation or even, in some cases, a deliberate intention not to disclose data. This may be done because farmers fear difficulties when trading their produce or when practitioners do not want to acknowledge what could be perceived as malpractice.

Direct use of untreated wastewater occurs where alternative water sources are scarce or unavailable, i.e., usually in drier climates but also in wetter climates in the dry season. The reasons for such use can be lack or low quality of alternative water sources (e.g., groundwater salinity), or the unaffordable costs of accessing freshwater (e.g., costs of pumping). Although officially disapproved or illegal in most countries, direct use of untreated wastewater is a reality that still takes place around towns and cities (Raschid-Sally and Jayakody 2008).

The most common reuse form is in agriculture. For example, untreated wastewater is used on farms because it is cheaper than using groundwater from boreholes, for which farmers have no capacity to pay. In other cases, farmers use wastewater from malfunctioning treatment plants or sewers, taking advantage of the already collected resource. In other cases, wastewater is the only water flowing in irrigation canals in the dry season and at the tail ends of irrigation schemes. In some extreme cases, farmers rupture or plug sewage lines to access the wastewater.

Indirect water reuse is by far the most extensive type of reuse in the region (Velpuri et al. in review). It occurs when treated or untreated wastewater is discharged into freshwater streams where it becomes diluted and is subsequently used – mostly unintentionally – by downstream users (e.g., farmers, households or industries). In areas where a large portion of the wastewater is still not safely treated (WHO 2021), the practice poses risks to farmers and consumers, particularly if such water is used to irrigate vegetables to be eaten raw. Additionally, the opportunity to sell crops into urban food markets encourages farmers to seek irrigation water in the city vicinity.

Several examples of indirect use of untreated wastewater have been reported across the region. For instance, in Egypt, untreated wastewater is discharged into el Rwahi Drain, which finally ends up in the Rosetta Branch of the River Nile. Similarly, the Zarkoun Drain discharges into the Mahmoudiah Canal. Eventually, this water is used for irrigation (Tawfik et al. 2021). Another example is from the extreme east of Algeria. The Medjerda wadi is one of the water sources used for agricultural irrigation in the city of Souk Alhras (northeast of Algeria). The wadi receives contaminated raw domestic and industrial wastewater, which farmers use to meet the water requirements of their crops (Mamine et al. 2020).

This reality should not be neglected. Farmers are using polluted water to irrigate. Risks need to be assessed (Mara and Bos 2010), and the practice needs to become safer. Solutions need to consider cost-effective wastewater treatment, but not only that. A combination of solutions from farm to fork can offer multiple barriers to health risks (WHO 2006, 2016). On-farm practices such as the use of drip irrigation or irrigation stoppage several days before harvesting to favor pathogen die off can be very effective to ensure food safety (Abi Saab et al. 2022) and can offer an additional safety net in case wastewater treatment is interrupted or dysfunctional. Once harvested, produce should not be recontaminated during transport or in markets by, for example, using unhygienic practices or unsafe water.

BOX 1.1 The benefits of planned water reuse in agriculture.

The recovery of resources such as water, nutrients/fertilizers and organic matter from wastewater, in support of food production, can have benefits for all sectors involved: cities, agriculture and the environment.

Agriculture can benefit from the reuse of urban effluents in several ways, the most important being: (i) improving the reliability of the water supply, (ii) improving the fertilizing capacity of the nutrients of the urban effluents and (iii) bringing agricultural production closer to consumption centers.

Cities can benefit from reuse mainly for three reasons: (i) they can strengthen their food security by supplying peri-urban agriculture with water and nutrients; (ii) reuse can effectively contribute to solve their wastewater treatment problem and in particular the removal of nutrients, which can be used by plants rather than ending up in water bodies causing eutrophication of lakes or pollution of groundwater with nitrates; and (iii) they can increase their water availability, when wastewater is reused for municipal uses, or when reclaimed water is exchanged for fresh water between cities and agriculture.

The environment, and especially aquatic ecosystems, can benefit from the safe treatment and reuse of wastewater. Reuse can improve water quality and increase its availability for environmental uses. In addition, reuse systems associated with peri-urban agriculture and agroforestry have a high potential for carbon sequestration and climate change mitigation.

On the other hand, despite increasing water scarcity, substantial amounts of wastewater (treated or untreated) are still lost in the sea or evaporated on land or across rivers with no beneficial use. The direct and planned use of recycled water is still marginal (see Chapter 2). Accelerating change toward more and safer water reuse has benefits for all sectors involved (Box 1.1) but will require the formulation and implementation of appropriate and effective policies (Box 1.2; see Chapter 3), including incentives for financial sustainability of wastewater treatment reuse projects (see Chapter 4) and affordable regulations that ensure safety (see Chapter 5).

BOX 1.2 Increasing importance of wastewater treatment in MENA's water strategies.

In the MENA region, and under the current water scarcity situation, which is expected to worsen, treated wastewater constitutes a constant and perennial resource. Most national water strategies and plans in the region rely on wastewater treatment as a key component in the national water resources mix to reduce water deficits, preserve the natural environment and support socioeconomic development.

In Morocco, and since the implementation of the National Liquid Sanitation Plan (PNA) in 2006 and the new National Shared Liquid Sanitation Plan (PNAM) in 2019, more than 157 wastewater treatment plants have been developed and the rate of treatment has increased from 7% in 2006 to more than 50% in 2020 (Alami 2022). The reuse of treated wastewater is part of the recently introduced water strategy relating to the development of water supply by valuing non-conventional resources. Morocco's long-term objective is to reuse 300 million m^3 per year by 2050, across the whole country (SK 2022).

The first pilar of Egypt's National Water Resources Plan (2017–2037) is composed of a set of actions to manage water quality, such as pollution control, and sewage and industrial water treatment. In 2021, Egypt's Minister of Housing, Utilities and Urban Communities announced that Egypt is constructing 151 sewage treatment plants across the republic, with a capacity of 5 million m^3 of water per day (Morsy 2021).

In Jordan, one of the most water-scarce countries in the world, the government has a 2016–2025 National Water Strategy which charts a target volume of treated wastewater of 240 million m^3 annually by 2025 (MWI 2016).

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Chapter 2

Wastewater production, treatment and reuse in MENA:
Untapped opportunities?

Javier Mateo-Sagasta, Naga Manohar Velpuri and Mohamed O.M. Orabi

Key messages

- Water reuse has great potential to help overcome some of the challenges posed by the increasing pressure on already stressed water resources.
- Wastewater is the only source of water that increases as population and water use grow. Currently, the MENA region[1] produces around 21.5 billion cubic meters (BCM) of nutrient-rich municipal wastewater per year.
- Many MENA countries are substantially improving their wastewater treatment rate, however, about 40% of produced domestic wastewater and a substantial portion of industrial wastewater in the region are still left untreated. This poses serious risks to human health and ecosystems and reduces the amount of fresh water that is safe to use.
- The region has doubled the number of projects for direct water reuse every decade since 1990, and indirect water reuse is frequent. Nevertheless, up to 54% of the municipal wastewater that is produced is still not put to good use. It is either being discharged into the sea or evaporated (on land or along rivers).
- This wasted wastewater, if recovered, can increase the energy, nutrients and water availability and enhance the region's ability to adapt to changes in climate and enhance food security. The lost wastewater, if fully recovered, could additionally irrigate and fertilize more than 1.4 million hectares (ha). The carbon embedded in the generated wastewater, if recovered in the form of methane, would have a caloric value to provide electricity to 8 million households.
- The region needs to overcome the factors that limit the materialization of the regional full water reuse potential, including: cultural barriers and distrust; institutional fragmentation; inadequate regulatory frameworks; and the lack of appropriate tariffs, economic incentives and financial models, which undermines cost recovery and the sustainability of reuse projects.
- The region also needs standardized data collection and reporting efforts across the formal and informal reuse sectors to provide more reliable and updated information, which is essential to develop proper diagnosis and effective policies for the safe and productive use of these resources.

[1]This book has compiled data from 19 Arab countries of the MENA region (namely, Algeria, Bahrain, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, the United Arab Emirates and Yemen). Throughout this book the terms 'MENA region' and/or 'the Region' refer only to those 19 countries."

2.1. Introduction

The Middle East and North Africa (MENA) is the most water-stressed region in the world. Freshwater withdrawals exceed renewable water resources in almost all countries in the region. The gap between the supply and demand is widening every year. Currently, the average per capita renewable water resources availability (551 m^3/year) is 10 times less than the worldwide average (FAO 2020).

Since 2000, the region has witnessed a series of conflicts and droughts. This has led to a considerable displacement of people and has potential for long-term impacts on the already stressed land and water resources (Taheripour et al. 2020). Pathogens heavily affect many rivers in the region (UNEP 2016). The occurrence of emerging pollutants in water is also a growing concern (Haddaoui and Mateo-Sagasta 2021; Ouda et al. 2021). Pollution reduces even further the amount of water that is safe to use. Water scarcity and pollution are impacting various sectors of the economy (Fragaszy et al. 2022a; Fragaszy et al. 2022b).

These pressures on the water resources and infrastructure may become structural and be aggravated by population growth, changes in our consumption patterns and climate change. Population and urbanization have grown and will continue to grow. The de facto population of the region has increased from 272.2 million inhabitants in 2000 to 418.3 million estimated for 2020 (UN 2019). Urban agglomerations like 'Greater Cairo,' Riyadh and Dubai now host 25.5, 8.6 and 4.5 million people, respectively, and are forecast to grow at an annual rate of 1.5–2% by 2030 (CAPMAS 2022; GASTAT 2019; GD 2021). Changes in calorie intake and diets have also increased the demand for a greater diversity of foods, including meat and dairy products, which have large water footprints. This has increased water demand for irrigation and food production (Mateo-Sagasta et al. 2018). Forecasts suggest that these drivers will continue to widen the water supply and demand gap in the next decades.

On top of all this, precipitation in the region is forecast to decrease, with more frequent and intense droughts, while evapotranspiration will increase (Zittis 2018; Babaousmail et al. 2022). Water scarcity is forecast to reduce GDP by 6–14% yearly by 2050 (World Bank 2018). Furthermore, increased water scarcity could reduce labor demand by up to 12% and lead to significant land-use changes, including loss of beneficial hydrological services (Taheripour et al. 2020).

Agriculture is the largest user of water in MENA and is particularly susceptible to water availability, accessibility and quality. The sector is expected to produce more food to ensure food security. This will require substantial and additional amounts of water.

Taheripour et al. (2020) conclude that "unless new and transformative policies for sustainable, efficient and cooperative water management are promoted, water scarcity will negatively impact the region's economic prospects and undermine its human and natural capital." Governments in MENA are responding to this water crisis by urgently seeking interventions to increase water security by optimizing water management, narrowing the supply-demand gap and preventing water quality degradation. Such interventions typically include increases in water use efficiency and productivity, reductions in unproductive water loses in water networks and increases of the water budget by using non-conventional sources of water, such as municipal effluents.

Municipal effluents are mostly (99%) made of water. The 1% that remains is made of different compounds including valuable resources such as nitrogen and phosphorus. These resources can be recovered and used as fertilizers for agriculture, organic carbon that can be used as an ameliorator of soils or energy in the form of methane. Nevertheless, these effluents also have pathogens and chemicals that can pose risks to human health and the environment. If these hazards are removed or controlled, the resources embedded in wastewater can be recovered and used with benefits for all.

Rather than losing wastewater that has been discharged to the sea or evaporated on land or along rivers, we can recover it and bring new water back to the water budget. Additionally, agriculture can benefit from a constant flow of water all year round, thus making agricultural systems more resilient to droughts. Nutrients such as phosphorus and nitrogen can be reused as fertilizers with increased yields.

Cities can increase their food security if water reuse favors the development of productive green belts around urban areas. Cities can also use agriculture as a tertiary treatment where crop uptake nutrients that otherwise could pollute receiving waters. The environment will also benefit from reduced pollution and the conservation of fresh water for environmental purposes.

Water reuse has great potential to help overcome some of the challenges posed by the increasing pressure on already stressed water resources (WWAP 2017). MENA cities and towns produce millions of cubic meters of wastewater every year. The fate of this wastewater is very different depending on the local context: wastewater can be collected or not, treated or not and finally used directly or indirectly or evaporate or be disposed in the sea with no beneficial use (Box 2.1; Box 2.2; Figure 2.1).

BOX 2.1 A note on definitions (adapted from Mateo-Sagasta 2015)

Wastewater can be defined as "used water discharged from homes, businesses, industry, cities and agriculture" (Asano et al. 2007). According to this definition, there are as many types of wastewater as water uses (e.g., urban wastewater, industrial wastewater or agricultural wastewater). When wastewater is collected in a municipal piped system it is called 'sewage.'

The term 'wastewater' as used in this book is basically synonymous with **municipal wastewater**, which is usually a combination of one or more of the following: **domestic wastewater** consisting of blackwater (from toilets) and greywater (from kitchens and bathing); water from commercial establishments and institutions, including hospitals; industrial effluent within the city or town, where present; and stormwater and other urban runoff. Municipal wastewater does not include industrial wastewater (including wastewater from the mining, manufacturing or energy sectors) or agricultural wastewater generated and collected outside human settlements.

Wastewater can be collected or not, treated or not, and finally used directly or discharged to a water body and be either reused indirectly downstream or lost when it is discharged to the sea or evaporates with no beneficial use.

Wastewater collection

Wastewater can be collected and treated on-site (e.g., in septic tanks) or off-site (e.g., in piped sewerage systems connected to a treatment plant). The design and size of a septic system can vary widely; typically, within the tank there is sedimentation and primary treatment of wastewater and the partially treated effluent percolates to the soil through a constructed soak pit. It is also frequent in middle- and low-income countries that such tanks are not properly designed and maintained and the effluent drains directly into open canals. Sewerage systems collect wastewater from households but also from other commercial activities and industries within cites as indicated above.

Types of wastewater treatment

Before being treated, sewage usually goes through *pre-treatment* to remove grit, grease and gross solids that could hinder subsequent treatment stages.

Later, *primary treatment* aims to settle and remove suspended solids, both organic and inorganic. The most common primary treatments are primary settlers, septic and imhoff tanks.

In *secondary treatment* soluble biodegradable organics are degraded and removed by bacteria and protozoa through (aerobic or anaerobic) biological processes. Typical secondary treatments include aerated lagoons, activated sludge, trickling filters, oxidation ditches and other extensive processes such as constructed wetlands.

Tertiary treatment aims at effluent polishing before being discharged or reused and can consist of the removal of nutrients (mainly nitrogen and phosphorous), toxic compounds, residual suspended matter or microorganisms (disinfection with chlorine, ozone, ultraviolet radiation or others). Nevertheless, this third stage/level is rarely employed in low-income countries. The tertiary treatment process can include membrane filtration (micro-, nano-, ultra- and reverse osmosis), infiltration/percolation, activated carbon and disinfection (chlorination, ozone or UV).

Finally, *water reclamation* refers to the treatment of wastewater to make it suitable for beneficial use with no or minimal risk.

BOX 2.2 Types and examples of uses of reclaimed water (adapted from Mateo-Sagasta 2015)

Agricultural and forestry irrigation: irrigation of crops, forests, agroforestry or commercial nurseries.

Landscape irrigation: reuse for parks, schoolyards, freeway medians, golf course, cemeteries, greenbelts or residential.

Industrial uses: cooling water, boiler feed, process water or heavy construction.

Groundwater recharge: groundwater replenishment for saltwater intrusion control or subsidence control.

Recreational uses: leisure activities like fishing, boating, bathing or snowmaking.

Environmental uses: lakes and ponds, marsh enhancement, stream-flow augmentation and fisheries.

Potable reuse: Planned augmentation of a drinking water supply with reclaimed water. It can be indirect potable reuse (e.g., through groundwater recharge or by blending in water supply reservoirs with a subsequent drinking water treatment) or direct potable reuse (e.g., pipe-to-pipe water supply).

Non-potable urban uses: All other urban uses that do not involve potable reuse or landscape irrigation, such as fire protection, air conditioning or toilet flushing.

The direct use of wastewater implies that treated or untreated wastewater is used for different purposes (such as crop production, aquaculture, forestry, industry, gardens or golf courses) with no prior dilution. When it is used indirectly, the wastewater is first discharged into a water body where it undergoes dilution prior to use downstream.

Reuse can be planned or unplanned. Planned water reuse refers to the deliberate and controlled use of raw or treated wastewater, for example, for irrigation. Most indirect use occurs without planning. Aquifer recharge might be an exception.

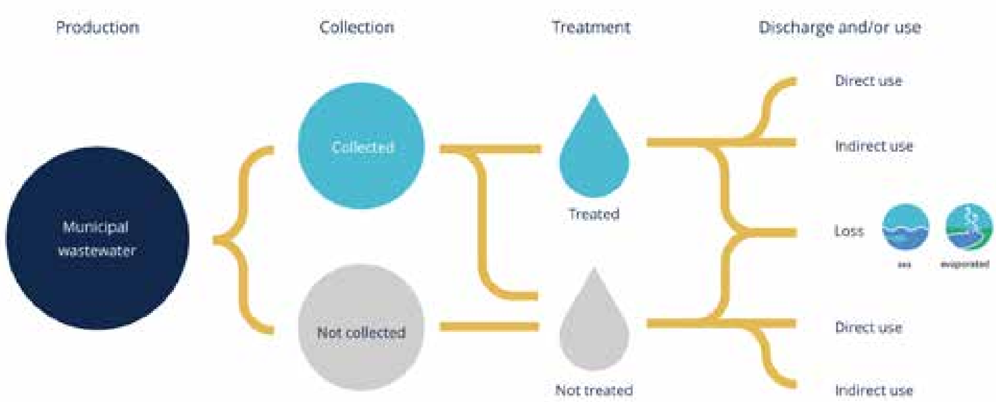


FIGURE 2.1 Wastewater fate flows (adapted from Mateo-Sagasta and Salian 2012).

Improving the treatment of wastewater, increasing the direct use of treated wastewater and making the indirect use of polluted water safer are key to addressing the MENA water crisis.

This chapter offers a systematic and synthesized review of municipal wastewater generation, composition and fate in MENA countries based on the best available data from hundreds of sources. The chapter also provides definitions and key figures to better understand the subsequent chapters of this book. The chapter also looks at the dimension of valuable resources embedded in wastewater streams and the extent to which these resources are so far being recovered for beneficial uses. Where data are weak or scarce, the causes of such data gaps are discussed.

2.2. Production, composition and treatment of municipal wastewater

2.2.1. Production of wastewater

Wastewater is a resource that can be mined, and as such, it is important to understand how it is geographically distributed in the MENA region. Municipal wastewater is generated where population concentrates, which is typically along the coasts and large rivers. Municipal wastewater production does not only depend on population density but also on the per capita wastewater production, which mainly depends on the per capita municipal water use, which, in turn, is more related to the income per capita than to actual renewable water resources abundance.

High-income countries such as Bahrain or Kuwait, which are water scarce but have access to seawater and can afford water desalination at a large scale, typically have much higher per capita wastewater generation than countries such as Yemen, Mauritania or Sudan or than water-scarce middle-income countries where desalination is limited, such as Jordan, Morocco or Tunisia (Figure 2.2).

Within countries, rural areas use less water per capita than urban areas and this also has an effect on the per capita wastewater generation.

Figure 2.2 illustrates how municipal wastewater generation per capita is calculated as the total municipal wastewater generated in 2015 as per AWC (2019) divided by the population per country in 2015 as per UNSTAT. Saudi Arabia (KSA) and Kuwait are exceptions and municipal wastewater data was drawn from GASTAT (2020) and CSB (2020), respectively, since the data from AWC (2019) was unrealistically low.

Domestic wastewater generation per capita in Figure 2.2 is calculated as the total domestic wastewater generated in 2020 as per WHO (2021) divided by the population per country in 2020 as per UNSTAT. Saudi Arabia and Qatar are exceptions and municipal wastewater data was drawn from GASTAT (2020) and PSA (2019) respectively as the data from WHO (2021) was unrealistically high for Saudi Arabia and low for Qatar.

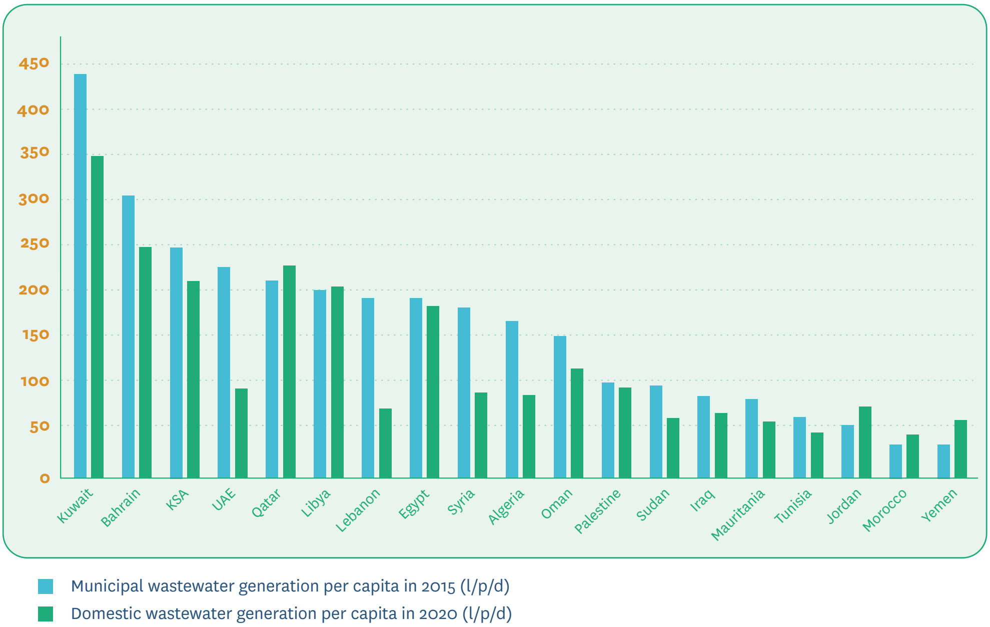


FIGURE 2.2 Per capita municipal and domestics wastewater generation in MENA countries.

By definition (see Box 2.1) figures for municipal wastewater should be larger than domestic wastewater, but this is not always the case in the data shown in Figure 2.2. This may be due to the different years compared (2020 for domestic and 2015 for municipal) or because of deeper methodological inconsistencies between sources. Both WHO (2021) and AWC (2019) collect data from country primary sources, which tend to use different methodologies and define terms differently. This may also be because in some MENA countries, there are very few industries, especially those that use lots of water, such as the textile industry.

Figure 2.3 shows the spatial distribution of the municipal wastewater generation in MENA resulting from combining per capita wastewater generation and population density based on Jones et al. (2021) and Velpuri et al. (forthcoming).

Jones et al. (2021) provided a spatially explicit distribution of global wastewater for 2015 at a special resolution of 5 arcmin (~10 km). This approach has been refined for the MENA region by developing and using the SEWAGE-Track model (Velpuri et al. forthcoming), which uses data from the nominal year 2015, has a resolution of 1 km, and differentiates and incorporates data on per capita wastewater production in rural and urban areas.

With these data and tools, we can precisely identify the location of where wastewater is generated (Figure 2.3). Cities are obviously hotspots of wastewater generation and produce 72% of the municipal wastewater in the region (the other 28% is generated in rural areas) (Velpuri et al. forthcoming). Nevertheless, water-demanding agricultural lands and tree plantations (the main users for reclaimed water in the region) are not always close to cities and sometimes are upstream of wastewater generation sites.

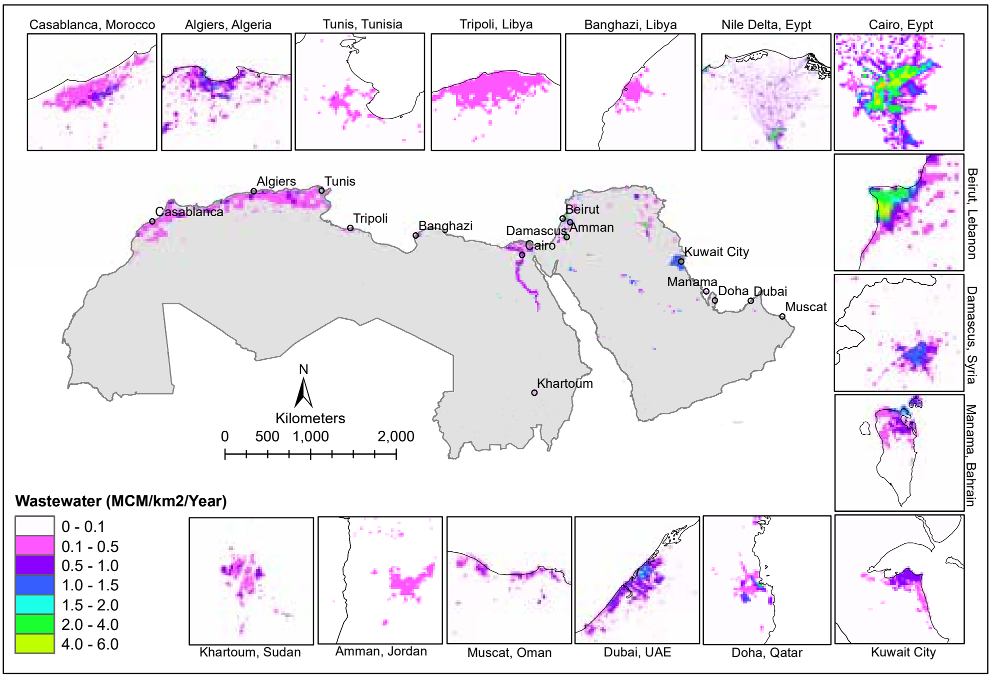


FIGURE 2.3 Wastewater generated in MENA.
NOTES: The map in the central region shows the distribution of wastewater generated by Jones et al. 2021. The insights for urban agglomerations in the periphery of the map show the wastewater generated by the SEWAGE-Track model (Velpuri et al. 2022).

This poses economic challenges for reuse since pumping wastewater back and beyond a given distance or height is not always economically feasible. In smaller towns and villages, which are closer to the WWTPs or surrounded by agricultural land, the challenge is typically that wastewater is collected on-site in septic tanks with limited treatment capacity. Effluents from septic tanks either percolate to groundwater or are discharged to open canals (if septic tanks are sealed) with very low treatment and poor removal of pathogens, which limits the potential for safe reuse.

When considering the trends, wastewater is the only source of water that increases as population and water use grow (Figure 2.4). This is particularly apparent in countries such as Egypt, which is the most populated country in MENA and experiencing booming growth of its urban areas, especially in and around Cairo. This trend is going to continue in the coming decades and the wastewater sector needs to adapt to cope with this increasing production of wastewater. An increasing body of evidence suggests that the economic costs (including environmental and health costs) of discharging wastewater into the environment untreated are higher than the costs of managing it properly (Hernandez-Sancho et al. 2015). From a resource mining perspective, the growth of wastewater production and treatment of wastewater as an economic asset (Drechsel et al. 2015) offer opportunities to increase economic and social benefits in a circular economy.

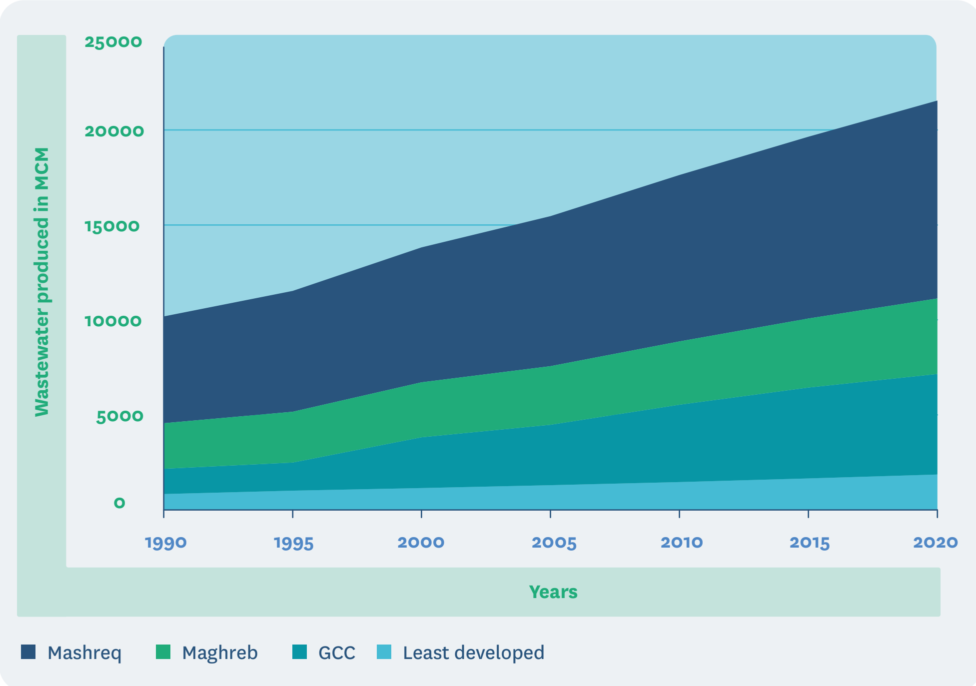


FIGURE 2.4 Trends in municipal wastewater generation in selected MENA countries.
NOTES: Mashreq includes Iraq, Jordan, Lebanon, Palestine, Syria and Egypt; Maghreb includes Algeria, Libya, Mauritania, Morocco and Tunisia; GCC includes Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates); Least developed countries include Sudan and Yemen.

The composition of raw municipal wastewater and the resources embedded, or the hazards contained in it, vary in different countries and in different cities within countries.

Water in municipal wastewater comes from households, from rainwater that drains cities and from industries and commercial activities. Most of the nutrients in wastewater come from human excreta. The excretion of nutrients per capita is highly dependent on diets (e.g., protein consumption), which differ depending on the country, wealth status and culture. Most of the nutrients are in urine. In wastewater, phosphorus does not come only from human excreta but also from detergents used in laundry and dishwashing (Mateo-Sagasta 2015).

As a result of these material flows, municipal wastewater concentrates valuable resources but also hazards such as pathogens or dangerous chemicals (Table 2.1; Box 2.3). Pathogens tend to come in excreta. Chemical hazards enter wastewater via discharges from economic activities connected to sewers, but also via household cleaning or pharmaceuticals excreted by people. The concentration of these resources and hazards depends very much on people's consumption patterns, diets, household and municipal water use and rainfall entering sewage systems (dilution). Table 2.1 shows the weighted average composition of raw wastewater in MENA countries based on influent data from 166 wastewater treatment plants (WWTPs). The averages have been weighted with the influent volumes of wastewater to the treatment plants

TABLE 2.1 Weighted average composition of influent wastewater in municipal wastewater treatment plants in MENA countries.

Country	TSS	BOD	COD	T-N	T-P	FC	EC	TDS	No. of WWTPs from which data has been collected
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(CFU/ 100 mL)	(dS/m)	(mg/L)	
Algeria	357	330	660	23.2	10.0	1.84E+08	2.4	1,642	20
Bahrain	179	219	410	NA	NA	NA	NA	NA	1
Egypt	243	209	391	40.2	6.4	1.43E+09	1.1	654	13
Iraq	230	214	395	NA	NA	NA	1.9	1,379	5
Jordan	628	624	1245	100.0	10.5	2.87E+07	1.4	978	22
Kuwait	250	234	431	31.5	21.8	3.41E+07	1.0	645	4
Lebanon	412	291	618	63.1	12.0	1.13E+06	1.3	962	15
Libya	216	298	431	NA	2.8	NA	2.8	1,664	5
Mauritania	658	535	1811	NA	NA	NA	2.1	1,506	1
Morocco	475	1354	907	82.7	11.3	7.83E+08	2.7	1,869	9
Oman	420	245	920	87.7	12.0	1.45E+08	1.7	944	7
Palestine	781	471	951	66.6	10.2	2.22E+06	2.9	2,268	10
Qatar	150	178	418	35.0	5.0	5.01E+06	2.0	1,329	2
KSA	321	213	413	25.6	13.2	2.54E+06	2.3	1,488	10
Sudan	447	411	1076	NA	NA	NA	1.2	709	3
Syria	539	355	542	46.8	2.5	3.90E+07	2.3	1,701	3
Tunisia	419	372	899	92.9	12.6	7.93E+06	3.2	2,477	23
UAE	277	258	589	NA	6.2	NA	3.8	2,108	8
Yemen	444	743	1307	NA	15.0	2.93E+06	2.6	1,899	5
MENA	296	285	523	55.2	13.2	7.15E+08	2.5	1,490	166

TSS: Total dissolved solids, BOD: biological oxygen demand, COD: chemical oxygen demand, T-N: total nitrogen, T-P: total phosphorus, FC: fecal coliforms, EC: electric conductivity, TDS: total dissolved solids.
Sources: See complete list of sources by country at http://bit.ly/3hsRkDL

so that the composition of the influent wastewater in large treatment plants has a larger influence on the national averages. Data shows that wastewater tends to be stronger (i.e., with higher concentrations) in counties with less municipal water use per capita, such as Jordan or Mauritania.

The composition of municipal wastewater offers valuable information on both the risks and opportunities of water reuse. WWTPs designers will consider the wastewater composition and concentration when selecting technology or resource recovery processes. For example, for strong wastewater in warm climates, WWTP designers may choose anaerobic systems that tend to yield less sewage sludge and maximize energy recovery through biogas generation.

BOX 2.3 Emerging pollutants (EPs) in raw and treated wastewater in MENA (from Haddaoui and Mateo-Sagasta 2021)

Emerging pollutants are of increasing concern. Raw municipal wastewater in the MENA region has been reported to concentrate pesticides like endosulfan or DDT, pharmaceuticals such as acetaminophen, ibuprofen, paracetamol, naproxen, diclofenac or carbamazepine, and dozens of other emerging pollutants. The limited actual treatment of these wastes and wastewater in many MENA countries results in a large portion of these EPs making their way to water bodies, in turn increasing the risk of exposure downstream. Even in the cases where wastewater is collected and treated, the removal efficiency for EP in existing WWTPs is at best limited.

The data on EP removal effectiveness in treatment plants of the MENA countries suggest that secondary treatment is ineffective in the reduction of most EPs (e.g., pharmaceuticals compounds like carbamazepine, erythromycin and sulfamethoxazole). Tertiary treatment improves the elimination of many EPs, but this improvement is inadequate for some pollutants (e.g., tetracycline, ciprofloxacin and amoxicillin).

The extent of the wastewater treatment coverage and the types of wastewater and drinking water treatment technologies in most MENA countries are far from sufficient to effectively address the environmental and health risks posed by the EPs. Given the limited financial capacities of the middle- and low-income countries, and the limited effectiveness of the removal of EPs by the tertiary treatments, it is not practical nor affordable to promote wastewater treatment as the only way to address waterborne EPs. Instead, we recommend prioritizing a more cost-effective combination of solutions that includes a change in consumption and production patterns to prevent pollution from EPs at the source, wastewater treatment expansion to the extent required for conventional pollutants including pathogens, adoption of good irrigation practices and universal coverage of drinking water treatment.

Anaerobic treatment may not work optimally with weaker wastewater. High concentration influent (like wastewater in Jordan, Mauritania, Sudan or Yemen) correlates with lower energy consumption and lower costs per kilogram of pollutant removed, and with a higher nutrient recovery potential in wastewater treatment plants, which are critical factors that influence the selection of technologies. But high concentration influent also correlates with a higher greenhouse gas emission potential when removing pollutants (Zhang et al. 2020).

2.2.2. Treatment of wastewater

The potential for safe water reuse depends on multiple factors beyond the location and concentration of wastewater. One key factor that determines the safe reuse is the level of treatment. Countries are increasingly aware of the impacts and economic costs of untreated wastewater and are investing in improved wastewater collection and treatment. Nevertheless, the growth in investments and infrastructure is not keeping pace with municipal wastewater generation growth in many MENA countries. As a result, the total amount of wastewater that is discharged untreated to the environment keeps increasing in these countries. For example, in Egypt the municipal wastewater treatment capacity has grown from 3.1 BCM in 2000 to 5.3 BCM in 2020. The amount of municipal wastewater generated has grown from 4.8 to 7.2 BCM in the same period, which means that the amount of untreated wastewater has grown from 1.7 to 1.9 BCM despite growth in treatment capacity (GWI 2021, MHUUC 2022). Substantial amounts of wastewater do not reach treatment plants and many existing facilities are overloaded and produce effluents below the expected quality. There are some exceptions to this trend particularly in some Gulf countries, where capacity of treatment plants has increased more than the actual wastewater production.

The World Health Organization and UN-Habitat are the custodians of indicator 6.3.1 of the United Nations Sustainable Development Goals (SDGs), which tracks the proportion of wastewater flows from households, services and industrial premises that are treated in compliance with national or local standards. The household component includes both sewage and fecal sludge, treated on-site and off-site, and is monitored as part of the sanitary chain with direct links to indicator 6.2.1 on access to sustainably managed sanitation services. Data on 6.3.1 are commonly collected by national line ministries and institutions (e.g., for water, sanitation, environment, health, public services, planning, housing, infrastructure or production), utilities and on-site service providers as well as the national statistical office (household surveys and registers of economic activities).

The most recent data for 2020 in MENA countries in the framework of SDGs monitoring shows that about 60% of the domestic wastewater that is generated is safely treated. This includes household wastewater transferred through sewers to a WWTP ('treated sewage'), released into an on-site treatment system ('treated in-situ') and released into an on-site system (e.g., septic tanks) for which fecal sludge is emptied and transported to a treatment plant ('treated from on-site').

The situation nevertheless varies greatly between countries (see Figure 2.5). Income per capita is a good predictor for the level of treatment. High-income countries such as Bahrain, Qatar, United Arab Emirates and Saudi Arabia treat most of the domestic wastewater generated. Lower middle-income countries such as Yemen, Sudan, Mauritania, Morocco and Egypt are having more challenges. Higher middle-income countries such as Jordan stand out and perform better than expected from their income, which reflects the relative high priority that wastewater and sanitation has in these countries' agenda despite limited budgets. The effect that conflict, social unrest or economic crisis has on wastewater treatment in countries such as Yemen, Lebanon, Libya, Iraq, Palestine and Syria is unclear but very likely is heavily limiting the treatment potential (Faour and Fayad 2014; Qadri et al. 2017; Zolnikov 2013).

Table 2.2 shows the weighted average composition of treated municipal wastewater in 19 MENA countries based on data from 211 WWTPs. The averages have been weighted with the volumes of the wastewater treated in treatment plants so that the composition of the effluent wastewater in large treatment plants has a larger influence on the national averages. Vari-

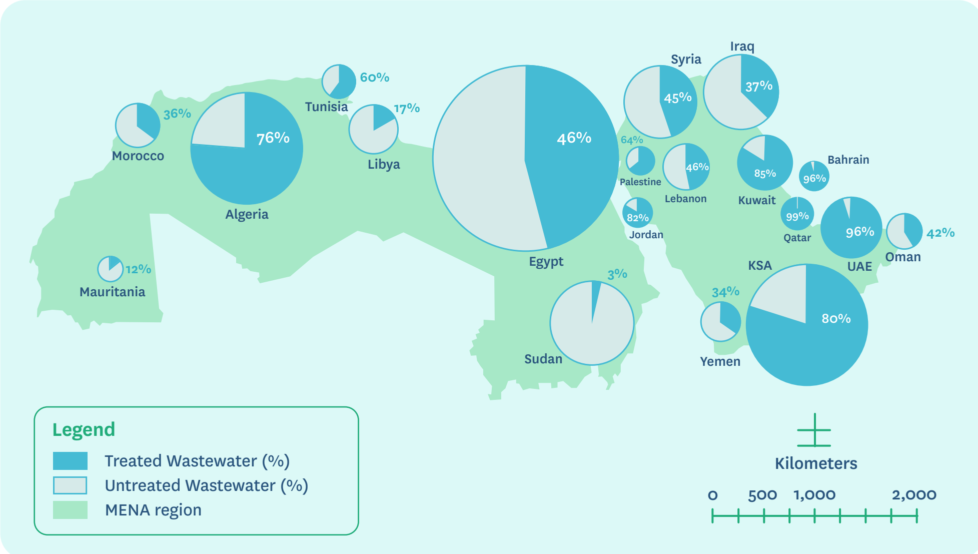


FIGURE 2.5 Proportion of domestic wastewater safely treated in 2020 as per WHO (2021).

ability within and between countries is mostly dependent on the quality of influent wastewater and the type and level of treatment.

On average, WWTPs in the region remove between 85 and 90% of the total suspended solids (TSS) and biological and chemical oxygen demand (BOD, COD). About 50% of the nitrogen and phosphorus is removed. The removal of fecal coliforms is on average in the order of 3-log, with larger removals in GCC countries, Jordan and others where large portions of the treated wastewater are disinfected. Removal of dissolved solids and salinity is nevertheless limited and averages only 12% in the region. In many instances, salinity removal is actually negative, which means that the salinity in the effluent is higher than in the influent. That is no surprise as only reverse osmosis and nano-filtration (which are rarely implemented in MENA to treat wastewater) remove salts and in other types of treatments that are commonly used in the region, water losses due to evaporation during treatment increase the concentrations of salts (Obotey Ezugbe and Rathilal 2020).

When treated wastewater is discharged to the environment, the removal of nitrogen and phosphorus helps prevent eutrophication of surface water or pollution of groundwater with nitrates. When the effluent is used in irrigation, nutrient removal will limit productivity if the concentration of nutrients in the irrigation waters is lower than the demand from crops (Chojnacka et al. 2020).

Salinity limits the potential of treated effluent to be reused. High concentrations of salts in irrigation make it difficult for plants to absorb water and cause reductions in crop yields. Farmers in the northern part of the Jordan Valley are concerned about the governmental plans to change the irrigation source to diluted reclaimed water from the Al Samra treatment plant, which has higher salinity levels than the water currently used (Tawfik et al. in review).

The most common indicator to monitor the salinity of water is electrical conductivity (EC). Salts in irrigation water can begin to accumulate in the soil, preventing plants from absorbing water and impacting the productivity of many crops and fruit trees. Crops such as onions, carrots or lettuce (Shannon and Grieve 1999) or fruit trees like citrus (Ruiz et al 1997; Levy and Syvertsen 2010) are particularly sensitive to salinity. Other crops such as asparagus or fruit trees such as dates, pistachio or pomegranate are more tolerant. Irrigation with brackish water will require the adoption of on-farm practices to mitigate agronomics risks such as changing to salt-tolerant crops, using additional water as leaching fractious and ensuring proper drainage.

TABLE 2.2 Weighted average composition of influent wastewater in municipal wastewater treatment plants in MENA countries.

Country	TSS	BOD	COD	T-N	T-P	FC	EC	TDS	No of WWTPs
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(CFU/100 mL)	(dS/m)	(mg/L)	
Algeria	26	27	66	8.5	5.1	6.28E+05	1.9	1,238	22
Bahrain	9	2	32	NA	NA	2.21E+03	4.9	3,574	1
Egypt	49	48	112	25.6	11.1	2.68E+06	1.1	628	27
Iraq	78	53	99	NA	NA	NA	2.1	1,545	9
Jordan	28	19	112	29.6		2.17E+01	2.3	1,025	25
Kuwait	6	3	21	5.1	11.3	1.89E+02	1.1	757	4
Lebanon	49	37	109	16.0	15.1	8.54E+05	1.2	796	17
Libya	10	17	44	NA	0.7	3.00E+02	3.2	1,972	5
Maurita-nia	NA	NA	257	NA	NA	1.90E+04	1.9	1,176	1
Morocco	25	18	51	23.4	4.3	5.45E+05	2.1	1,385	8
Oman	28	3	34	8.0	2.6	1.00E+01	1.6	915	11
Palestine	95	72	232	8.9	3.2	9.68E+04	2.3	1,656	10
Qatar	2	2	13	5.9	0.8	0.00E+00	2.1	3,410	3
KSA	25	30	66	13.7	4.8	2.12E+02	1.9	1,263	17
Sudan	111	59	223	NA	NA	2.40E+03	1.7	1,097	3
Syria	165	83	140	29.0	1.4	NA	2.2	1,606	3
Tunisia	54	37	137	27.3	11.7	6.19E+04	4.4	3,005	27
UAE	5	4	36	10.1	6.3	2.00E+00	3.2	1,697	10
Yemen	194	84	285	NA	6.7	3.87E+06	3.1	2,223	8
MENA	38	32	84	21.5	8.3	8.04E+05	2.2	1,337	211

TSS: Total dissolved solids, BOD: biological oxygen demand, COD: chemical oxygen demand, T-N: total nitrogen, T-P: total phosphorus, FC: fecal coliforms, EC: electric conductivity, TDS: total dissolved solids.
Sources: See complete list of sources by country at http://bit.ly/3hsRkDL

2.3. Actual water reuse

It is challenging to describe the present quantities of water reuse in MENA due to the lack of reliable and sufficient data from national statistics. Much of the available information does not use uniform terms and units when describing water reuse, making it difficult to compare data between countries or establish regional inventories. The most recent and comprehensive attempts to compile data on municipal wastewater generation, treatment and reuse include the *Third State of the Water Report for the Arab Region* (AWC 2019) with data from 2015 or AQUASTAT with data from many of the MENA countries but with almost no recent data. The reported data on water reuse by these sources has major data gaps for recent years and at times includes data on indirect water reuse (i.e., treated wastewater discharged to rivers or drainage canal where it is diluted and reused indirectly downstream).

The ReWater MENA project, a regional project led by IWMI and funded by the Swedish International Development Cooperation Agency (SIDA), has established the largest inventory of projects to our knowledge for direct water reuse in the region so far. These are projects where reclaimed water is used directly for different purposes including the irrigation of agriculture and planted forests, landscaping (including golf courses), industrial processes, environmental uses and others. The inventory has collected data for more than 400 projects that are still operational and includes data on the startup year of the reuse projects, volumes treated and reused, and type of use made of the reclaimed water.

The region has been proactively investing in water reuse in recent decades. According to the ReWater MENA database, the number of water reuse projects has doubled every decade since the 1990s. In the 19 countries that were analyzed, the number of reuse projects has specifically grown from 40 in 1990, reusing a total quantity of 0.421 BCM, to 97 projects in 2000 (and 0.655 BCM directly reused), 200 in 2010 (with 1.249 BCM) and finally 409 in 2020 (with 2.275 BCM). In the last decade, the growth in the number of direct water use projects has been particularly high in countries like Saudi Arabia, United Arab Emirates, Qatar, Oman, Egypt, Algeria and Morocco.

The dominant uses of reclaimed water are for forestry, agriculture and landscaping, including irrigation of parks and gardens (See Box 2.2. for definitions). As shown in Figure 2.6, different countries have invested differently in various typologies of water reuse. Forestry and agriculture are the dominant users of reclaimed water, for example, in Egypt, Tunisia and Jordan, while landscaping is the preferred option in countries like Morocco, United Arab Emirates, Oman and other GCC countries. The pattern in other areas is not so clear, with a more mixed project portfolio. These patterns are a consequence of different factors, including perceptions about reuse, the quality of the effluents, and the different policies and legislation that have been shaped across the region as further discussed in subsequent chapters of this book.

The presence of water reuse projects for other purposes such as industrial use, non-potable urban use, aquifer recharge or environmental restoration are scattered and much less frequent. Examples include Al Shabab Power project and Jazan IGCC project in Egypt and

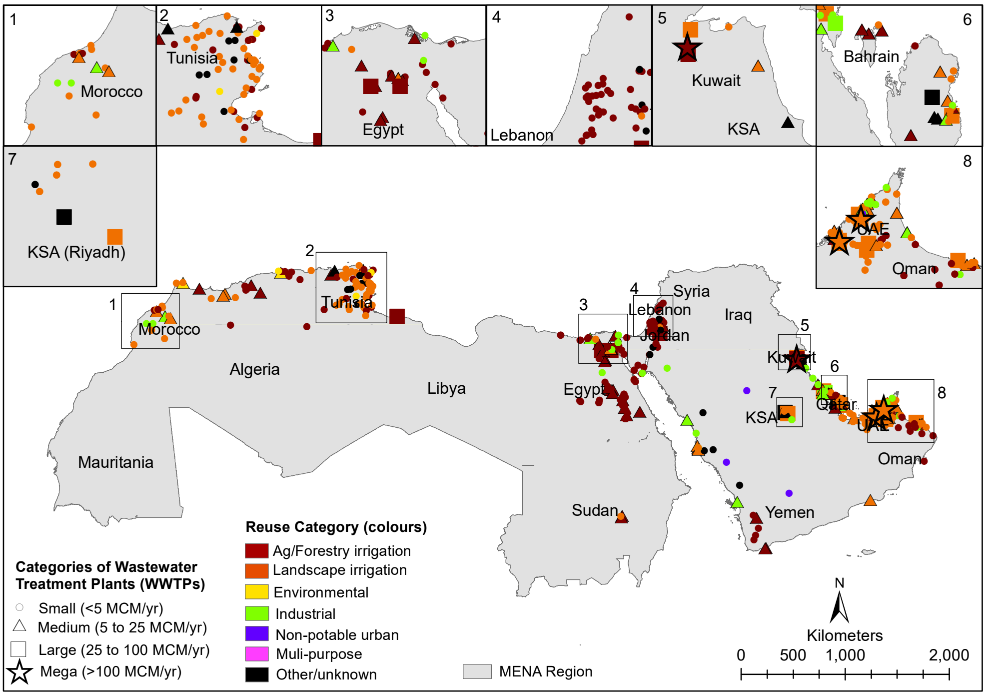


FIGURE 2.6 Location and distribution of operational water reuse projects in MENA as of 2020 (N=409).
NOTES: The shape/size of each point indicates the capacity of the WWTPs classified as small (N = 312); medium (N = 76), large (N = 20) and mega (N = 1) and the color indicates the reuse category.

Saudi Arabia for industrial purposes (GWI 2021) and Emicool project and West Bay project in UAE and Qatar for non-potable urban use (GWI 2021). In Section 2 of this book, we have characterized in detail several key water resource projects from Morocco, Tunisia, Jordan, the West Bank and United Arab Emirates.

Despite the rapid growth of water reuse projects across the region, the amount of municipal wastewater that is treated and directly reused for beneficial purposes is still very limited in MENA and averages only around 10% of the total wastewater generated in the 19 countries that were analyzed (Table 2.3). The main exceptions are in the GCC with Qatar, UAE, Kuwait, Oman or Bahrain leading the ranking.

Jordan is a case in point. Most of the effluent from the Al Samra treatment plant, which serves Amman and surrounding areas, is fully reused in the Jordan Valley after traveling along the Al Zarqa wadi and being stored in the King Talal dam. This reclaimed water undergoes minimal dilution with other sources of water so it is considered in the literature and by the authorities as indirect water reuse and is not part of the national statistics on direct water reuse presented in Table 2.3. If, because of the negligible degree of dilution, this reclaimed water was considered as directly reused, then Jordan would be considered to reuse directly 70% of the generated wastewater, becoming one the leaders in direct water reuse in the whole region.

TABLE 2.3 Wastewater production, treatment and reuse in 19 countries within MENA in 2020 (or latest available year).

Country	Total municipal wastewater generated**	Municipal wastewater that is treated and directly reused	Directly reused from municipal wastewater	Projects where municipal wastewater is treated and directly reused	Methodological notes and sources to calculate municipal wastewater that is treated and directly reused
	(BCM)	(BCM)	(%)	(N)	
Algeria	2.649	0.100	3.8	22	Data up to 2015 from AbuZeid et al. 2019 with no additional projects found up to 2020
Bahrain	0.186	0.045	24	4	Data up to 2015 from AbuZeid et al. 2019 updated to 2020 with individual project data from GWI 2021
Egypt	7.196	0.341	4.7	77	Aggregation of individual project data up to 2020 from MHUUC 2022; GWI 2021
Iraq	1.232	NA	NA	NA	NA
Jordan	0.187	0.071	37.9	25	Aggregation of individual project data up to 2020 from Ibrahim et al. 2019; Kassab et al. 2020, GWI 2021
Kuwait	0.666	0.271	40.7	6	Aggregation of individual project data up to 2020 from Aleisa and Alshayji 2019; GWI 2021
Lebanon	0.481	0.002	0.4	4	Data up to 2015 from AbuZeid et al. 2019 with no recent projects up to 2020
Libya	0.514	0.040	7.8	1	Aggregation of individual project data from Kamizoulis et al. 2003
Mauritania	0.138	NA	NA	NA	NA
Morocco	0.415	0.076	18.3	22	Data up to 2015 from AbuZeid et al. 2019 updated to 2020 with individual project data from Nahli et al. 2016; Bensaad et al. 2017; Haji et al. 2021; GWI 2021
Oman	0.275	0.079	28.6	30	Data up to 2015 from AbuZeid et al. 2019 updated to 2020 with individual project data from Suaad et al. 2017; GWI 2021
Palestine	0.180	0.007	3.7	24	Aggregation of individual project data up to 2020 from PWA 2021; GWI 2021
Qatar	0.225	0.165	73.6	17	Data up to 2015 from AbuZeid et al. 2019 updated to 2020 with individual project data from PSA 2021; GWI 2021
Saudi Arabia	3.144	0.431*	13.7	40	Aggregation of individual project data up to 2020 from Al-Jasser 2011; Chowdhury and Al-Zahrani 2012, 2015; Alkhudhiri et al. 2019; GWI 2021
Sudan	1.533	0.029	1.9	3	Aggregation of individual project data from Maki 2010
Syria	1.147	NA	NA	NA	NA

Country	Total municipal wastewater generated**	Municipal wastewater that is treated and directly reused	Directly reused from municipal wastewater	Projects where municipal wastewater is treated and directly reused	Methodological notes and sources to calculate municipal wastewater that is treated and directly reused
	(BCM)	(BCM)	(%)	(N)	
Tunisia	0.254	0.034	13.4	63	Aggregation of individual project data up to 2020 from DGGREE 2021; ONAS 2021
UAE	0.801	0.549	68.6	64	Aggregation of individual project data up to 2020 from Dawoud et al. 2012; EAD 2021; GWI 2021
Yemen	0.326	0.036*	11.1	7	Aggregation of individual project data up to 2020 from Al-Gheethi et al. 2014; Rageh 2014; Rageh et al. 2017
MENA	21.549	2.275	10.5	409	

NOTES: *may include some indirect reuse or blending. **Estimated as the produced municipal wastewater in 2015 from Abu Zeid et al. (2019) plus the generated municipal wastewater in the period 2015–2020, the latter is calculated based on per capita wastewater in 2015 and the population growth in the period 2015–2020.

The potential to increase direct water reuse and free up freshwater for other high added value purposes remains large in most other countries. In the next section, we review such potential.

2.4. Potential for resource recovery and reuse

The 19 countries in the region that were analyzed produce around 21.5 BCM of municipal wastewater every year. This wastewater contains valuable resources, mainly water, nutrients (nitrogen, phosphorus, potassium, etc.) and organic carbon. All of these can be recovered for different uses. Water is the most important and abundant asset in wastewater and can be used as a substitute for freshwater if appropriately treated. Nutrients are valuable in agriculture and aquaculture. Organic carbon can be used as a soil conditioner or to generate energy. Based on the actual composition of municipal wastewater in the region (Table 2.1), we can estimate the amounts of nitrogen and phosphorus potentially contained in municipal wastewater and the amount of methane potentially generated from wastewater (Table 2.4).

The potential energy value from carbon in wastewater could be estimated based on the biogas production in relation to chemical oxygen demand (COD), which is about 0.5 liters (L) of biogas per gram (g) COD removed, corresponding to a methane production of approximately 0.35 L CH_4 per gram (g) of COD removed at 20°C. In practice, the amount of methane recovered per gram of COD removed will be less as some of the COD may be used as source of reducing equivalents for microbial growth; also not all COD may be biodegradable.

With the conservative assumption that 70% of the COD in wastewater can be actually transformed into methane (De Mes et al 2003) and considering that the caloric value of methane is 34.9 MJ/m^3 CH_4, the 21.5 BCM of municipal wastewater estimated to be produced in the region could potentially produce 2.650 BCM CH_4 with a global caloric value of 92.5 10^9

TABLE 2.4 Resources embedded in municipal wastewater in MENA countries.

Country	Water	T-N	T-P	CH4 potential***
	(BCM)	(Tm**)	(Tm)	(BCM)
Algeria	2.649	61,371	26,400	0.428
Bahrain*	0.186	10,268	2,459	0.019
Egypt	7.196	289,150	46,097	0.689
Iraq*	1.232	50,555	2,931	0.117
Jordan	0.187	18,718	1,970	0.057
Kuwait	0.666	20,959	14,554	0.070
Lebanon	0.481	30,313	5,786	0.073
Libya*	0.514	28,359	1,429	0.054
Mauritania*	0.138	7,610	1,823	0.061
Morocco	0.415	34,348	4,711	0.092
Oman	0.275	24,147	3,302	0.062
Palestine	0.180	12,003	1,842	0.042
Qatar	0.225	7,860	1,123	0.023
KSA	3.144	80,548	41,580	0.318
Sudan*	1.533	84,595	20,264	0.196
Syria*	1.147	29,671	7,107	0.071
Tunisia	0.254	23,558	3,207	0.056
UAE*	0.801	44,193	4,933	0.116
Yemen	0.326	18,014	4,896	0.104
MENA	21.549	876,240	196,414	2.650

NOTES: *countries where the average regional wastewater composition has been used for one or more parameters. ** Tm=Terameter ***Assuming 0.35 L CH_4 per g of COD removed at 20°C and that 70% COD is transformed into CH_4. Source: authors' calculations.

megajoules (MJ), which, if fully recovered, would be enough to provide electricity for about 8 million households, considering an average electricity consumption of 3,350 kilowatt hours (kWh)/household (World Energy Council 2016; Qadir et al. 2020).

Almost 9,000 tons (t) of nitrogen and 200,000 t of phosphorus are potentially embedded in the 21.5 BCM of wastewater generated in MENA (Table 2.4). Because part of the wastewater is treated, some of these resources are removed. Also, irrespective of treatment, part of the wastewater is discharged to water bodies and reused indirectly in agriculture, forestry and other productive water users and nutrient sinks, which means that part of this water and these nutrients are already recycled, although not in a planned or efficient manner.

There is nevertheless a good portion of the (treated or untreated) wastewater that is discharged into the environment that evaporates or ends up in the sea with no productive use. Some nutrients end up in non-productive sinks, such as weeds or algal blooms. Recent estimates from Velpuri et al. (forthcoming) suggest that the wastewater evaporated or lost in the sea can be as high as 54% of the total wastewater produced in MENA, while the rest is reused directly or indirectly (see a detailed analysis for Egypt in Box 2.5). There is still potential to recover these wasted resources (evaporated or lost in the sea) and to make a more efficient use of the wastewater that is currently reused indirectly.

BOX 2.4 The paradox of direct and indirect water reuse and health risks

Direct water reuse differs from indirect water reuse because, in the former, (treatment of untreated) wastewater is first discharged into a water body where it undergoes dilution prior to use downstream. Indirect water reuse is typically considered safer, so it is normally not regulated or controlled. Nevertheless, indirect reuse can be unintentional, and users downstream do not know the sources or quality of the water they are using. Farmers, for example, could irrigate vegetables to be eaten raw with diluted untreated wastewater, with obvious health risks.

On the other hand, direct reuse is often strongly regulated and sometimes prohibited for food crops (see Chapter 5), even when the quality of treated wastewater may have pathogenic concentrations orders of magnitude lower than the 'freshwater' (or better diluted wastewater) that is used to irrigate in many settings across MENA (Abi Saab et al. 2022). Paradoxically, at times, reclaimed water from an advanced treatment plant is discharged, diluted and wasted into a heavily polluted water body because direct reuse is not allowed.

The degree of dilution of (treated or untreated) wastewater in water bodies is not a good indicator of the safety of reuse. First, because we would need a dilution of five orders of magnitude (i.e., diluting 1 L of wastewater into 100,000 L of clean water) to get a reduction of *E. coli* of 10+EXP5, needed to get the 1,000 colony-forming unit (CFU)/100 mL required for unrestricted irrigation. Second, because a strong wastewater (i.e., with relatively high concentration of pollutants such as a COD of around 1,000 milligrams/liter (mg/L)) that undergoes only little dilution in a drain, canal or creek can have more concentration of pollutants than a weak wastewater (i.e., with relatively low concentration of pollutants such as a COD of around 250 mg/L) that is reused directly.

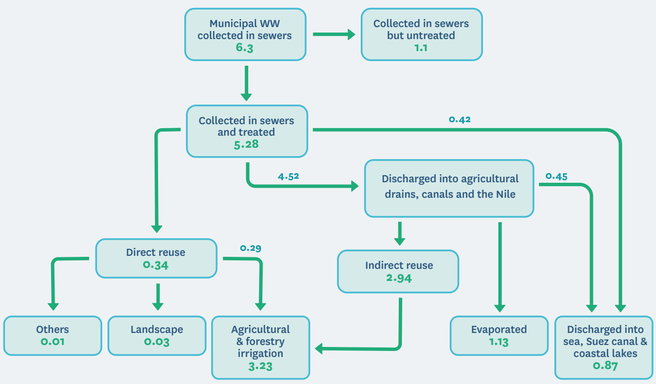
Indeed, all pollutants generated in urban settlements undergo some degree of dilution. Water used to flush toilets dilutes excreta and urine. Water used in kitchens dilutes organic matter from food waste and cleaning products. And water used in showers or house cleaning dilutes soaps and detergents. Pollutants are not only diluted within household premises, but also outside premises, with rainwater and urban runoff. In areas where precipitation and water use are high, dilution will be also high resulting in weak wastewater, with relatively low concentration of pollutants. This weak wastewater could then have a similar, or even lower, pollution concentration than the water in a canal or drain that receives a stronger wastewater even when this is diluted to an extent in this canal or drain.

BOX 2.5 Wastewater fate in Egypt

Egypt is the most populous country in the MENA region with around 106 million inhabitants (UN 2019). The wastewater sector is operated by the government through the Holding Company for Water and Wastewater (HCWW) and its subsidiaries in all provinces of Egypt. The Government of Egypt has paid a great deal of attention to the wastewater sector recently in order to better utilize the source of water that could contribute to mitigating the impacts of the water crises in Egypt (Orabi 2017).

HCWW operates more than 500 WWTPs. According to the Ministry of Housing, Utilities and Urban Communities (MHUUC), the amount of treated wastewater (TWW) was about 5.28 BCM in 2020 (MHUUC 2022, GWI 2021). Because the proportion of sewered wastewater safely treated at treatment plants is reported by WHO (2021) to be 84% in 2020, we estimate the volume of wastewater collected in sewers to be approximately 6.3 BCM. On the other hand, an additional amount of wastewater is collected in on-site systems like septic tanks.

Once treated, reclaimed water can be used directly and indirectly (after dilution), or it can be lost when it evaporates or ends up in the sea with no productive use. In Egypt, 0.29 BCM of reclaimed water are directly used for agroforestry irrigation, 0.03 BCM for green areas' irrigation and 0.01 BCM for non-potable urban uses (MHUUC 2022; GWI 2021). The remaining 4.94 BCM is discharged into agricultural drains, canals and the Nile (4.52 BCM), or coastal lakes, the Suez canal and the sea (0.87 BCM). A relatively small portion of treated effluents is evaporated before reaching any water body or reuse. Assuming a loss through evaporation in running waters of 25%, and that 10% of the wastewater discharged into the surface wasters is dumped in the sea unproductively (Simpson et al. 1991, Zhu et al. 2022), we estimate that 2.94 BCM are reused indirectly after dilution in surface waters. Therefore, the total balance is as follows:



Fate of municipal wastewater in Egypt 2020 *(Units: billion cubic meters)*

According to the Egyptian code for wastewater reuse (no. 501/2015), edible crops cannot be irrigated by treated wastewater directly, regardless of the treatment level (Ahmed et al. 2022). However, as mentioned in Box 2.4, treated wastewater is sometimes better than water in canals and drains used for irrigation, which collects pollution from uncontrolled point and non-point sources. This is something to be considered by policy.

If all wastewater that is lost was recovered, the region can unlock new opportunities whilst enhancing the region's ability to adapt to changes in climate and enhance food security. The 11.6 BCM of municipal wastewater estimated to be lost, if fully recovered, could additionally irrigate and fertilize about 1.4 million ha with a relatively high application rate of 8,000 m^3/ha/year (Steduto 2012). If no wastewater was lost and 70% of the COD was recovered in the form of methane, the energy produced could provide electricity to around 4 million households, or to all wastewater treatment plants in the region and an additional surplus for hundreds of thousands of households.

As the population grows, so does the demand for fertilizer. Nutrient recovery from wastewater, sludge and other wastes (such as food waste) can regionally and locally help to meet this demand and is particularly interesting in and around cities, close to where these wastes are produced, and where intensive agriculture is expanding to feed the increasingly hungry cities. Moreover, for an essential nutrient like phosphorous, its recovery from waste is decreasingly an option but is a necessity as it is a non-renewable resource obtained from mining of finite deposits in a few countries (Mihelcic et al. 2011).

However, structural and financial shortcomings in the wastewater sector, combined with challenges of governance and inadequate regulatory frameworks for reuse management, impede the fulfillment of this potential. Poor administrative capacities in the planning, implementation and management of existing WWTPs and future reuse systems further hinder the water reuse potential. The mandates of state authorities are frequently fragmented and often conflicting. In countries under economic, financial and political crisis, such as Lebanon, these barriers have become more entrenched and tend to attenuate the technical potential (Eid-Sabbagh et al. 2022). There are nevertheless ways to address part of these constraints as shown in Section 2 and in the regional success stories in Section 3.

2.5. Conclusion

Wastewater treatment and reuse for beneficial purposes offers the means to combat water scarcity and pollution at the same time. Nevertheless, the spread of managed wastewater reuse is uneven across the MENA region despite it being one of the most arid and water-scarce regions in the world. Some countries, such as the Gulf countries, Jordan and others, promote wastewater treatment and reuse as an integral component of their water management strategy; however, many other countries make very limited use of wastewater. Regional statistics indicate the considerable potential to increase treatment and reuse of wastewater in the MENA region.

The region needs overcome the factors that limit the fulfillment of the regional water reuse potential. These limiting factors are: cultural barriers and distrust; institutional fragmentation; inadequate regulatory frameworks; and the lack of appropriate tariffs, economic incentives and financial models, which undermines cost recovery and the sustainability of reuse projects.

The region also needs to increase efforts to collect and report standardized data across the formal and informal reuse sectors to provide more reliable and updated information, which is essential to develop proper diagnosis and effective policies for the safe and productive use of these resources.

Although water reuse in the region is currently limited, there are noteworthy water reuse success stories at different scales in and beyond the region. Subsequent chapters of this book analyze the economic, policy and social challenges to uncap the water reuse potential and suggest practical ways to address them.

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Chapter 3

Water reuse policy and institutional development in MENA:
Case studies from Egypt, Jordan, Lebanon, Saudi Arabia and Tunisia

Mohamed Tawfik, Marie-Hélène Nassif, Olfa Mahjoub, Alaa El Din Mahmoud, Ghada Kassab, Mohamed Alomair and Jaime Hoogesteger

Key messages

Egypt – Food and water security are the key drivers behind Egypt's pursual of 'new' water sources. Therefore, Egypt plans to optimize the use of treated agricultural and municipal wastewater to maintain its socio-economic development. However, due to increasing health and environmental concerns regarding water reuse safety, the country has maintained its centralized control over the different aspects of wastewater management and reuse. This has led to overlapping responsibilities and legal mandates, which challenges the full expansion of water reuse in Egypt.

Jordan – Jordan's institutional and policy landscape development shifted from decentralization (i.e., the leading role of municipalities in wastewater management) to a 'semi-centralized' institutional landscape where infrastructure development, operation and maintenance activities are delegated to regional institutions and state-owned companies. This institutional landscape has enabled Jordan to lead the MENA region in water reuse. However, it has created gaps in the decision-making process, which have slowed down the implementation of the current water reuse policy.

Lebanon – Despite massive investments in infrastructure development and successive institutional reforms, the wastewater sector in Lebanon appears to be dysfunctional, with a very low rate of operational WWTPs. The under-performance of the wastewater sector lies in conflicting and/or diluted administrative responsibilities and a weak operationalization of State institutions' legal mandates further exacerbated with the recent financial and political crisis.

Saudi Arabia – Saudi's experience in managing the water and wastewater sector (including water reuse) reflects a successful transformative shift toward the involvement of the private sector (and state-owned service providers) through an enabling policies and institutional reforms, while the government maintained its regulatory and monitoring role.

Tunisia – The water sector is highly regulated and institutionalized. However, the sector is characterized by competing interests between the existing institutions. This leads to a lack of coordination between the different institutions (e.g., National Sanitation Utility [ONAS] and The Ministry of Agriculture, Water Resources and Fisheries [MAHRP]), which causes a shortage in treated wastewater (TWW) reuse and availability to satisfy the agricultural sector's needs. On the other hand, overcoming these challenges has led to relatively flourishing water reuse arrangements for the irrigation of golf courses, where there is a collaboration between ONAS and the Ministry of Tourism.

3.1. Introduction

This chapter explores the policy and institutional landscape of wastewater treatment and reuse in Egypt, Jordan, Lebanon, Tunisia and Saudi Arabia. It aims to analyze the key elements that contribute to, or hinder, the development of water reuse policies and institutional arrangements in the selected countries. It does so by observing the different trajectories each country has followed in developing its water and sanitation sector over the years and focuses on addresses the following aspects:

- country-specific contextual constraints (e.g., population growth, agriculture expansion, water scarcity and dependency on transboundary water resources);
- institutional roles and responsibilities within the sector; and
- the historical development of water reuse governance and management modalities (e.g., from centralization to decentralization and privatization).

The selected countries are suffering from an increased water supply-demand gap and a rapidly increasing population that requires continuous socio-economic development. This growth leads to competition over the scarce water resources particularly between the agricultural and domestic sectors (Figure 3.1). In this context, governments have sought to reduce this gap by developing the reuse of TWW. However, this shift is problematic as different technical, social, economic, health and institutional problems often challenge the adoption of water reuse schemes.

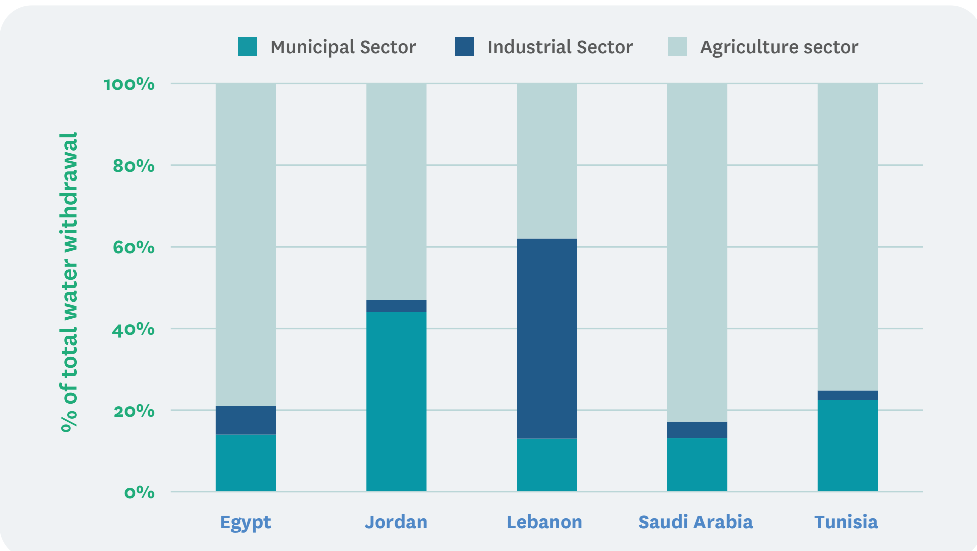

FIGURE 3.1 Water withdrawal by sector in the five countries in 2017 (FAO 2022a).

This chapter analyzes the key policy and institutional milestones as well as the bottlenecks that shaped this development throughout the years. It starts by identifying the most important policies and institutional reforms (milestones) that shaped the current water reuse institutions and arrangements, then analyzes the current interactions and de facto functioning of the different governmental institutions that operate in the sector.

3.2. Egypt

3.2.1. Toward water reuse development

Egypt's annual per capita water share reached 800 m^3 in 2017 (FAO 2022a). This is below the 'stress' conditions threshold of 1,000 m^3 per person described by the Food and Agricultural Organization of the United Nations (FAO 2022b). This supply-demand gap is expected to increase with population growth, climate change impacts and the development of the GERD dam in Ethiopia, which would affect Egypt's annual share of the Nile River.

The Government of Egypt has reacted to the dwindling per capita water share by reallocating freshwater to priority uses (i.e., drinking water supply) while maximizing the share of drainage water reuse in the agricultural sector. The latter is the largest water consumer in Egypt and consumes around 76% of the country's water budget (Tawfik et al. 2021). This policy orientation includes public investments in large-scale water reuse projects both related to treated municipal wastewater and agricultural drainage water. It is one of the mitigation measures that Egypt adopts to maintain its socioeconomic development in a water-scarce context (IWMI 2019).

3.2.2. The historical development of water reuse: Policy and institutional milestones

Since the 1960s, Egypt's successive governments have worked to expand the agricultural area through desert land reclamation to achieve food self-sufficiency and create job opportunities (Molle et al. 2019). This agricultural expansion relied on freshwater sources (either surface water from the Nile or non-renewable groundwater). However, from the late 1970s to the early 1980s, there was a noticeable increase in drainage water reuse for irrigation (Molle et al. 2019). Many more farmers started to rely on agricultural drainage water as an important resource to reduce the supply-demand gap. Drainage water reuse enabled the country to meet its land reclamation objective.

However, the lack of comprehensive sanitation coverage (particularly in rural areas) and the low capacity of some WWTPs, led to the illegal discharge of untreated wastewater into the agricultural drainage system (Tawfik et al. 2021). Accordingly, beginning in the 1980s, the government started to regulate water reuse to prevent the pollution of the agricultural drains through a set of institutional and organizational actions. This included donor-driven reforms such as the establishment of the Egyptian Water Regulatory Authority (EWRA) and the Holding Company for Water and Wastewater (HCWW), Law 48, Code 501, environmental law) and mega infrastructure projects such as El Mahsama and Bar El Baqar treatment plants. To achieve the desired quality of wastewater treatment and safe reuse, a top-down, centralized governance approach was implemented, as reflected in the prominent role given to central state institutions in the different management activities of water reuse (Table 3.1).

TABLE 3.1 The historical development of wastewater treatment and reuse in Egypt.

Year	Type	Description	Overarching policy orientation
1962	Policy orientation	The policy aimed to increase water supply (in rural and urban areas) and sanitation coverage (mainly in urban areas).	
1962	Regulatory actions	*Law 93* – regulates wastewater discharge into public sewers (predominantly responds to the sewer network expansion in urban areas).	
1979	Policy orientation	Similarly, the government aimed to expand the newly reclaimed agricultural lands (i.e., the new lands) to increase the cultivated area through freshwater irrigation (either surface water from the Nile or groundwater).	
1979	Institutional & management approach	Establishment of the New Urban Communities Authority (NUCA), which became responsible for the water and sanitation services in the new cities.	
1981	Institutional & management approach	Establishment of the National Organization for Potable Water and Sanitary Drainage (NOPWASD) and the Cairo and Alexandria Potable Water Organization (CAPWO).	Policy orientation: Respond to the increasing demand for water resources through expanding and regulating agricultural drainage water reuse.
1982	Regulatory actions	*Law 48* – Protection of the Nile River and waterways, which puts restrictions on drainage water use by individual farmers and prohibits the discharge of effluents in the Nile an other waterways (including drains and canals) unless it meets the quality standards specified by Law 48.	Policy orientation: Respond to the increasing demand for water resources through expanding and regulating agricultural drainage water reuse.
1994	Regulatory actions	*Law 4* for the protection of the environment.	Policy orientation: Address the problem of surface water quality which was significantly compromised.
1997	Institutional & management approach	The establishment of the Ministry of State for Environmental Affairs (The Ministry of Environment).	Policy orientation: Address the problem of surface water quality which was significantly compromised.
2002	Institutional & management approach	The establishment of the water quality departments in the Ministry of Water Resources and Irrigation (MWRI).	Policy orientation: Address the problem of surface water quality which was significantly compromised.
2004	Institutional & management approach	The establishment of the Egyptian Water Regulatory Agency (EWRA) responsible for the regulation, monitoring, and evaluation of all activities related to water supply services, and wastewater disposal.	Policy orientation: Address the problem of surface water quality which was significantly compromised.
2004	Institutional & management approach	The establishment of the Holding Company for Water and Wastewater (HCWW) and its 25 (now 27) affiliated companies.	Policy orientation: Address the problem of surface water quality which was significantly compromised.
2005	Regulatory actions	The release of Egyptian Code No. 501 for wastewater reuse including qualitative standards.	Policy orientation: The adoption of a safe wastewater treatment and reuse policy for agricultural purposes.
2015	Regulatory actions	Revising the Egyptian code for wastewater reuse 501, which now includes different categories of TWW and their acceptable crop types.	Policy orientation: The adoption of a safe wastewater treatment and reuse policy for agricultural purposes.
2017	Policy orientation	Integrate the use of treated wastewater in overall water management policies.	
2017	Policy orientation	Large, centralized plants are implemented with a reuse component aiming at reclaiming new lands cultivated with timber crops.	
2017	Regulatory actions	The National Water Resources Plan (2017–2030–2035) adopts an Integrated Water Resources Management Approach (IWRM).	

3.2.3. Institutional roles, responsibilities and bottlenecks in water reuse

The water and wastewater sector's institutional landscape in Egypt is based on a form of institutional pluralism, where the various responsibilities are distributed among different organizations with overlapping mandates and limited coordination and/or communication channels. For instance, the state-owned HCWW was established to improve the sector's performance and meet the donor's prerequisites (World Bank 2016). However, the establishment of the HCWW in 2004 overlapped with the mandates of previously established institutions (particularly the National Organization For Potable Water and Sanitary Drainage, NOPWASD). This overlapping led to conflict and disagreement between the two institutions regarding new water and wastewater projects (e.g., Integrated Sanitation & Sewerage Infrastructure Project in 2016) (World Bank 2016; Tawfik et al. 2021). These overlaps are evident particularly in the operation and maintenance (Table 3.2).

Another example is the Egyptian Water Regulatory Authority (EWRA) whose role as a regulatory body started in 2004 but was challenged by the overlapping of its regulatory responsibil-

TABLE 3.2 Institutional mapping of the responsible institutions for wastewater management and reuse activities in Egypt.

Wastewater management (collection, treatment, discharge or transfer)		Water reuse (license, approval and allocation)			Codes and standards	Monitoring
Infrastructure development	Operation and maintenance	Industry	Agriculture	Urban (e.g., landscaping)		
Strategy and policy formulation: The Ministry of Water Resources and Irrigation (for all aspects related to water allocation)						
NOPWASD	HCWW (25 affiliated companies in the different governorates)				Cabinet	EWRA
Strategy and policy formulation: The Ministry of Housing Utilities and Urban Communities (for all aspects related to water and sanitation services in urban and rural communities)						
NOPWASD	CAPW (Cairo & Alexandria)				Parliament technical committees	Ministry of Environment
Strategy and policy formulation: The Ministry of Agriculture and Land Reclamation (for all aspects related to agricultural expansion)						
Hayah Karima project (National project to improve the livelihoods of rural communities in Egypt through infrastructural development projects in remote villages)	NUCA (new cities)					
	Suez Canal Authority (Suez Canal cities)					Ministry of Health

ities with other institutions such as the HCWW, relevant ministries and the cabinet (Ménard 2022). Overlaps in mandates diluted leadership and diluted responsibilities of monitoring and enforcement, hence affecting the performance of treatment.

These institutional bottlenecks compromise the sector's performance and result in the spread of 'informal' practices developed by local users (i.e., water users from different locations and sectors but mainly agricultural water users). For example, in the Nile Delta, informal drainage water reuse in agriculture (often mixed with raw wastewater) was estimated between 4 to 6 BCM/year (Reymond et al. 2014). Given the under-performing and low rate of treatment and the difficulty to enforce regulations on the ground, these water reuse quality standards remain overly ambitious (Reymond et al. 2014; see Section 1, Chapter 5).

3.3. Jordan

3.3.1. Toward water reuse development

Jordan's annual per capita water share continues to decline and is now approximately 106 m^3 and places it as one of the most water-scarce countries in MENA and the world (Hussein 2018). Since the 1970s, Jordan has become one of the first MENA countries to consider reuse as part of its national water plan (Table 3.3) (see Chapter 5).

Jordan has increased the reallocation of water reuse toward the agricultural sector so it can serve as the primary water source for irrigation. This strategy enabled Jordan to partially adapt to its water scarcity by reallocating large volumes of freshwater to priority domestic needs (MWI 2001). This strategy relies on expanding the sanitation services in urban areas to generate 0.184 BCM of TWW annually (MWI 2016).

TABLE 3.3 The historical development of the water reuse sector in Jordan.

Policy orientation (1955–1977)
Aimed at expanding the sanitation services throughout the country and securing the water resources through a series of lawsthat established several governmental agencies.

1955

Regulatory actions
Law 29 – municipalities' mandates.

Institutional & management approach
Enables municipalities to be responsible for the construction, operation and maintenance of sewer systems.

1965

Institutional & management approach
Establishment of the Natural Resources Agency with a mandate to plan water resource development and irrigation policies.

1966

Regulatory actions
Law 79 – wastewater management regulation.

Institutional & management approach
Government agencies are responsible for the regulation of wastewater management activities (collection, disposition and discharge).

1971

Regulatory actions
Law 21 – treated wastewater quality. monitoring.

Institutional & management approach
The Ministry of Health became responsible for the regulation and monitoring of TWW quality.

1977

Regulatory actions
Law 18 – establish the Jordan Valley Authority.

Institutional & management approach
Establishment JVA as a regional agency responsible for the planning and implementation of all development aspects in the Jordan Valley, including water reuse in agriculture.

Policy orientation (1978–1996)
The first wastewater reuse policy aimed to operationalize water reuse in agriculture.

1978

1982

Regulatory actions
Law 2 – first water reuse standards.

1983

Regulatory actions
Law 34 – establish the Water Authority of Jordan.

Institutional & management approach
Establishment of WAJ to manage, regulate and set policies for water and wastewater services (WAJ responsibilities were defined by Law No. 18 in 1988).

1992

Institutional & management approach
Establishment of MWI as a centralized body to manage water resources in the country.

1996

Regulatory actions
The Sewage Sludge Use in Agriculture Specification, Jordanian Standard, No. 1145 set by Jordan's Department of Standards.

Policy orientation (1998–2006)
Policy recommendations to adopt water reuse plans in high priority areas (e.g., the Northern Jordan Valley).

1998

2001

Regulatory actions
Amendment of Law 18/1988 opens the door to the private sector to provide water and wastewater services.

2002

Regulatory actions
Law 893 – set standards for treated wastewater discharge into wadis.

Regulatory actions
Agriculture Law 44

Institutional & management approach
The Ministry of Agriculture regulates water reuse for irrigation and penalizes violators.

2006

Regulatory actions
Law 52 – the monitoring role of the Ministry of Environment.

Institutional & management approach
The Ministry of Environment takes part in monitoring and evaluating of environmental impacts of TWW on the environment through the issuance of regulations and permits for reuse.

2009

Policy orientation
Policies focused on regulating water reuse quality by adopting WHO and FAO.

Policy orientation
The promotion of a decentralized wastewater management approach.

Regulatory actions
Jordan's water strategy *Water for Life* (2008–2022) focuses on regulating environmental and health impacts by complying with the WHO and FAO water reuse guidelines (See Nassif et al. 2022 for more details on the WHO and FAO guidelines).

2013

Regulatory actions
Water substitution and reuse policies focused on the gradual substitution of freshwater with water reuse for agricultural use in priority areas.

Institutional & management approach
Establishment of National Framework for Decentralized Wastewater Management in Jordan (NICE), an interministerial committee established by MWI to develop a regulatory and administrative framework for implementing decentralized wastewater management.

2016

Regulatory actions
Jordan's water strategy (2016–2025) includes the following key policies: Water substitution and reuse policy, water reallocation policy and decentralized wastewater management policy.

3.3.2. The historical development of water reuse: Policy and institutional milestones

Table 3.3 (above) shows the progressive inclusion of water reuse in the Jordanian water budget, particularly the one allocated for irrigation. In the 1950s, Jordan relied solely on freshwater resources (notably groundwater). By the late 1970s, Jordan started the shift toward large-scale water reuse in agriculture and to reallocate freshwater to urban areas (e.g., water reuse and reallocation scheme in the middle Jordan Valley) (Tawfik et al. forthcoming). Jordan established centralized governmental agencies – Jordan Valley Authority (JVA) and Water Authority of Jordan (WAJ) under the umbrella of the Ministry of Water and Irrigation (MWI) – to control, operate and regulate wastewater treatment and reuse activities.

Since the 1980s, Jordan has followed donor recommendations and has further expanded water reuse in agriculture and saved freshwater for domestic uses. The country has identified key priority areas to implement the reuse–reallocation plans (MWI 2001). This includes the involvement of the private sector to facilitate this expansion.

3.3.3. Institutional roles, responsibilities and bottlenecks in water reuse

Municipalities managed wastewater treatment and reuse activities in Jordan since the 1950s. However, this decentralized role of the municipalities was abolished in the late 1970s when the Government of Jordan established the JVA, WAJ and MWI.

Although MWI was the latest to be established in 1992, it became the central body entitled to set policies and strategies at the national level (Table 3.4). WAJ was created in 1983 and assumes a wide range of executive responsibilities related to the sector's operation and management. These responsibilities include regulating and monitoring water and sanitation services through government-owned water and wastewater utilities in Aqaba, Amman and Northern Governorate as well as recommending tariffs based on the cost of water services (UFZ 2022).

JVA is responsible for the 'socioeconomic development' of the Jordan Valley. This broad mandate includes water resources management and irrigation water allocation (either fresh-

TABLE 3.4 Institutional mapping of the Ministry of Water and Irrigation (MWI), the responsible institution for wastewater management and reuse activities in Jordan.

<table>
<tr><th colspan="2">Wastewater management (collection, treatment, discharge or transfer)</th><th colspan="3">Water reuse (license, approval and allocation)</th><th rowspan="2">Codes, standards and tariffs</th><th rowspan="2">Monitoring</th></tr>
<tr><th>Infrastructure development</th><th>Operation and maintenance</th><th>Industry</th><th>Agriculture</th><th>Urban (landscaping)</th></tr>
<tr><td rowspan="3">WAJ (regulate the construction of the infrastructure development)</td><td rowspan="3">WAJ (by supervising the water utilities through its Program Management Unit PMU)</td><td rowspan="3"></td><td rowspan="3">JVA (in the Jordan Valley)</td><td></td><td>Cabinet</td><td>MWI</td></tr>
<tr><td></td><td>Jordan Standards and Meteorology Organization (JSMO)</td><td>The Ministry of Health</td></tr>
<tr><td></td><td>WAJ (tariff recommendation)</td><td>WAJ</td></tr>
</table>

water or water reuse) (MWI 2016). Its overarching role often puts the JVA at a 'superior level relatively' to the acting ministries (directorates) in the Jordan Valley. More recently, the JVA delegated some of its mandates (mainly irrigation water allocation and some maintenance tasks regarding irrigation water distribution networks) to the newly established water user associations (WUAs) in the Jordan Valley (Mustafa et al. 2016).

3.4. Lebanon

3.4.1. Toward water reuse development

Lebanon, compared to its neighboring countries, is endowed with relatively plentiful water resources. However, in the past few decades, it is experiencing water shortages that are expected to worsen due to rapid urbanization, population growth, poor governance and climate change (MEW 2020). Reuse has been considered as part of the solution to water problems according to Lebanon's latest national water sector strategies (MEW 2010; 2020). If collected and distributed in organized projects, treated effluents could potentially irrigate some 5,000 ha of lands and reduce pressure on freshwater and groundwater pumping (Eid-Sabbagh et al. 2022). Only one small municipal reuse project (20 ha around Ablah WWTP) was implemented through an international fund while no state projects were planned. No institutional framework for reuse planning and management has been developed and there is a lack of official water reuse quality regulations. The delay in developing reuse can be explained by a dysfunctional wastewater sector where despite 30 years of massive investments in building sanitation infrastructure, less than 20% of treatment facilities are currently operational.[1]

3.4.2. The historical development of water reuse: Policy and institutional milestones

Water governance in modern Lebanon is shaped by a long path of successive political regimes including Arab, Ottoman, French and a complex political history after its independence in 1943. It is today characterized by legal pluralism, institutional overlaps and competition over administrative scales that recent donor-oriented reforms failed to resolve (Riachi 2013; Ghiotti and Riachi 2013; Eid-Sabbagh 2015; Nassif 2019; Allès, 2019). Although relatively recent, legal and institutional development in the sanitation sector follow the same path. The first regulation of wastewater disposal was issued in 1930s, under the French Mandate (1920–1943), along other legal texts establishing water as Property of the State. Since then, water and wastewater use were further regulated and their formal governance progressively centralized. The Ministry of Hydraulic and Electric Resources (MHER) was created in 1959 amidst a period of building state institutions to plan water resources development and coordinate the services of the progressively created 22 public offices responsible for drinking water services. In parallel, hundreds of municipalities (locally elected administrations) and irrigation committees were governing their own water systems with little state intervention (Allès 2019; Nassif 2019). Between the 1950s and the 1980s, while large State-led hydraulic irrigation

[1] This number is further reducing starting the end of 2019 and the bankruptcy of both the Lebanese government and the banking sector (Eid-Sabbagh et al. 2022).

systems were being planned to replace community-based systems (Nassif 2019), wastewater management was still not a state priority. In 1977, municipalities were tasked with a number of responsibilities related to sewerage and treatment management and given competencies to levy taxes in this regard (Mashayekhi et al. 2014). In the same period, two years after the beginning of a long war, the Council for Development and Reconstruction (CDR) was established to manage reconstructions funds and would become a central actor in the sanitation sector after the war.

Between 1975 and 1990, the Lebanese civil war weakened state institutions and paralyzed national hydraulic plans while water and sanitation services were governed locally by militias and/or municipalities and private initiatives. After the war, a large reconstruction program fueled by donors' investments brought back all hydraulic plans on the table. Public investment in sewage collection and treatment became increasingly important and both sectors underwent large institutional transformations. The Ministry of Environment was founded in 1993 and tasked with setting environmental laws and regulations including water pollution. In 1994, Decree 5343 organized the work of the Sanitation Department at the MHER, tasking it with planning and implementing sewerage networks and treatment plants, and approving municipalities' projects (Mashayekhi et al. 2014). A few years later, to comply with the World Bank's governance orientations, the water and sanitation sector were completely restructured (Riachi, 2013; Eid-Sabbagh 2015; Allès 2019).

Issued in 2000, Law 221 created four Regional Water Establishments (RWEs) as decentralized bodies working under the Ministry of Energy and Water,[2] merging the 22 local water offices and taking over the operation of drinking water, irrigation and sanitation services from municipalities and local committees. Later in 2002, the government issued Environmental Law 444

[2]The new name of the Ministry of Hydraulic and Electric Resources

TABLE 3.5 The historical development of the water reuse sector in Lebanon.

Year	Category	Description
1974	Regulatory actions	*Decree 8735* – Prohibits wastewater discharge into water bodies.
1976	Regulatory actions	*Decree 8765* – Prohibits wastewater use in irrigation.
	Institutional & management approach	Each municipality is mandated to assign a location for wastewater treatment.
1977	Institutional & management approach	Establishment of the Council for Development and Reconstruction (CDR) as an autonomous entity directly reporting to the council of Ministries, with the comprehensive task of planning, reconstruction and rehabilitation of the country.
1999	Regulatory actions	Water Master Plan (2000–2009) by the Ministry of Hydraulic and Electric Resources (MHER).
2000	Regulatory actions	*Law 221* – creating the regional water establishments (RWEs).
	Institutional & management approach	Creates four RWEs with administrative and regional autonomy, responsible for the implementation, operation and maintenance of water-related projects. The law was enacted in 2018.
2001	Regulatory actions	*Law 337* – establishing the Ministry of Energy and Water (MEW).
	Institutional & management approach	Transforms MHER to MEW.
2002	Regulatory actions	*Law 444* – Environmental law.
	Institutional & management approach	Environmental law to combat pollution, where the MEW and the Ministry of Environment have competencies in developing standards and imposing measures to monitor water quality in collaboration with relevant stakeholders.
2012	Regulatory actions	The National Water Sector Strategy (NWSS).
	Regulatory actions	The National Strategy for the Wastewater Sector (NSWW).
2018	Policy orientation	The international conference in support of Lebanon's development and reforms in Paris (Paris IV - CEDRE) where the Lebanese government committed to implementing sectoral and multi-sectoral reforms that encouraged a large flow of soft loans and grants.
	Regulatory actions	Water Code *(Code de L' Eau – Law 77)* – complements and/or operationalizes Law 221 (issued in 2000) by assigning the MEW the responsibility of developing sustainable strategies for water governance at a national level. It states that the RWEs should handle water and wastewater services within their regions and satisfy water demand through conventional and non-conventional sources (including TWW), also for RWEs to propose water and wastewater tariffs.

TABLE 3.6 Institutional mapping of the responsible institutions for wastewater management and reuse activities in Lebanon.

<table>
<tr><th colspan="2">Wastewater management (collection, treatment, discharge or transfer)</th><th colspan="3">Water reuse (license, approval and allocation)</th><th rowspan="2">Codes and standards</th><th rowspan="2">Monitoring</th></tr>
<tr><th>Infrastructure development</th><th>Operation and maintenance</th><th>Industry</th><th>Agricul-ture</th><th>Urban (e.g., landscaping)</th></tr>
<tr><td colspan="6">Strategy and policy formulation: The Ministry of Water and Energy</td><td rowspan="3">The Ministry of Water and Energy</td></tr>
<tr><td>The Council for Development and Re-construction (CDR)</td><td>The Council for Development and Reconstruction (CDR)</td><td></td><td></td><td></td><td>The Ministry of Water and Energy</td></tr>
<tr><td></td><td>Regional Water Establishments (RWEs)</td><td></td><td></td><td></td><td>The Ministry of Environment</td></tr>
<tr><td colspan="6">Strategy and policy formulation: The Council for Development and Reconstruction (CDR)</td><td rowspan="2">The Ministry of Environment</td></tr>
<tr><td></td><td>Municipalities</td><td></td><td></td><td></td><td></td></tr>
</table>

that introduced the 'Environmental Police' in charge of enforcing pollution control regulations. In 2004, a 'Code de l'Eau' was developed in collaboration with the Agençe Française de Développement (AFD) as a comprehensive law that governs both water and sanitation and establish new financial and governance mechanisms such as the 'Polluter-Payer' principle and the 'Water Police' responsible for enforcing pollution control regulations. This Code was only ratified in 2018 under donors' pressure on the eve of the 'Cedre' Conference, aiming at attracting loans from the international community (Nassif 2019).

3.4.3. Institutional roles, responsibilities and bottlenecks in water reuse

The under performance of the wastewater sector lies in conflicting and/or diluted administrative responsibilities and a weak operationalization of institutions' legal mandates (Machayekhi et al. 2014; Eid-Sabbagh et al. 2022). For instance, while the MEW's formal role is to lead and supervise planning, infrastructure projects and funds have been typically managed by the CDR since the end of the war with generally weak involvement from the lead ministry. The CDR has indeed been granted the responsibility to implement donors' funds by direct approval of the Prime Minister, and is seen as instrument to concentrate decision-making and the associated financial benefits in the hand of the different political elites[3] (Leenders 2004; Eid-Sabbagh 2015; Nassif 2019). The Ministry of Environment seems also marginalized in planning since not enabled to perform Environmental Impact Assessments for WWTPs as per its mandate.[4] As regularly reported in the literature, implementation of state infrastructure in Lebanon lacks transparency and is associated with large individual political and financial benefits (Leenders 2004; Farajallah et al. 2015; Ibrahim and Seoud 2016; The Monthly 2017).

The wastewater sector has other vexing issues such as inability of RWEs to recover costs in

[3]In the past decade, a national shift in political dynamics has put the MEW in a better position concerning planning and project implementation (Nassif 2019). The latest wastewater sector strategies (NWSS 2012; NWSSU 2021) were issued by the MEW, including a National Wastewater Master Plan (NWSS 2012). Recent interviews with MEW officials reveal that co-ordination with the CDR has been improving and that it is an important objective for the current Ministry and the upcoming update of the National Water Strategy.

[4]Interview conducted by the second author with an official at the MEW in September 2019.

order to operate the WWTPs as per its mandate. It was hoped, following the reform model and dominant market logic, that operations and maintenance could be financed via revenues from fees. However, 20 years after the reform, RWEs are still struggling to implement their mandate due to their weak political power on the ground. They are poorly staffed and subject to interference from the various political factions (World Bank 2010; NWSS 2012; Eid-Sabbagh 2015; Nassif 2019). Currently, among the country's 104 wastewater treatment plants, only 10 are managed by the RWEs and five are well operational. The rest are managed by the CDR, and many have been funded by international projects and managed by the municipalities (Eid-Sabbagh et al. 2022).

3.5. Saudi Arabia

3.5.1. Toward water reuse development

The average annual water use per capita in Saudi Arabia is around 278 m^3 in 2018 (GASTAT 2018). The country has no natural surface water sources and extremely low annual rainfall.[5] The high rate of population growth and the steadily increasing water demand of the agricultural sector which grows at an annual rate of 7% and consumes around 84% of total water requirements has intensified the pressure on the limited water resources (MEWA 2020).

Wastewater reuse in Saudi Arabia is an integral component of the *National Water Strategy 2030*, where wastewater reuse is expected to help the country save its non-renewable groundwater aquifers from the continuous depletion and reduce around 2% of the country's annual electricity consumption (Kajenthira et al. 2012). Water reuse would also attend to the growing water demand of the industrial sector, which is a major contributor to Saudi's economy (Alkhudhiri et al. 2019).

TWW is expected to have contributed to Saudi Arabia's water supply with 0.6 BCM (2% of total resources) in 2016 while increasing to 1.9 (15% of total resources) by 2020. In 2018, the Kingdom produced around 1.46 BCM of TWW of which 17% is reused for agricultural purposes (MEWA 2020).

Water reuse projects in Saudi Arabia have aimed at conserving the non-renewable groundwater, while maintaining sustainable agricultural development and food security, improving the living standards of farmers, and maximizing environmental and economic benefits. This is pursued through a national scale policy and institutional reforms that support the sector's privatization and services subsidization by the government (i.e., water and sanitation services), while maintaining the country's regulatory role (Ouda et al. 2014).

3.5.2. The historical development of water reuse: Policy and institutional milestones

Saudi Arabia's water sector development started at a later stage compared with other coun-

[5]Not exceeding 100 mm in most of the country except the south-western region (Al-Zahrani et al. 2011)

tries in the MENA region (Table 3.7). This can be explained by the Kingdom's recent agricultural development which came at a later stage than Egypt, Jordan and Tunisia. The country has historically depended on groundwater resources but in the 1950s it developed advanced seawater desalination capacities. Currently, Saudi Arabia generates 18% of the global desalinated water (Oxford Business Group 2018). However, the country's quest to expand the less-energy demanding safe water reuse started in the late 1990s with a policy objective that aims for greater involvement of the private sector in the provision of the services while maintaining the regulatory role of the governmental institutions.

3.5.3. Institutional roles, responsibilities and bottlenecks in water reuse

Saudi Arabia managed to integrate unconventional water resources (i.e., desalinated water and TWW) into its water sector plan, while minimizing the institutional overlaps and gaps between the existing agencies. This has been established by clearly allocating roles and responsibilities between the public and private sectors (Tables 3.7 and 3.8). This clear allocation of responsibilities helped as well to minimize the competition of interests between the various actors.

TABLE 3.7 The historical development of the water reuse in Saudi Arabia.

1997

Policy orientation
The policy aimed to expand safe water reuse as a non-conventional water resource for agricultural and other purposes through institutional strengthening, which includes identifying the roles and responsibilities of the various actors in the public and private sectors. The government maintained a regulatory role, while the private sector is responsible for service provision.

Policy orientation
The industrial sector received most of the policy attention by creating Saudi Authority for Industrial Cities and Technology Zones (MODON) and Marafiq (the power and utility company for the cities of Jubail and Yanbu).

2000

Regulatory actions
Royal Decree No. M/6.

Regulatory actions
Resolution No. 42 (FAO 2000) – Law of treated sewage water and reuse (34 articles including technical standards for water reuse).

Institutional & management approach
Establishment of Marafiq to provide integrated operation and maintenance services for water and power utilities in the industrial cities of Jubail and Yanbu.

Institutional & management approach
The Ministry of Agriculture and Water is responsible for providing licenses for treated wastewater reuse.

Regulatory actions
Council of Ministers' Resolution No. 2042 on industrial water reuse.

Institutional & management approach
The Ministry of Commerce and Industry (MoCI) is responsible for providing licenses for industrial treated wastewater reuse.

2001

Institutional & management approach
Establishment of MODON tosupervise, regulate and develop industrial cities and technology zones in the Kingdom (including water, wastewater, and water reuse services) in collaboration with the private sector.

2002

Policy orientation
The policy aimed to establish a framework for a future key role of the private sector in the water and energy sectors through independent water and power projects (IWPPs) through a build-operate-transfer or build-own-operate schemes.

Regulatory actions
Council of Ministries' Resolution No. 542.

Institutional & management approach
The regulatory role of the full value chain for water and wastewater services, excluding groundwater wells, is assigned to ECRA (Electricity and Cogeneration Regulation Authority).

Policy orientation
The policy aimed for full privatization of the water sector.

2005

Regulatory actions
MoWE's five-year strategic transformation plan for the sector's privatization.

Institutional & management approach
Privatization of the Saudi Water Conversion Corporation (SWCC) (into a state-owned private company) that buys water from the Water and Electricity Company (WEC).

2008

Regulatory actions
Ministerial Decree 671.

Institutional & management approach
Establishment of the National Water Company (NWC) – a state-owned joint-stock company – to provide water and wastewater services.

Institutional & management approach
NWC buys water from SWCC and then sells it to consumers.

Regulatory actions
Treated wastewater reuse policy (launched by NWC).

2016

Policy orientation
Saudi Arabia's Vision 2030 (in line with the GCC vision 2030), considered TWW as a sustainable water resource to be integrated into the national water management.

Policy orientation
National Water Strategy 2030.

2017

Regulatory actions
Council of Ministers' Resolution No. 494.

Institutional & management approach
Water and Electricity Company (WEC) is mandated as the primary buyer for water and treated wastewater and has the right to re-sale of desalinated water and treated wastewater.

2018

Regulatory actions
Ministerial Resolution No. 187.

Institutional & management approach
Saudi Irrigation Organization (SIO) is mandated to enforce and monitor the quality of soil and water used in irrigation.

2020

Institutional & management approach
The approval of the water law empowers the Ministry of Environment, Water and Agriculture (MEWA) as the main entity to oversee water and wastewater related matters (Almadani 2022).

The Saudi case provides a successful example of privatization, while maintaining the regulatory and monitoring role of the governmental agencies to ensure the private sector's compliance with the national codes and standards. However, the well-established privatization does not mean a transformative shift toward a decentralized sector. On the contrary, the water sector in Saudi Arabia is a centralized one that employs the vast experience of the private sector to increase efficiency and reduce the cost-of-service provisions (including water supply, sanitation and water reuse).

These transformative changes are reflected in the institutional structure of Saudi Arabia's water sector, where the state-owned companies and private investors are playing a key role in the value chain of water reuse which starts with the IWPP contracts (build-own-operate or build-operate-transfer) followed by providing water for consumers through the state-owned companies (WEC, SWCC and NWC) (Biygautane 2017) (Table 3.8).

TABLE 3.8 Institutional mapping of the responsible institutions for wastewater management and reuse activities in Saudi Arabia.

Wastewater management (collection, treatment discharge or transfer)		Water reuse (license, approval and allocation)			Codes and standards	Monitoring
Infrastructure development	**Operation and maintenance**	**Industry**	**Agriculture**	**Urban (e.g., landscaping)**		
Strategy and policy formulation: MEWA (Ministry of Environment Water and Agriculture)						
Independent water and power projects (IWPPs). This includes NWC, WEC and SWCC in addition to Marafiq and MODON.		MoCI (Ministry of Commerce and Industry)	SIO (Saudi Irrigation Organization)	MEWA (Ministry of Environment Water and Agriculture)	ECRA (Electricity and Co-generation Regulation Authority)	MEWA (Ministry of Environment, Water and Agriculture)
		MEWA (Ministry of Environment Water and Agriculture)				

3.6. Tunisia

3.6.1. Toward water reuse development

The annual per capita water share in Tunisia was estimated at around 440 m^3 in 2017 (FAO 2022a) and is expected to drop to 360 m^3 by 2030 (Chouchane et al. 2018). The increasing water stress and the variability of rainfall and drought periods, additionally to the limitation of conventional water resources, and the degradation of their quality to cover agricultural water needs, are the main drivers to use every 'single water drop,' including TWW.

Water reuse projects started early in the 1960s in the La Soukra region mainly to irrigate citrus trees. This major crop used to be irrigated with depleting shallow coastal aquifers, which resulted in seawater intrusion and salinization of groundwater and made it unsuitable for irrigating crops as sensitive as citrus trees. Hence, the main objective of wastewater reuse was the preservation of the groundwater resources from salinization and the preservation of citrus orchards, even before the promulgation of the overreaching national regulation *Water Law*, so-called *The Water Code* established later in 1975 that regulates water reuse among other objectives.

3.6.2. The historical development of water reuse: Policy and institutional milestones

Tunisia presents a unique case where the implementation of the water reuse project in the La Soukra area preceded the institutional development of water reuse in the country. This is in contradiction to the other case studies, where implementation steps come after the regulatory and institutional ones. However, starting from the mid-1970s, Tunisia directed its policy orientation toward building the institutional capacity of water reuse by establishing the central governmental institution to manage the sanitation sector (i.e., ONAS). From the 1980s onward, the successive Tunisian governments issued a series of standards and laws to regulate the effluent and influent quality, and to comply with the national and international standards.

Since 2018, expanding water reuse has gained momentum and was promoted under the flagship of the *Strategic Study Eau 2050* accompanied by a *National Master Plan* for reuse, the so-called *Reuse 2050*.

3.6.3. Institutional roles, responsibilities and bottlenecks in water reuse

Water reuse started early in the 1960s in Tunisia (Table 3.9), but policy and institutional settings were only established in the 1990s (e.g., creation of ministries and national agencies). These institutions can be classified into producers, managers, users and distributors, controllers and consumers (of the irrigated products or services) (Table 3.10).

Within this 'value chain-like' structure, the Ministry of Agriculture and Hydraulic Resources and Fisheries (MARHP) plays a prominent role through its directorates and/or subsidiaries. MARHP's wide range of responsibilities includes water resources (mobilization and use) and agricultural production as well as urban (through the National Water Supply Utility, SONEDE) and rural drinking water (through the Department of Rural Engineering and Water Exploitation and the Water Users' Association so-called Agricultural Development Groups).

In the early 1990s, ONAS (established in 1974) and the National Agency of Environmental Protection (ANPE, established in 1988) were moved under the Ministry of Environment (ME) created at that time (ONAS also operates under the Ministry of Local Affairs, since it maintains its role as the main operator of sanitation services). Since then, all wastewater reuse projects have had to submit an Environmental Impact Study to be approved by ANPE. MARHP is the main manager, user and distributor of TWW. It intervenes only downstream of the treatment plant (the upstream being managed by ME) and it operates at various levels, mainly national and regional through its representative regional departments (the Regional Department for Agricultural Development, CRDA) located in the 24 governorates.

Together with the farmers' associations (i.e., GDA), the CRDA is managing TWW reuse and the irrigated areas including the operation and maintenance of the irrigation network, assuring farmers' involvement and participation at local and regional levels. For this purpose, the Agricultural Extension and Training Agency (AVFA) and its representatives in the regions (Extension Territorial Service, CTV) is responsible for the dissemination of the good practices of water reuse in irrigation and to offer extension services to end-users. The Ministry of Health and its regional affiliated agencies and departments are the main bodies controlling and monitoring the quality of TWW and the quality of the irrigated environment and products.

In terms of governance and the agricultural water reuse, Tunisia has the required actors including the ministries, agencies, committees, and associations at the national, regional and local levels for a successful implementation. However, the relationships between the actors are still weak due to the lack of information sharing, which might reflect a certain mistrust. Currently, there are no mechanisms to reduce the existing overlap in missions and define the roles and responsibilities of each actor. The non-agricultural water reuse is facing weak governance caused by the lack of specific regulations (except the agricultural standards established in 1989, which are applied for water reuse in golf courses, recreational activities and aquifer recharge).

TABLE 3.9 The historical development of the water reuse sector in Tunisia.

Policy orientation (1965–1990)
The policy aimed to replace irrigation using depleting groundwater resources with treated wastewater through water reuse projects and developing the government's institutional capacity (particularly laws, regulations and standards).

1965
- Institutional & management approach: First water reuse project in La Soukra area.

1974
- Regulatory actions: *Law 1974* – established the National Sanitation Utility.
- Institutional & management approach: Establishment of the National Sanitation Utility (ONAS) to manage the sanitation sector.

1975
- Regulatory actions: Issuance of the *Water Code* prohibiting water pollution and the use of raw wastewater.

1985
- Regulatory actions: *Decree 85-56* – industrial effluent standards into the receiving environment.

1988
- Institutional & management approach: Establishment of the National Institute for the Protection of the Aquatic Environment (ANPE).

1989
- Regulatory actions: Establishment of the *NT 106.03* The standards of water quality dedicated to the reuse of reclaimed water in agriculture.
- Regulatory actions: Establishment of the *NT 106.02* The standards of discharge of effluents in the receiving environment including sewer systems, water bodies and the marine environment.

1990
- Regulatory actions: The first strategy for the mobilization of water resources includes the reuse of reclaimed water.

Policy orientation (1991–2000)
The policy aimed to develop and build the capacity of state administrations to expand infrastructure building and improve pollution monitoring.

1991
- Institutional & management approach: Establishment of the Ministry of Environment.

1992
- Institutional & management approach: Modifying ANPE's mission to work under the supervision of the newly created Ministry of Environment.

1993
- Regulatory actions: Amendment of *Law 1974*.
- Institutional & management approach: ONAS started to monitor the physicochemical and microbiological quality of urban influents and effluent. Under this law amendment, ONAS became a key player under the Ministry of Environment, with its financial autonomy.

2000
- Regulatory actions: Ten-year strategy for water resources mobilization.

Policy orientation (2018–2020)
Policies geared towards revising the existing standards and providing a national strategy for water reuse in Tunisia.

2018
- Regulatory actions: Revision of the standards of discharge of effluents in the receiving environment (*NT 106.02,1989*) and enacting of the *Decree No 2018-315* of 26 March 2018.

2019
- Regulatory actions: Launching the Master Plan Reuse 2050 where wastewater reuse in agriculture and for other purposes was promoted (ongoing).

2020
- Regulatory actions: Revision of the standards of reuse for agricultural irrigation and the integration of other purposes (ongoing).
- Regulatory actions: New Water Code under discussion.

The lack of collaboration between many institutions, mainly from different sectors, is one of the major bottlenecks. For instance, there are no institutional arrangements between ONAS and the regional departments of MARHP, which means that there is no guarantee of the production and distribution of TWW that satisfies the agricultural water demand. Therefore, it was repeatedly suggested to create an independent multi-sectoral organization that would oversee water reuse to avoid redundancy and overlap of missions.

TABLE 3.10 Institutional mapping of the responsible institutions for wastewater management and reuse activities in Tunisia.

Wastewater management (collection, treatment, discharge or transfer)		Water reuse (license, approval and allocation)			Codes and standards	Monitoring
Infrastructure development	**Operation and maintenance**	**Industry**	**Agriculture**	**Urban (e.g., landscaping)**		
Strategy and policy formulation: MARHP						
Ministry of Equipment and Infrastructure	ONAS		MARHP through the Regional Departments for Agricultural Development (CRDA)		MARHP, ME, MH	The Ministry of Environment through ANPE and ONAS (practicing self-evaluation)
			Farmers' Association (GDA)			The Ministry of Health

3.7. Conclusion

The MENA region suffers from a lack of technological and infrastructural development, the absence of standards and regulations, and the weakness of institutional arrangements that govern these services (Ait-Mouheb et al. 2020; Mayaux and Ennabih 2020). 'Decentralization' and 'private sector participation' (e.g., public-private partnerships) are common policy recommendations. This is often not reflected in the actual policy orientation that informs the regulatory and institutional development of the sector. Where the top-down, centralized institutional set-up of the sector is dominating in most of the MENA countries in various forms. The policy and institutional development of water reuse in the five countries have shown the following key features that characterize wastewater management and reuse in MENA:

- Wastewater management and reuse are a second priority in the five countries where the increased pressure on water resources was the key driver to adopt water reuse as a new source of water and it was primarily directed toward the agricultural sector.
- Policy and institutional measures to regulate wastewater reuse often lag other water-related projects (i.e., supply management projects). Accordingly, an increased share of freshwater is turned into the system as untreated wastewater.
- The absence of independent regulatory agencies, the overlapping roles and responsibilities, and the absence of specialized institutions to monitor water reuse in the different sectors are key factors that lead to institutional weaknesses and thus hinder the governments' efforts to shift toward decentralization and private sector involvement (with Saudi Arabia as an exception).

- Institutional and policy reforms initiated by donors (e.g., in Egypt and Lebanon) do not achieve their goals of improving the sector's performance unless there is a country-driven reform based on needs assessment and long-term planning.
- There is a trend toward centralization and increased regulation of water quality and water flows. This is logical in a context of increased, competing demands for water, and weak/poor institutional capacity to handle water, sanitation and reuse services at a local level (e.g., the reduced role of municipalities as service providers in Lebanon after the establishment of RWEs, and the centralization of water and sanitation service provision in Egypt by the establishment of the HCWW).
- There is a lack or absence of policy enforcement and implementation, which creates a 'gray zone' that is often filled with informal (often illegal) reuse arrangements (Tawfik et al. 2021).

Finally, reviewing and analyzing the policy and institutional challenges/trajectories for the five countries resulted in the following recommendations that will help policy- and decision-makers in MENA overcome the policy and institutional bottlenecks in their countries by:

- Creating spaces for local stakeholders to participate in policy and institutional development that concern their localities.
- Creating an enabling environment to encourage private sector involvement. This includes clear roles and responsibilities for the various institutions in the sector, policy incentives, and long-term concession contracts.
- Entrenching the concepts of transparency and collaboration between the different institutions to develop a multi-sectoral water policy that is inclusive of their various needs.
- Ensuring that each policy item must have a corresponding institutional action to avoid overlapping of responsibilities.
- Understanding that the transition from centralized to decentralized water management is not a 'silver bullet' for the sector challenges. However, implementing this transition must go through phases to avoid institutional 'shocks' and to ensure the financial, regulatory and legal 'maturity' of the newly created autonomous entities.
- Recognizing the key role of donor-driven policies and institutional reforms in the sector's performance might hinder the sector's ability to set a clear vision that meets the country's needs and long-term planning goals.

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Chapter 4

Cost of water reuse projects in MENA and cost recovery mechanisms

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Key messages

- Recovering the water, energy, nutrients and other materials embedded in wastewater is a key opportunity in water-scarce countries for meeting water demand as non-conventional water resources can be used for irrigation in agriculture, groundwater recharge and other uses.
- Understanding public perception about the use of reclaimed water for different purposes and addressing concerns of end-users are key in securing public support and hence in determining the willingness of end-users to pay for reclaimed water.
- The cost of energy is the major cost for wastewater treatment plants with tertiary treatment systems. On-site energy generation from wastewater has a high potential to contribute to energy cost savings and revenue generation through sales to other sectors.
- The pricing of reclaimed water depends on several factors and varies across countries and treatment plants in the MENA region. Most of the water reuse projects supplying water for irrigation charge lower water prices, are unlikely to achieve full operational cost recovery and are only able to cover part of the operational costs.
- Supplying reclaimed water to sectors with a high ability to pay such as for landscaping and golf courses achieves a higher cost recovery rate as the price charged for water is higher.
- Harnessing key resources in wastewater such as nutrients and energy can increase the likelihood of recovering operational and maintenance costs as well as generate revenues.

4.1. Introduction

Wastewater treatment and reuse is a viable way to address the water security risk in the MENA region (see Chapter 1). Among other things, wastewater treatment and reuse provides a reliable water supply when there is a regional shortage; improves local economic growth; it reduces freshwater withdrawals from aquifers and rivers; and reduces fertilizer usage in agriculture. The recovery of water, energy, nutrients and other materials embedded in wastewater is gaining more attention in water-scarce countries as an approach to meet water demands since non-conventional water resources can be used for irrigation in agriculture, industrial use and groundwater recharge.

Wastewater treatment and reuse requires large investments in infrastructure, equipment and capacity development and involves substantial recurrent costs in the operation and maintenance of the wastewater treatment plants (WWTPs) and transport and distribution networks. While the need for water reuse is generally well recognized, mechanisms to support implementation of water reuse projects in MENA region are sometimes lacking. Examples of hurdles identified include the lack of cost-effective investments in wastewater treatment, missing cost recovery mechanisms from water reuse with various value propositions, low pricing of irrigation water, lack of creating financial incentives for safe water reuse and lack of understanding among the public about the environmental benefits of wastewater treatment and reuse (Otoo and Dreschel 2018).

There are, however, an increasing number of examples where wastewater treatment and reuse projects have been successfully implemented for agriculture, forestry, industrial uses, landscaping and other useful purposes in MENA countries. Understanding the costs and benefits of water reuse for various value additions is important and can make a stronger case for investments in water reuse solutions for cost recovery.

This chapter assesses several wastewater treatment and reuse projects in the MENA region by focusing on their economic indicators such as their costs and cost recovery or revenue generation mechanisms and the associated technologies. We use the primary and secondary data collected from existing WWTPs in the region with varying value propositions to estimate the investment and operational cost of WWTPs per volume of wastewater treated and operational cost recovery from water reuse.

The analysis focuses on operational cost recovery from water reuse. In the context of water reuse, most water reuse projects such as those supplying water for irrigation are unlikely to achieve full cost recovery and might only recover part of the operation costs (Hanjira et al. 2015a). Cost recovery from water or sanitation fees charged to households as well as operational costs of on-farm treatment of wastewater are not included in the study.

4.2. Considerations for assessing costs, benefits and cost recovery of water reuse

The potential for enhanced reuse of water is possible when decision-makers understand the costs and associated benefits of water reuse in various sectors of the economy, especially in agriculture, while highlighting its implications for public health and the entire ecosystem (Hanjira et al. 2015b). Despite the investments on water reuse projects across MENA, the region still wastes millions of cubic meters of valuable resources in wastewater that are discharged to the sea or disposed in the environment and evaporated with no direct or indirect beneficial use (see Chapter 2).

Water reuse projects are developing at a slow pace in part due to an incomplete economic analysis of wastewater treatment and reuse options, which can provide a sound justification to invest. Additionally, there is a lack of economic incentives (or the removal of economic barriers) to invest once such investment has been economically justified. The few existing studies have been limited to financial feasibility analysis and have highlighted the high costs and low financial returns of developing wastewater collection networks and wastewater treatment plants with less focus on the water reuse components (Qadir et al. 2010).

4.2.1 Financial vs. economic analysis

Financial analysis considers the direct costs and benefits of a water reuse project. *Economic analysis* considers the viability of a project from a societal perspective. In contrast to a financial analysis, an economic analysis takes a broader perspective and determines the project's overall value to society. Furthermore, financial viability may not necessarily imply profit maximization in the case of water reuse projects but could be a cost recovery target depending on the objective of the water reuse project especially given that water reuse projects aim at improved living conditions or reduced environmental pollution (Otoo et al. 2016). The results of the financial and economic analyses can also be targeted to different users; for example, the results of financial analyses are usually used in informing business decisions or guiding potential investors. The findings of economic analysis will inform policy-makers to justify public co-funding.

In addition to the direct costs and benefits that are considered in the financial analysis, the economic analysis includes other indirect costs and benefits, which are also referred to as positive and negative externalities (Figure 4.1). The economic analysis thus relies largely on the overall financial analysis for direct costs and benefits, but also on the assessment of potential social and environmental impacts. Other methods such as cost-effectiveness analysis can also be implemented in choosing among alternative solutions to address water-related challenges (Box 4.1).

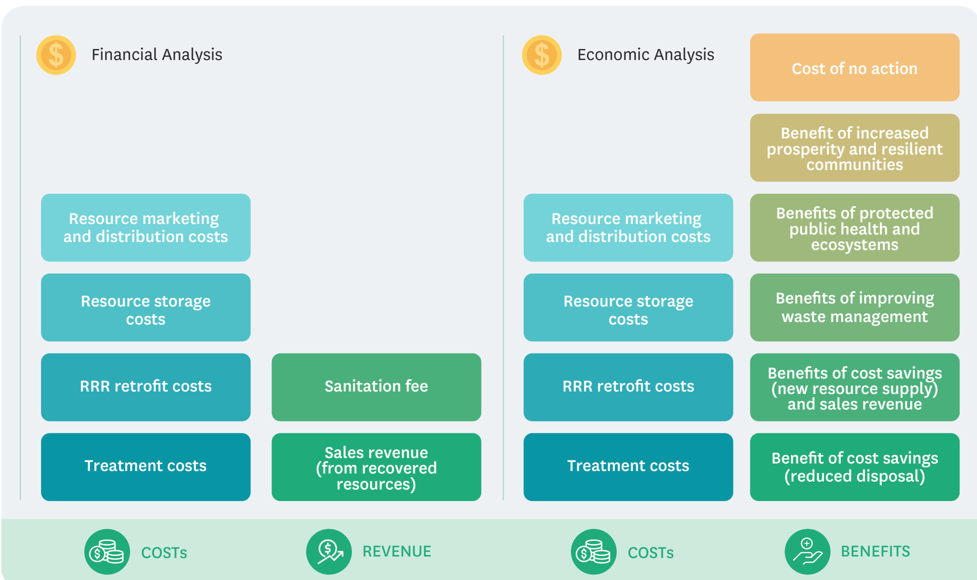

FIGURE 4.1 Financial versus economic analysis of water reuse solutions (adapted from Otoo et al. 2016).

4.2.2. Determinants of willingness to use and pay for reclaimed water

Studies show that some farmers in the MENA region are willing to use reclaimed water; however, they are only willing to pay less amount for reclaimed water compared to freshwater (Saidan et al. 2020). Factors that potentially influence users' willingness to pay for reclaimed water include the price of alternative water sources such as potable, surface water and groundwater supplies; their perception about the scarcity of alternative sources; the capital and operating costs of switching to wastewater supply; and wastewater quality, quantity and levels of service and reliability of supply.

Various pricing systems for reclaimed water could be viable in different MENA countries depending on the local context. Alternative pricing schemes which can be employed as a stand-alone or in combination include:

- *Us*er fee systems where end-users finance the infrastructure installation and then the usage charge offsets the supply cost of the reclaimed water. The Australian government adopted this type of pricing mechanism in 2003 under the national water reform process.
- *Connection* fee system, where a one-time contribution is made toward the cost of infrastructure needed to deliver reclaimed water to the connecting industry delivery point. Such fees may be negotiated between the supplier and the industries to agree on a financial arrangement such that both parties may fully or partially cover the fee of the actual work to deliver the reclaimed water to the delivery point.
- Take or pay arrangement is a flat fee system regardless of use. For instance, it does not matter the rate or times of actual use – industries are obliged to pay for a certain

BOX 4.1 Cost-effectiveness analysis

Another crucial question to consider is whether there are other viable alternatives to water reuse to achieve a given objective and whether reuse is the cheapest alternative. For example, if the goal is to address water scarcity by increasing available water resources, potential alternatives could be rainwater harvesting and storage, water transfers from other basins or desalination of seawater, if the target area is close to the coast. The reliability of rainwater harvesting is often dependent on the local climate which makes the effectiveness of these systems difficult to predict, while wastewater is a resource less dependent on rainfall patterns.

Inter-basin transfers often require very high initial investments and have considerable operation and maintenance costs, including pumping costs. They also face significant environmental and political challenges, especially in the donor basins, which is why they are becoming less popular.

Seawater desalination can compete with water reuse in coastal areas if the water quality required is potable or pre-potable. Desalination costs tend to be higher, especially with energy costs, and the management of the resulting brines is a major environmental challenge.

On the other hand, reuse projects are gaining dynamism as they provide local solutions that are more flexible and robust and can be adjusted to local conditions. The cost of alternative options must be carefully examined before proceeding with a reuse project. If equally effective alternatives exist to deal with water scarcity, but if water reuse is the least expensive solution, then the choice of reuse project would be justified.

percentage of the contracted recycled water volume and for all water consumed by the industries above the contracted level. It is worthy of note that this system of pricing ensures that WWTPs have guaranteed income that sustains the financial needs to run. However, it could lead to the overuse of reclaimed water by the target industry as well as improper discharges to the environment potentially resulting in negative externalities.

Irrespective of the pricing mechanisms in place, certain agreements regarding supply and use should be in place to ensure an effective and efficient system, while guiding supply and use behaviors. Negotiations and agreements between suppliers of reclaimed water and potential end-users such as industries could result in establishing obligations and responsibilities under which the reclaimed water reuse scheme could operate (Gould et al. 2003; Saidan et al. 2020). Saidan et al. (2020) outline important aspects that reclaimed water agreements should cover, including:

- price, quantity and quality of reclaimed water;
- security of the reclaimed water supply;
- measures to identify, allocate and manage risks and ensure safe use of reclaimed water;
- liabilities and insurance for potential damages caused by supply and use; and
- compliance with legislative and common law requirements.

4.3. Financial costs and benefits and cost recovery mechanisms in water reuse projects in MENA

The investment cost of WWTPs with varying reuse options includes the cost of wastewater collection and transportation, cost of wastewater treatment and transportation of reclaimed water to end-users. The investment cost per unit of wastewater treated depends, among other factors, on the type and level of treatment, the targeted reuse option and the capacity of the wastewater treatment plant. Several studies estimate the cost of WWTPs using a variety of methods and types of costs addressed which renders comparability of results limited. For example, some studies consider the volume of wastewater treated, while others consider the quality of influent and effluent (Hernández-Sancho et al. 2015). Similarly, when estimating the cost of operations, some studies consider all costs of operation and maintenance, while others estimate these based only on estimated energy costs. In order to allow comparisons across scales, we need to identify common indicators across different scales (Murray et al. 2011).

In this section, we estimate the investment and operational cost of wastewater treatment plants per volume of wastewater treated based on primary and secondary data collected from existing WWTPs in the MENA region with varying value propositions. We assess the investment cost and operational cost of wastewater treatment plants at different scales across different countries to provide insight into the relationship between wastewater treatment costs and the volume of wastewater treated. The reuse purpose of the reclaimed water in these treatment plants is mainly for agriculture, landscaping and golf courses.

4.3.1 Water reuse for agriculture, landscaping and golf courses

Investment cost of wastewater treatment plants

Table 4.1 presents the investment cost of WWTPs in different countries in MENA. All treatment plants use the tertiary treatment method. Most WWTPs assessed are operated by public sector utilities and rely on financial support from government and other donors with few plants having public private financing models. The investment cost per volume of wastewater treated varies across cases and countries.

TABLE 4.1 Investment cost of WWTPs with tertiary treatment system (USD/m³).

Wastewater treatment plant	Country	Treatment capacity (m³/day)	Investment cost (USD/m³)	Source[1]
South Amman	Jordan	52,000	6.46	Primary data
As Samra	Jordan	364,000	3.34	Drechsel et al. 2018
Wadi Mousa	Jordan	3,400	-	Case Study #7; SWIM 2013
Tala Bay	Jordan	1,000	-	Case Study #6
Marrakech	Morocco	143,606	3.52	Case Study #1
Tangier	Morocco	42,700	1.63	Case Study #2
Draga	Morocco	2,250	2.10	Danso et al. 2018
Nabeul SE3 and SE4	Tunisia	29,500	-	Primary data
South Sfax	Tunisia	49,500	-	Case Study #3
El Berka	Egypt	450,000	0.20	Kress and Targetti 2014
Dowoud Jabal Ali	UAE	1,050,000	1.61	Primary data
Al Wathba II	UAE	300,000	2.59	Case Study #8; Dawoud 2017
Jericho	Palestine	9,600	6.66	Case Study #5
Haya Water	Oman	100,000	-	Zekri et al. 2014

NOTES: [1]Case studies refer to those published in Section 3 of this book.

In Jordan, the investment cost per volume treated is higher compared to the treatment plants assessed in the other countries based on the wastewater treatment assessed. In Morocco, the investment cost per volume treated was lower for the smaller plants (Tangier and Draga wastewater treatment plants) than for the larger plants. This disparity might indicate that there are no economies of scale, while in Jordan and UAE plants with higher treatment capacity have lower investment cost per unit of wastewater treated compared to the plants with lower treatment capacity. This might indicate that there are economies of scale in investment costs of wastewater treatment plants in those countries. However, to ascertain this, we need to assess a larger sample. The case from Egypt (El Berka) showed the lowest investment cost per volume treated, while the case from Palestine (Jericho) showed the highest investment cost per volume treated.

We also analyzed the investment and operational costs of WWTPs with different treatment systems in Egypt to provide insight into the relationship between wastewater treatment costs and the volume of wastewater treated using different treatment methods. The treatments considered include secondary and tertiary treatment systems. Table 4.2 shows the investment and operational cost for each type of treatment system. Looking at the type of treatment system, the natural pond system has less investment and operational cost per volume treated compared to the more advanced treatment systems.

TABLE 4.2 Investment and operational cost of varying treatment systems in Egypt.

Treatment plant	Treatment system	Capacity (m^3/day)	Investment cost (USD/m^3)	Operational cost (USD/m^3)	Source
El Barka	Biological and activated sludge (tertiary treatment)	450,000	0.20	0.022	Kress and Targetti 2014
Serapium	Natural system (algae pond – primary treatment)	91,250	0.06	0.001	SWIM 2013
El-Gabal El-Asfar	Secondary system	450,000	0.30	0.019	Drechsel and Hanjira 2018

Operation costs of wastewater treatment plants

Wastewater treatment and reuse comprises different operational cost components, which include staff, energy and other costs such as chemicals and maintenance costs. Table 4.3 and Figure 4.2 are based on primary data collected from wastewater treatment plants and show the operation cost per each cost category and their importance in five plants in Tunisia, Jordan and Palestine. These costs relate to the direct treatment costs in Figure 4.1 (above).

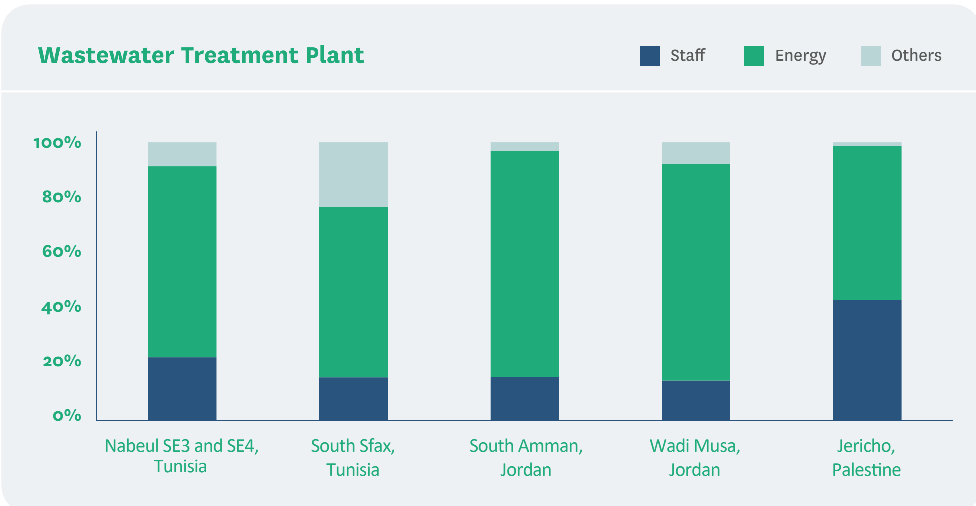

FIGURE 4.2 Share of cost components in the total operational cost.

TABLE 4.3 Operational cost per unit of wastewater treated with tertiary treatment systems (USD/m^3).

Cost item	Nabeul SE3 and SE4, Tunisia	South Sfax, Tunisia	South Amman, Jordan	Wadi Musa, Jordan	Jericho, Palestine
Staff	0.02	0.01	0.05	0.06	0.03
Energy	0.06	0.02	0.26	0.35	0.04
Others	0.01	0.01	0.01	0.03	0.00
Total	0.09	0.03	0.32	0.45	0.08

Energy cost stands out as the major cost for all plants accounting for more than 50% of the total cost of the plants in Tunisia and Palestine and 75% of the total cost of the plants in Jordan. This is because the plants use advanced treatment systems (tertiary treatment) with high energy usage. This is followed by staff costs accounting for 15% of the operational costs in Jordan and Tunisia. Staff cost in Palestine is, however, a major cost accounting for 45% of the total cost. The energy cost per volume of wastewater treated varies between the countries. Plants in Tunisia and Palestine have lower energy cost (USD 0.02–0.06/m^3), while in Jordan the energy cost per volume treated is USD 0.26–0.35/m^3.

Cost recovery rates and mechanisms of wastewater treatment plants

The majority of WWTPs in the MENA region rely on subsidies and water fees charged to households as the main source of revenue for cost recovery. However, in some cases there is additional revenue generation through the sale of reclaimed water for different value creation. This is more frequent when reclaimed water is used by growing sectors with a high capacity to pay such as golf courses, hotels or industries. Farmers have less ability to pay. Their contribution to cost recovery of WWTPs through payments for reclaimed water is marginal. Irrigation water is in most cases subsidized and farmers have little willingness to pay more for reclaimed water.

The price of reclaimed water for irrigation varies across the MENA region depending on the local context and the end use. Factors that potentially influence users' willingness to pay for reclaimed water include price of alternative water sources, i.e., potable, surface water and groundwater supplies as well as the perception about and ability to pay for reclaimed water. Industries and golf courses or landscaping, for example, have a higher ability to pay than farmers.

Table 4.4 shows the volume of reclaimed water sold, the price per volume of reclaimed water and operational cost recovery from the use of reclaimed water for different end uses. The operational cost recovery rate is the ratio of total revenue from sales of reclaimed water to total operating costs and is a key indicator of financial performance.

In Tunisia and UAE, farmers are supplied with reclaimed water free of charge to promote the use of reclaimed water, while in other countries different pricing mechanisms are used. Depending on the end use, in Jordan the price of reclaimed water showed a high variation amongst the wastewater treatment plants assessed with higher prices charged for hotels and landscaping (USD 0.015–1.05/m^3). The operational cost recovery from the use of reclaimed water ranged from a maximum of 31% to a minimum of 3%. The As Samra wastewater treatment plant showed the highest cost recovery from sale of reclaimed water for irrigation at a price of USD 0.015/m^3 and 13 MW of energy production, which resulted in a savings in energy cost for the plant.

The wastewater treatment plants in Morocco showed the highest cost recovery from the use of reclaimed water for golf courses and landscaping. In Palestine and Oman, the cost recovery from water reuse for irrigation is 30%. In Tunisia and UAE, farmers are charged no fees and

TABLE 4.4 Price and volume of reclaimed water and operational cost recovery from sales of water.

Reuse project	Country	Volume of reclaimed water sold (million m³/year)	Price of reclaimed water (USD/m³)	Operational cost recovery through water sales (%)	Water user
South Amman	Jordan	1.67	0.035	3%	Irrigation
As Samra[a]	Jordan	133	0.015	31%	Irrigation and energy recovery
Wadi Mousa	Jordan	0.54	0.2	23%	Irrigation
Talabay	Jordan	0.06	1.05	21%	Hotels for landscaping
Marrakech	Morocco	16.80	0.69	200%	Golf courses and landscaping
Tangier	Morocco	0.78	0.27	218%	Golf courses and landscaping
Draga[b]	Morocco		0.05	-	Irrigation
Nabeul SE3 and SE4	Tunisia		0	-	Irrigation (free of charge)
South Sfax	Tunisia		0	-	Irrigation (free of charge)
Dowoud Jabal Ali	UAE		0	-	Irrigation (fully subsidized by government)
Al Wathba II[c]	UAE		0.46	-	Irrigation (currently fully subsidized but future plans to charge tariffs for water reuse)
Jericho	Palestine	0.50	0.16	30%	Irrigation
Haya Water[d]	Oman		0.50	30%	Landscaping

NOTES: [a] Drechsel et al. 2018, [b] Danso et al. 2018, [c] Dawoud, 2017, [d] Zekri et al. 2014.

thus no cost recovery from use of reclaimed water. The use of reclaimed water results in a freshwater savings, which has a high economic value but was not covered in our analysis. Furthermore, at the time of the assessment, the Al Wathba II WWTP in UAE supply water for irrigation at no cost to the farmers but, in the future, the plant plans to charge a fee of USD 0.46/m³ and this is estimated to recover about 32% of the operation costs.

Some countries such as Tunisia and Jordan consider reuse of reclaimed water as an important and strategic water and wastewater sector planning and management from a policy point of view. For example, Tunisia launched a nationwide water reuse program to increase the country's usable water resources in the early 1980s (Qadir et al. 2010). This program necessitated the treatment of municipal wastewater using secondary biological treatment, usually activated sludge as well as some tertiary treatment. Reclaimed water in Tunisia is mostly used for agricultural irrigation as well as for landscape irrigation in golf courses. Jordan is considered as a leader amongst the MENA countries with its well-developed policy framework on use of reclaimed water. The three key pillars of the 1998 wastewater policy of Jordan are:

- reclaimed water is considered as part of the water budget in the country;
- water reuse is planned at a basin scale; and
- fees for wastewater treatment are charged to water users (Qadir et al. 2010).

4.3.2. Water reuse for potable water or aquifer recharge

Some MENA countries are working to use reclaimed water for additional uses beyond irrigation in agriculture, agroforestry and landscaping. Some countries have made efforts to harness the potential of reclaimed water for use in other sectors such as for domestic use and/or aquifer recharge (Qadir et al. 2010). Water reuse increases supply of water and several countries in the MENA region are expanding the water supply through investments in recharging aquifers by reusing reclaimed water (Zekri et al. 2014).

The Tunisian government initiated some investigations through pilot projects to unearth the potential of reclaimed water for groundwater recharge, irrigation of forests and wetlands development. Experience has shown that successful reuse projects should be preceded by significant information dissemination that aims at addressing concerns of project communities and to ensure their active participation.

In Oman, domestic users rejected the potential of treated wastewater for aquifer recharge due to perceived health risks (Zekri et al. 2014). Similarly, in Mashhad, Iran's second largest city, untreated wastewater had been injected into the aquifer without proper treatment resulting in contamination of groundwater, rivers and their tributaries with pollutants (Alaei 2011). To address this, the Iranian government constructed two WWTPs to produce an estimated annual volume of treated wastewater of 253 million m^3 for groundwater recharge as well as for use in agriculture and green spaces (Qadir et al. 2015; Alaei 2011).

The difference between water price and reclaimed water price is key in the willingness of industries to accept reclaimed water as substitutes. The average cost of reclaimed water through a tertiary treatment method in Jordan is JOD 0.55, while the cost of fresh water is JOD 1.00/m^3 indicating that reclaimed water has a competitive advantage in terms of price over freshwater (Saidan et al. 2020). In cases where the reclaimed water had to be piped over a long distance to supply end-users, the cost of reclaimed water will be high (JOD 2.00/m^3) and will no doubt affect the willingness of end-users to pay for reclaimed water.

In such cases, to promote use of reclaimed water, subsidies in the form of discounted cost of water in combination with fund allocation for capital costs coverage may be useful when on-site treatment is needed (Saidan et al. 2020). Understanding public perception about use of reclaimed water for different purposes and addressing concerns of end-users would be helpful in securing public support. Furthermore, legal frameworks, supportive policies and institutions are key in promoting planned use of reclaimed water for aquifer recharge (Qadir et al. 2015).

Aquifer recharge can be i) unintentional, whereby recharge occurs through deep seepage under irrigation areas, leaks from water pipes and sewers, ii) unmanaged, such as stormwater drainage wells without intent for reuse or iii) managed, whereby recharge occurs through injection of storm and reclaimed water into wells as well as infiltration basins with the intention for subsequent reuse for urban, agricultural, environmental and industrial uses (Dillon 2009).

Table 4.5 shows the cost of aquifer recharge through injection wells for different technologies. The recharged water is treated wastewater through secondary treatment method, desalted brackish water reverse osmosis (BWRO) or desalted seawater reverse osmosis (SWRO). The volume recharged varied between 0.27 million and 1.95 million m^3/year in UAE, while the volumes in Oman and Cyprus are higher. The costs varied widely among countries with Oman reporting the lowest recharge cost of USD 0.10/m^3, while in Cyprus the recharge cost is USD 1.53/m^3 of wastewater treated using a secondary treatment method. In UAE, the recharge costs ranged between USD 0.37/m^3 and USD 0.59/m^3 for different technologies. The differences in costs arose, among others, from the size of the project and the type of treatment applied prior to recharge (Almulla et al. 2003; Aydarous 2006).

TABLE 4.5 Cost of managed aquifer recharge for different technologies.

Technology	Country	Capacity (million m^3/year)	Cost per unit of water recharged (USD/m^3)
Ultrafiltration		0.27	0.49
Crystallization and ultrafiltration with pre-treatment by SWRO	UAE	0.84	0.59
Crystallization and UF with BWRO brine recovery	UAE	1.95	0.46
BWRO brine recovery – SWRO	UAE	1.11	0.37
Secondary treated wastewater	Oman	5.48	0.10
Secondary treated wastewater	Cyprus	15.33	1.53

SOURCES: Zekri et al. 2014; Allmula et al. 2003; Aydarous 2006; Koussis et al. 2010

4.3.3. Value creation for on-site use

Small-scale sanitation is a promising solution as it permits reduction of operating and maintenance costs as well as the reuse of reclaimed water such as nutrients and energy close to the source of generation. Small-scale sanitation systems are widely implemented in Egypt, especially in touristic resorts because the enabling conditions already exist (Reymond et al. 2018). However, civil society such as building owners, peri-urban or rural communities are usually interested in, and are ready to finance, the construction of sewer systems rather than considering treatment facilities.

The Al Samra wastewater treatment plant produces energy for onsite use. It has a potential energy recovery of 95% of its needs through hydro energy and biogas production with only 5% of its energy needs taken from the national grid (Saidan et al. 2020). Furthermore, about 300,000 tons of carbon dioxide is saved each year through energy recovery and renewable energy utilization. Data in Jordan has shown that having anaerobic sludge digestion in a small- and medium-scale wastewater treatment plant ($<10 \times 10^4$ m^3/day) could produce electricity that would equate to an offset of about 0.11 – 0.53 kWh/m^3 (Saidan et al. 2020, 2019; Smith et al. 2018; McCarty et al. 2011). Moreover, energy produced from anaerobic sludge digestion could be increased by co-digestion of kitchen and other organic waste. However, in Jordan, co-digestion is only conducted at a laboratory scale (Saidan et al. 2020).

Other studies have evaluated the potential of biogas production from the co-digestion of food waste and wastewater sludge at refugee camps. Co-digesting organic waste and wastewater sludge can generate 38 Nm^3/day of methane – which in theory has the potential to generate about 4 MW in remote refugee camps (Al-Addous et al. 2019). In another study, Saidan et al. (2018) evaluate on-site treatment of institutional building's wastewater. They took samples on weekly basis to determine values of parameters such as BOD, COD, TSS, pH and *E. coli*, while investigating the effluent quality of 1 m^3 per day on-site wastewater treatment processes. They report that the process was modified with an installation of in-line UV unit to ensure highest disinfection of treated wastewater suitable for reuse especially in irrigation. Based on that and per Jordanian standards of treated wastewater quality, four classifications of plants have been proposed and two of these classifications have been recommended for irrigation with treated wastewater (Saidan et al. 2018). In this regard, it is recommended that such on-site treatment processes could be utilized in refugee camps where there are no centralized wastewater treatment plants.

4.4. Conclusion

The assessments of the costs and benefits of water reuse for agriculture, landscaping, aquifer recharge or energy recovery are important. They can make a stronger case for investment in water reuse solutions for cost recovery and overall sustainability. The potential for enhanced use of reclaimed water is possible when decision-makers understand the costs and the role of water reuse in recovering capital and operational costs of the wastewater treatment plants.

In this chapter, we assessed wastewater treatment and reuse projects with varying value propositions in the MENA region. We focused on their costs and cost recovery or revenue generation mechanisms across different countries to provide insight into the relationship between wastewater treatment costs and the volume of wastewater treated as well as the opportunities in recovering operational costs from water reuse. Most WWTPs assessed in this study are operated by public sector utilities and rely on financial support from government and other donors.

The investment cost per unit of wastewater treated depends on, among other factors, the type and level of treatment, the targeted reuse option as well as the treatment capacity of the wastewater treatment plant. Energy cost constitutes the major operational cost, accounting for more than 60% of total cost of WWTPs with tertiary treatment systems, indicating that energy is a critical input for the running of wastewater treatment plants with advanced treatment systems.

The ability to minimize energy cost and achieve cost savings through generation of energy for on-site use (as in the case of the As-Samra WWTPs) or revenue generation through sales of energy to external end-users can be considered as energy cost saving mechanisms for the waste treatment plant. Recovering energy can achieve up to 85% energy self-sufficiency as well as save on energy costs (Hanjira et al. 2015a).

The use of reclaimed water has the potential to recover part of the operational costs of the WWTPs. The majority of the plants assessed supply reclaimed water for agriculture with a few plants supplying reclaimed water for landscaping and golf courses. The pricing of reclaimed water depends on several factors and varies across countries and treatment plants in the region. Notable among these factors are the target end-users, prices of alternative water sources, perception about and willingness to pay for reclaimed water and strategic policy focus of the country.

Most of the water reuse projects supplying water for irrigation charge lower water prices. They are unlikely to achieve full operational cost recovery and are only able to cover part of the operational costs. On the other hand, higher prices are charged to sectors with a greater ability to pay such as golf courses, hotels or industries. For instance, in Jordan, the price of reclaimed water varies among the plants depending on the end-users with lower prices charged to farmers than to hotels. The WWTPs in Morocco generated revenues from sales of reclaimed water for golf courses and landscaping. Cases in Tunisia and UAE represent strategic policy focus where farmers are supplied with reclaimed water free of charge.

Harnessing key resources in wastewater such as nutrients and energy, in addition to supplying water for irrigation, can increase the likelihood of recovering operational and maintenance costs as well as the capital costs if these resources are sold to other end-users. Furthermore, water reuse projects should be assessed in terms of their overall economic costs and benefits to society and not just the financial implications.

This study focused on the financial aspects of water reuse projects; however, economic benefits and costs associated with the water reuse projects need to be considered. Assessing the economic viability of water reuse projects is an important tool for decision-making to ensure that the projects result in desired socioeconomic benefits to society and thus justify their development and promotion.

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Chapter 5

Water quality standards and regulations for agricultural water reuse in MENA:
From international guidelines to country practices

Marie-Hélène Nassif, Mohamed Tawfik and Marie Therese Abi Saab

Key messages

- This chapter analyzes national water quality standards, regulations and guidelines for irrigation water reuse in the MENA region with a focus on Egypt, Lebanon, Morocco, Jordan and Tunisia and compares them to other countries in the region and different international guidelines such as WHO (1989, 2006a), FAO (1992), UNEP (2005) and EPA (2012).
- The five countries still follow a standardized model targeting the formal waste-water sector where treated effluents are to comply with a fixed and often stringent set of standards to be considered safe for reuse.
- Four MENA countries (Egypt, Jordan, Lebanon and Morocco) adopt the model developed by WHO (1989) and three of them (Morocco being the exception) adapted it by setting more stringent microbial thresholds and a complete restriction on vegetables to be eaten raw.
- The WHO (2006a) multi-barrier approach has been widely promoted in the region but does not reflect in countries' regulations despite the development of project-based guidelines, which remain indicative.
- Countries still favor a top-down approach with complete restrictions on certain crops and irrigation techniques regardless of the context. Enforcement is often ineffective with farmers having poor incentives or support to find alternative practices.
- Several factors hinder the design and implementation of more adaptive approaches such as the lack of institutional leadership, technocratic institutional processes to design standards and reluctance to take decisions perceived as unethical or entailing additional responsibilities.
- On a more positive note, the study identified recent research initiatives and field experiments studying risk management measures to propose guidelines adapted to local conditions. Knowledge-building should be expanded, shared with decision-makers in appropriate institutional settings, given visibility and support to influence regulations and policy practices.
- There is a need for more systemic research on regulations in the region that goes beyond the traditional technocratic reflection on standards and borrow from the fields of human geography and political economy to study decision-making processes, institutions and local practices.

5.1. Introduction and objectives

While water reuse offers multiple benefits, it also comes with concerns on its potential impact on health, crops and ecosystems. To manage these hazards, governments typically issue water quality 'standards' usually promulgated through regulations centered around several water quality parameters and thresholds, monitoring protocols and best practices (Box 5.1).

BOX 5.1 Terminology

Standards: A rule, principle or measure typically including qualitative restrictions in terms of numerical limits. Water quality standards for agricultural water reuse include physicochemical, health-based and agronomic parameters. Typically, they are formulated according to different categories of use applications or level of restriction on uses.

Regulations: They are compulsory dispositions, officially promulgated by state legislature and entail legal responsibilities and sanctions. Water quality regulations for agricultural water reuse typically include standards as well as monitoring protocols. They sometimes include enforcement mechanisms and sanctions.

Guidelines: Standards and best practices usually developed by international expert organizations and followed by countries to promulgate their own regulations.

Source: Adapted from Shoushtarian and Negahban-Azar 2020.

Despite the expanding technical knowledge and disseminated policy guidelines in this field, designing and enforcing water reuse regulations is an uphill battle.

Since the 1970s, international regulatory approaches have evolved considerably to find the right trade-offs between safety and enforceability (Dreschel et al. 2010; Shoushtarian and Negahban-Azar 2020). The World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO) have progressively adapted their guidelines to support low-income countries ensuring safe water reuse without investing in costly treatment technologies (WHO 1989, 2006a; FAO 1992). The most recent WHO guidelines (2006a) shifted the regulatory paradigm from a 'single barrier' approach where hazard reduction is achieved by treatment to a 'multi-barrier' approach where pathogen elimination measures can be distributed along other less technology-intensive steps such as low-cost treatment, on-farm and post-harvest practices. More generally, there is a growing call for designing adaptive and achievable regulations that consider financial, socioeconomic and institutional circumstances (WHO 2006a, b; Dreschel et al. 2010; EPA 2012; EU 2016).

In the MENA region, agricultural water reuse has been expanding since the 1970s driven by different environmental, economic and socio-political circumstances (see Chapter 3). Often abiding by international guidelines, most countries issued national regulations to manage the safety of water reuse. Some countries, such as Egypt and Jordan, have adapted them several times. Yet experts still underline a need for regulatory improvement in MENA, highlighting excessive levels of stringency, lack of adaptiveness to local contexts and discrepancies between countries, which would skew commercial exchange (WHO 2006b; Choukra-Allah 2010; Ait-Mouheb et al. 2020; MEDAWARE 2003). However, the existing literature does not sufficiently document and analyze these problems, at least not in a comprehensive way: what specific regulatory orientations are favored and why? Do countries abide by the recent international guidelines such as the WHO multi-barrier approach and if not, why? To which specific 'contexts' do regulations fail to correspond? How do decision-making processes shape the design of water-reuse regulations in the region and how these can be enhanced? This work contributes to unpacking these questions.

This chapter analyzes national regulations and guidelines for irrigation water reuse in the MENA region with a focus on five countries: Egypt, Lebanon, Morocco, Jordan and Tunisia. It introduces the main regulatory approaches adopted worldwide with a focus on the WHO (1989, 2006) and FAO (1992) guidelines that proved influential in the region. The second part reviews the historical development of countries' regulations within the larger development of water reuse policies. The third part compares the health-based, agronomic and physicochemical standards against different international guidelines and other MENA country regulations, with a particular interest for human-health standards and restrictions imposed on agricultural practices. The fourth part of the chapter questions the adoption (or lack thereof) of the internationally promoted risk management approaches and unpacks some challenges preventing their translation into national policies and practices. The chapter concludes on common trends in designing qualitative regulations for agricultural water reuse in the MENA region and draws recommendations for future policy and research activities.

5.2. Regulating treated water quality: technical standards and management challenges

5.2.1 International reuse guidelines and their evolution: from the 'zero risk' to the 'multi-barrier' approach

Irrigation from sewage water has been practiced by humans since the Bronze Age (3200–1100 BC). This led to the development of water-borne diseases and epidemics such as cholera and typhoid and pushed governments to start deploying efforts to better collect and treat effluents and regulate their use (Shoushtarian and Negahban-Azar 2020; Ait-Mouheb et al. 2020; Abu-Madi 2004).

The US state of California developed the first regulations in 1918, which influenced policy agendas and research programs worldwide. By the 1970s, the interest in regulating water quality had grown globally and produced substantial technical knowledge on the parameters to be monitored in treated effluents to protect human health and agronomic systems.[1] Those can be grouped into 'human health', 'agronomic' and 'physicochemical' parameters (Figure 5.1).

Two main regulatory approaches took shape, particularly diverging on the stringency level of pathogen control and trade-offs to be made between safety on one hand and cost of treatment on the other (UNEP 2005; Drechsel et al. 2010). With the evolution of scientific studies and the application of regulations in different contexts, regulatory approaches increased in

[1] See Shoushtarian and Negahban-Azar (2020) for a synthetic overview of tested parameters and their impacts.

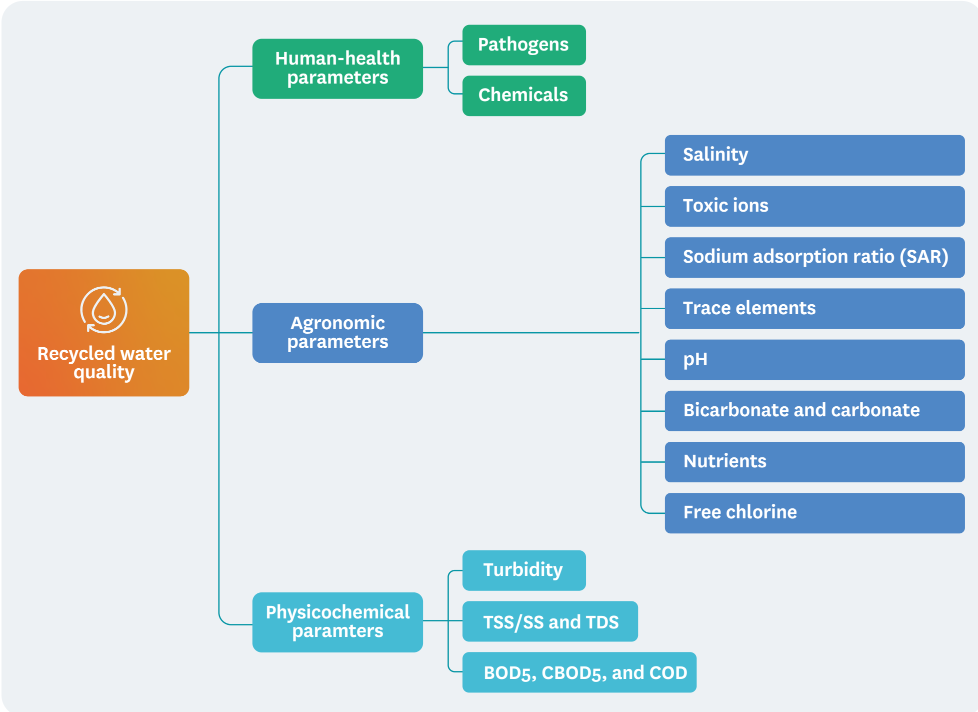

FIGURE 5.1 Main parameters monitored in treated effluents.
SOURCE: Shoushtarian and Negahban-Azar 2020

sophistication with an ambitious aspiration to design, align and monitor further practices to reduce contaminants along the wastewater treatment and reuse chains. The following section presents the main guidelines that have been influential worldwide and more particularly in the MENA region.

The conservative Californian model

The first treated water quality regulations were issued by the US state of California. They instituted a total elimination of pathogens in reclaimed wastewater based on the premise that any pathogenic microorganisms constitute a health hazard. The Californian model promotes a 'zero risk' approach associated with the use of the 'best available technology', (Shoushtarian and Negahban-Azar 2020; Ait-Mouheb et al. 2020). In 1973, the World Health Organization (WHO) proposed similar stringent guidelines for pathogen control in irrigation water (UNEP 2005; Bos et al. 2010; Shoushtarian and Negahban-Azar 2020).[2] However, the standards proved difficult to meet especially in low-income countries due the associated high costs of advanced treatment. This challenge drove the development of epidemiological studies and allowed issuing the less stringent guidelines described below (WHO 1989; Bos et al. 2010). The Californian model continued to be favored in higher income countries although some of them opted for the WHO guidelines (UNEP 2005).[3] The Californian model influenced guidelines developed by the United States Environmental Protection Agency (Shoushtarian and

[2]Threshold of 100 coliforms per 100 mL

[3]Such as France and Italy.

Negahban-Azar 2020; EPA 2012) and is adopted in some high-income MENA countries such as those of the Gulf Cooperation Council (GCC) region (Choukr-Allah 2010; Ait-Mouheb et al. 2020).

The influential WHO (1989) and FAO (1992) guidelines

While treated wastewater volumes remained globally low and unplanned reuse continued to expand in arid and semi-arid countries, the WHO developed a more realistic approach and issued new guidelines in 1989 (Drechsel et al. 2010; Bos et al. 2010). The 1989 WHO guidelines established three different categories of 'use condition' (A, B, C) according to which pathogen thresholds are gradually less restrictive (Table 5.1). Different treatment technologies were recommended for each of these categories which also become gradually less cost demanding. This differentiation between different water uses is intended to allow for more flexibility in the selection of technologies and treatment levels. Guidelines included risk management approaches that would complement available treatment processes or could even be used in the absence of wastewater treatment. Restrictions on certain crops and irrigation techniques (e.g., prohibition of sprinklers) are recommended to reduce pathogen contamination when advanced treatment is not available.

In the same period, FAO (1992) also developed guidelines for water reuse and included the same approach for pathogen control as WHO (1989).[4] FAO added agronomic parameters such as salinity, rate of water infiltration into the soil, specific ion toxicity or some other miscellaneous parameters.[5] The guidelines identified three categories of 'restriction on use' (none, slight to moderate, severe) and for each parameter and level of restriction, recommended

[4]An earlier edition of FAO guidelines for water reuse was issued in 1970 addressing the water-quality challenged of salinity and specific ion toxicity.

[5]Complete guidelines are available at https://www.fao.org/3/t0234e/T0234E01.htm#ch1

TABLE 5.1 WHO guidelines for the safe use of wastewater in agriculture.

Category	Use condition	Exposed group	Intestinal nematodes[b]	Fecal coliforms (geometric mean no. per 100 mL[c])	Wastewater treatment expected to achieve the required microbiological quality
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks[a]	Workers, consumers, public	≤1	≤1000[d]	A series of stabilization ponds designed to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees[e]	Workers	≤1	No standard recommended	Retention in stabilization ponds for 8–10 days or equivalent helminth and fecal coliform removal
C	Localized irrigation of crops in category B if exposure of workers and the public does not occur	None	Not applicable	Not applicable	Pretreatment as required by the irrigation technology, but no less than primary sedimentation

NOTES: [a]In specific cases, local epidemiological, socio-cultural and environmental factors should be taken into account and the guidelines modified accordingly; [b]*Ascaris* and *Trichuris* species and hookworms arithmetic mean no. of eggs per liter during the irrigation period; [c]During the irrigation period; [d]A more stringent guideline (< 200 fecal coliforms per 100 mL) is appropriate for public lawns, such as hotel lawns, with which public may come into direct contact. [e] In the case of fruit trees, irrigation should cease two weeks before fruit is picked and no fruit should be picked off the ground. Sprinkler should not be used. *SOURCE*: WHO 1989.

management alternatives to deal with these potential problems (FAO 1992). Both the WHO and FAO pinpoint that guidelines are indicative and need to be adapted to countries' or sites' local conditions. WHO (1989) underlines that the local epidemiological, socio-cultural and environmental factors should be considered and the guidelines modified accordingly (such as microbial thresholds against use conditions) (Table 5.1 above). FAO (1992) points out that water quality classifications are only indicative guidelines, and their application will have to be adjusted to conditions that prevail in the field (climatic conditions, physical and chemical properties of the soil, the salt tolerance of the crop grown and the management practices).

The WHO (1989) and FAO (1992) produced leading guidelines to which countries' regulations have globally referred to including in MENA (UNEP 2005; EPA 2012; Shoushtarian and Negahban-Azar 2020). In 2005, to support Mediterranean countries in establishing suitable standards UNEP, in collaboration with the WHO and researchers from the Mediterranean, proposed *Guidelines for municipal water reuse in the Mediterranean countries,* where a fourth water category has been differentiated with more stringent microbial thresholds (UNEP 2005). This approach has been influential in some countries as seen below.

The WHO (2006) multi-barrier approach

The slow progress in wastewater treatment in developing countries coupled with increasing unsafe reuse practices challenged the application potential of the 1989 WHO guidelines. The WHO (2006a) developed a new regulatory method drawing from the 'Hazard Analysis Critical Control Point' (HACCP) known as the 'multi-barrier approach' (Bos et al. 2010). A major change is the focus on 'health-based targets' to be attainable at the end of the reuse chain instead of prescribing threshold levels that are often unattainable when conventional treatment facilities are lacking or underperforming (Bos et al. 2010; Dreschel et al. 2010). The approach covers both conventional and non-conventional wastewater treatment methods as well as other health-protection measures to meet health targets, be it for the farmer or consumer (Figure 5.2). Non-conventional wastewater treatment methods include the use of low-cost systems such as on-farm ponds, sedimentation traps and biosand-filters while health-protection measures include improved irrigation methods, like drip irrigation, cessation of irrigation before harvesting and produce-washing (WHO 2006; Bos 2010). Health-based targets are measured in DALYs (Disability Adjusted Life Years), which is increasingly becoming an essential unit in comparing disease outcomes from different exposures.[6]

As for earlier guidelines, the WHO (2006a) recommends that countries perform their own studies to set health-based targets and associated pathogen reduction control points based on local conditions. It also offers shortcuts where research capacities are constrained (Bos et al. 2010). Conducting QMRAs (Quantitative Microbial Risk Assessment) is recommended instead of the costly epidemiological studies. Today, although the use of QMRA is growing and allowing for more tailored guidelines, these studies are complicated to perform as they require capable research institutions, strong expertise and data relevant to the specific regions (De Keuckelaere et al. 2015). More generally, the WHO multi-barrier approach is also

[6]See Drechsel et al. 2010 for extensive explanation on this concept and its use in the multi-barrier approach.

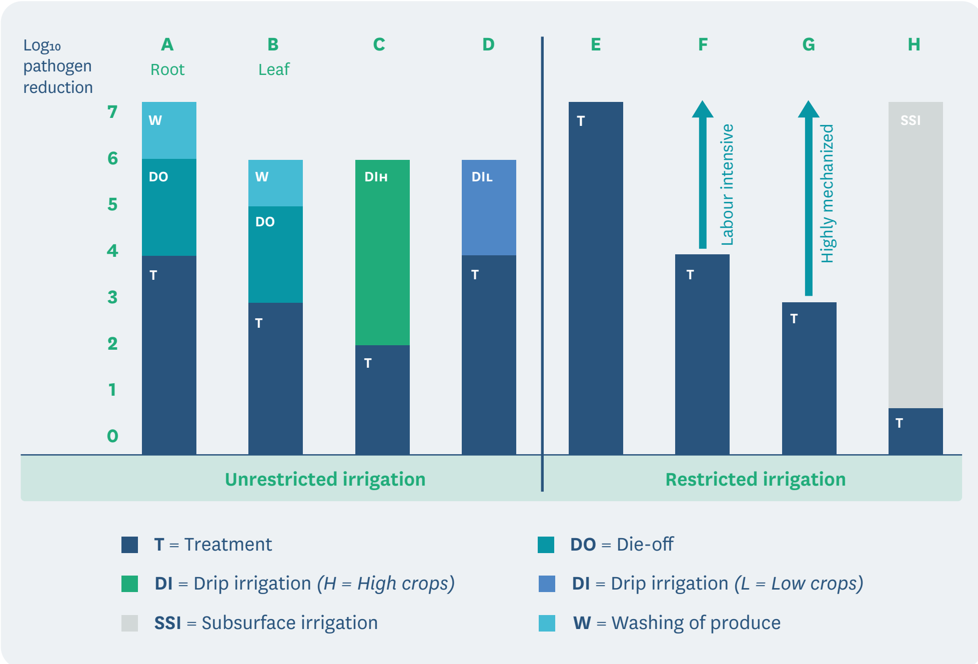

FIGURE 5.2 Examples of options for the reduction of pathogens by different combination of health measures that achieve the health-based targets of ≤ 10-6 DALYs per person per year.
SOURCE: WHO 2006a.

seen as complicated to understand and apply for authorities with weak expertise (Bos et al. 2010). The WHO guidelines (1989) are considered more straightforward, especially for countries that already have comprehensive wastewater collection and treatment in place (Jiménez et al. 2010).

5.2.2. The multi-level governance challenges of designing and enforcing risk management approaches

Awareness is increasing that developing water quality regulations is not merely a technical question and comes with complex governance challenges. Both conservative and more lenient regulatory approaches recommend that standards should be 'adaptive' and integrate multiple factors such as other regulatory aspects (i.e., environmental discharge limit values), treatment capacities and technologies, enforcement capabilities, technical know-how and others (Table 5.2). Integrating all these interfaces can only be done through cross-administrative collaboration but also establishing links with the lower scales to incorporate contextual factors and design appropriate monitoring mechanisms (Evans et al. 2010).

Risk management approaches (such as the multi-barrier) are particularly challenging in terms of context-based planning and multi-scale coordination. The WHO (2006) recommends that "social feasibility of changing certain behavioral patterns [...] needs to be assessed on an individual project basis." Empirical experiments with farmers revealed that low-cost measures have the potential to reduce pathogens "especially if they are developed with the user" but

TABLE 5.2 Challenges and solutions for the development and implementation of agricultural reuse standards.

Challenge	Recommendation
Guidelines, frequently copied from developed countries, are directly adopted as national standards	Every country should adapt the guidelines based on local conditions and derive corresponding national standards.
Guidelines values are treated as absolute rather than target values	Guidelines values should be treated as target values, to be attained over the short-, medium- or long-term, depending on the country's technological, institutional and financial conditions.
Treatment plants that do not comply with global standards do not obtain licensing or financing	Environmental agencies should license, and banks should fund control measures that allow for stepwise improvement in water quality, even though standards are not immediately achieved.
No affordable technology leads to compliance with standards	Control technologies should reflect countries' financial conditions. The use of appropriate technology should always be pursued.
Standards are not enforced	Standards should be enforceable and enforced. Standard values should be achievable and allow for enforcement, based on existing and affordable control measures. Environmental agencies should be institutionally well developed to enforce standards.
Discharge standards are not compatible with water quality standards	The objective of pollution control is the preservation of the quality of water bodies. Discharge standards should be based on practical and justifiable reasons, assuming a certain dilution or assimilation capacity of the water bodies.
Number of monitoring parameters is not optimal (too many or too few)	The list of parameters should reflect the desired protection of the intended water uses and local laboratory and financial capacities, without excess or limitation.
No institutional development supports or regulates the implementation of standards	Efficient implementation of standards requires adequate infrastructure and institutional capacity to license, guide, monitor and control polluting activities and enforce standards.
Reduction of health environmental risks associated with compliance with standards is not immediately perceived by decision makers or the population	Decision makers and the population at large should be well informed about the benefits and costs associated with the maintenance of good water quality, as specified by the standards.

SOURCE: EPA 2012, adapted by authors.

"their success depends largely on the adoption rate which requires appropriate analysis of possible economic and social incentives" (Bos et al. 2010, 42). This requires strong coordination mechanisms between central-state institutions and users first to design adaptive regulations and second to incentivize enforcement. As explained below, this is still the most challenging aspect in institutionalizing such risk management approaches in MENA.

5.3. Issuing water quality regulations: comparative trajectories of five countries

The MENA countries have considerably different trajectories in terms of wastewater treatment and reuse growth (see Chapter 1). However, comparing the evolution of agricultural water reuse regulations between Egypt, Lebanon, Jordan, Morocco and Tunisia reveals three common historical periods, consistent with the evolution of the WHO and FAO international guidelines described above (Table 5.3).

TABLE 5.3 Historical development of agricultural water reuse quality regulations in five MENA countries.

	Policy orientation in agricultural water reuse	Main policies and quality regulations
1950 – 1975: **1973** *WHO First water reuse health guidelines*	First legal tests prohibiting wastewater discharge in the environment and the use of polluted water.	• Jordan Municipality Law *(No. 29/1955)* • Egypt regulation *(No. 93/1962)* • Tunisia Water Code *(1975)* • Lebanon *(Decree 8735/1974 and Decree 8765/1976)*
1975 – 1990: **1989** *WHO updated guidelines*	Development of national plans, projects and quality regulations for agricultural reuse in Jordan and Tunisia.	• Egypt first standards for drainage water reuse *(Law No. 48/1984)* • Jordan first standards for water reuse in agriculture *(Law No. 2/1982)* • Tunisia first standards for water reuse in agriculture and discharge of water in the environment *(1989)*
1990 – 2000: **1992** *FAO Water reuse agronomic guidelines*	Water reuse starts being integrated in most countries national water strategies. Reuse projects expand. Some countries update their water reuse standards.	• Water Act in Morocco *(1995)* • Jordan Wastewater management strategy including reuse *(1998)* • Tunisia First strategy of mobilization of water resources including water reuse *(1990)*
2000 – Present: **2006** *WHO Multi-barrier approach*	Water reuse becomes a national goal in all countries. New strategies and regulations supported by International Organizations are developed to expand and improve reuse.	• Moroccan regulations on water quality for irrigation *(2002)* • Jordan update of reuse standards *(No. 893/2006)* • Egyptian Standards for Wastewater Reuse *(No. 501/2005)* revised in 2015; • First Lebanon water reuse guidelines under an FAO project *(2010)* • Ongoing Egypt Water Reuse Strategy supported by IWMI • Ongoing revision of Lebanon standards supported by IWMI *(2021)* • Ongoing revision of Tunisian standards *(2020)* • Jordan Water Substitution and Reuse Policy *(2016)*

5.3.1. 1920s–1970s: First pollution control regulations and restriction on wastewater reuse in the five countries

The first half of the twentieth century was a period of European mandates and state building in the MENA region. The first laws were promulgated establishing water as a public domain (see Chapter 3). Starting in the mid-1900s, the development of large state irrigation projects and the expansion of private pumping had dramatically increased water use. Water flows were reduced and as population and economic activities grew, the impact of pollutants increased. With awareness about pollution impact going global, the five governments issued regulations prohibiting the use of polluted waterways in irrigation. This was the case in Tunisia (Water Code issued in 1975), Jordan (Public Health Law in 1971) and Lebanon (Decree 8765 in 1976). In Egypt, using drainage water was restricted in the Nile Delta and other waterways and, by 1976, the government started to install monitoring stations on the Delta to monitor the quality of drainage water (Loutfy 2010).

5.3.2. 1980s–1990s: First wastewater reuse policies and regulations

Jordan and Tunisia were the first countries in the region to implement agricultural water reuse projects. Amongst the five studied countries, they were the only ones to regulate water reuse quality before the twenty-first century. Tunisia was a pioneer state in developing water reuse studies, policies and projects (Abu-Madi 2004; Ait-Mouheb et al. 2020; Choukr-Allah 2010; Condom et al. 2012). The first reuse project was implemented in La Soukra area as early as 1965 as a solution to water salinity problems. Aquifer recharge plans from treated water were also considered very early on (in 1989 in Nabeul) (Condom et al. 2012). The first (and only) reuse standards were issued in 1989 inspired by the WHO (1989) and the FAO (1992 guidelines. Besides the environmental drivers, Tunisia's pioneering efforts can be attributed to the leadership of a well-known researcher in the field.[7]

Jordan, constrained by its natural water scarcity, was one of the first countries to consider reuse as part of national water planning (Abu-Madi 2004; Choukr-Allah 2010). A first set of qualitative standards was issued at the end of the 1980s[8] and a few years later, new qualitative standards for industrial and domestic effluents were produced based on the WHO guidelines (Nazzal et al. 2000; Abu-Madi 2004).[9]

Jordan and Tunisia were noticeably the first to develop national-scale strategies for reuse, respectively in 1990 and 1998. This translated into a substantial increase in reuse ratios in both countries. By the end of the 1990s, about 67 million m^3 were used for irrigation in different parts of Jordan. About 52 million m^3 was indirectly used for unrestricted irrigation in the Jordan Valley after blending with freshwater in wadis and King Talal Dam. About 15 million m^3 was directly used for restricted irrigation indoor and within the surroundings of existing (Abu-Madi 2004; 36). In Tunisia, the amount of reused water tripled (Abu-Madi 2004).

In Egypt, water reuse essentially takes place in the Nile Delta where irrigation effluents, often mixed with domestic and industrial pollutants, are discharged in drainage canals and reused indirectly. Water reuse became an official goal in national water strategies in 1984 with a law that governed the disposal and reuse of drainage water (Loutfy 2010). Until the beginning of the next century, the goal was to minimize wastewater discharge to drains and separate pollutants from irrigation water while plans for direct reuse were not yet on the table (Loutfy 2010; see Chapter 3).

In Morocco, the Water Act of 1995 represented a turning point in terms of regulating pollutant discharge and setting the ground for the mobilization of treated wastewater. However, no major investment was done until the end of the 1990s when the need for irrigation water pushed farmers in many areas to informally tap into raw wastewater from nearby cities (Ait-Mouheb et al. 2020).

[7]Dr. Akissa Bahri started her career in the Research Institute for Agricultural Engineering in Tunisia and became Minister of Agriculture. She was very influential in research and policy-making in the field of agricultural water reuse in Tunisia and the MENA region. Interviewed in September 2021, Dubai.

[8]Included in Law No. 2 in 1989.

[9]Respectively, Standard 202/1991 and Standard 893/1995.

In Lebanon, the civil war from 1975 to 1990 slowed down all public water and wastewater projects. Only some small-scale WWTPs were built by external funds and community initiatives. During the reconstruction period, wastewater treatment was one of the major governmental goals and received tremendous attention from international banks and NGOs, but reuse has only appeared in donors' agendas in the past two decades (Eid-Sabbagh et al. 2022).

5.3.3. 2000–onward: Large developments in infrastructure, policies and regulations

The beginning of the millennium saw an increased attention toward sanitation and reuse in Lebanon, Egypt and Morocco. Driven by international development agendas, several countries underwent major administrative and institutional reforms in the wastewater sector (see Chapter 3). Encouraged by the World Bank, Lebanon issued a new water law in 2000 (Law 221) and created four regional water and wastewater establishments (RWWEs) to merge the 21 earlier decentralized water offices and take over the responsibility of managing wastewater networks and facilities from municipalities. The Ministry of Environment was created in 2002 (Law 444) with the support of UNDP.

In Egypt, two major agencies were created in 2004: the Egyptian Water Regulatory Agency (EWRA) responsible for the regulation, monitoring and evaluation of all activities related to water supply services (Presidential Decree No. 2004) and the Holding Company for Water and Wastewater (HCWW) and its 25 (now 27) affiliated companies, to manage all water and wastewater facilities.

In Morocco, the 2006 National Sanitation Plan was issued (French acronym PNA) and aimed to increase the overall treatment from 8% to 60% by 2020 (Ait-Mouheb et al. 2020).

In the three countries, water reuse started to be incorporated within national policy objectives for water management. In the early 2000s in Egypt, the Ministries of Agriculture and Land Reclamation (MALR) and Water Resources and Irrigation (MWRI) set a plan to reclaim 1.2 million ha by 2017, utilizing both treated water from large municipal WWTPs and agricultural drainage water from the Delta (Loutfy 2010). The plan targeted water reuse for non-food crops such as cotton, flax and trees with the goal of reducing wood and timber imports (Loutfy 2010).

In 2009, the Moroccan National Water Plan aimed for a reuse rate of 19% by 2020 and 31% by 2030 (Ait-Mouheb et al. 2020).

In 2012, the Lebanese National Water Sector Strategy included water reuse as one of the means to ensure water security (MEW 2012). During this period, the three countries developed the first quality regulations for agricultural water reuse. Inspired by the WHO (1989) guidelines, Morocco released their regulations on water quality for irrigation in 2002. The Egyptian Ministry of Agriculture released its first Code of Practice for Wastewater Reuse in 2005 and revised it in 2015. In Lebanon, the first *Guidelines for wastewater reuse and sludge* *reuse*, were published in 2010 under an FAO project (FAO 2010) but efforts for their ratification is still ongoing (Table 5.3 above).

Jordan and Tunisia, where good progress was made in wastewater treatment, directed their focus on improving reuse policies and regulations. Jordan issued a new version of the reuse standards in 2006 following the same approach promoted by the WHO (1989). It developed several reuse policies such as the Water Substitution Policy in 2016 and has been working on developing institutional arrangements to organize the distribution of treated wastewater between public institutions and farmers (Regulation No. 7/2016). Tunisia updated its reuse standards twice in 2018 and 2020 but those are still not formally endorsed (Table 5.3 above).

5.4. Regulating water reuse quality in MENA: trends and influence by international guidelines

The following section analyzes the main regulatory aspects adopted in each of the five countries as compared to the main international guidelines (see first section of this chapter) and other countries in the region. Other countries have been selected depending on data availability. The focus is put on regulations for human-health protection, more particularly pathogen thresholds and restrictions put on farmers' practices. Other key physicochemical and agronomic parameters are also compared as well as on-farm practices recommended both for pathogen control and crop productivity. The analysis is based on a compilation of the standards included in official regulations or found in the literature when access to official documents was not possible.

5.4.1. Human health protection

Predominance of the WHO (1989) approach

The five selected MENA countries – Egypt, Lebanon, Morocco, Jordan and Tunisia – have all adopted the regulatory approach of the 'fixed standards' (as opposed to the health-based approach) where it is mandatory that treated water complies to a set of human-health, physicochemical and agronomic parameters for it to be used in irrigation. Four of the five countries have followed the approach set by the WHO (1989) guidelines and identified different categories of 'use conditions' similarly to the approach presented in Table 5.1 (above). The exception is Tunisia where only one category of water quality exists according to the first standards issued in 1989. The revision of the Water Code (2012) and many pioneering research efforts to assess local health and agronomic risks (Bahri 2001; Caucci and Hettiarachchi 2018) still have not translated into official regulations.

Table 5.4 presents the different 'use conditions' categories as defined in the regulations and guidelines of 12 MENA countries, as well as in four international guidelines presented in the Section 1: EPA (2012), WHO (1989), WHO (2006) and the Mediterranean guidelines issued by UNEP (2005). It shows that while most countries were influenced by the 1989 WHO classifications, only two (Morocco and Iran) have adopted the same proposed uses without adaptation. Lebanon and Jordan's categories are different than the WHO but comparable (three main categories and similar uses). Egypt has opted for four categories such as in the UNEP Mediterranean guidelines (2005), but target uses are classified differently. In general, categories vary greatly between countries' regulations which makes standards not easily comparable. Despite these variations, important trends can be found when it comes to microbial thresholds and food crop restrictions as seen in the following sections.

Pathogen thresholds and crop restrictions

High-income countries (mostly GCC countries such Kuwait, Oman, Saudi Arabia and the United Arab Emirates) are often presented as following more stringent standards than the lower-income ones (WaDImena 2008; Choukr-Allah 2010). A closer comparison of bacterial thresholds in the region leads to a more nuanced conclusion. The majority of the five coun-

TABLE 5.4 'Use conditions' categories in 12 MENA countries.

Standards	Target use
EPA 2012	A: Food crops
	B: Processed food crops
	C: Non-food crops
Mediterranean guidelines (UNEP 2005)	I: a) Residential reuse: private garden watering, toilet flushing, vehicle washing; b) Urban reuse: irrigation of areas with free admittance (greenbelts, parks, golf courses, sport fields), street cleaning, firefighting, fountains and other recreational places; c) Landscape and recreational impoundments: ponds, water bodies and streams for recreational purposes, where incidental contact is allowed (except for bathing purposes).
	II: a) Irrigation of vegetables (surface or sprinkler irrigated), green fodder and pasture for direct grazing, sprinkler-irrigated fruit trees; b) Landscape impoundments: ponds, water bodies and ornamental streams, where public contact with water is not allowed; c) Industrial reuse (except for food, beverage and pharmaceutical industry).
	III: Irrigation of cereals and oleaginous seeds, fiber and seed crops, dry fodder, green fodder without direct grazing, crops for canning industry, industrial crops, fruit trees (except sprinkler irrigated), plant nurseries, ornamental nurseries, trees, green areas with no access to the public.
	IV: a) Irrigation of vegetables (except tuber, roots, etc.) with surface and subsurface trickle systems (except micro-sprinklers) using practices (such as plastic mulching, support, etc.) guaranteeing absence of contact between reclaimed water and edible part of vegetables; b) Irrigation of crops in category III with trickle irrigation systems (such as drip, bubbler, micro-sprinkler and subsurface); c) Irrigation with surface trickle irrigation systems of greenbelts and green areas with no access to the public; d) Irrigation of parks, golf courses, sport fields with sub-surface irrigation systems.
WHO 2006	Unrestricted
	Restricted
WHO 1989	A: Irrigation of crops likely to be eaten uncooked, sports fields, public parks
	B: Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees
	C: Localized irrigation of crops in cat. B if exposure of workers and the public does not occur
Abu Dhabi 2018	Unrestricted irrigation
	Restricted irrigation
Egypt 2015	A: Fruit crops; green spaces in educational facilities and public and private parks;
	B: Fruit crops; medicinal crops; dry grains and cooked and processed vegetables, of all types;
	C: Seeds; all types of seedlings which are later transplanted to main fields; roses and cut flowers; trees suitable for afforestation of highways and green belts; all fiber crops; grass and legume fodder crops; berries for silkworm production; all nurseries or ornamental plants and trees;
	D: Solid biomass crops; liquid biomass crops; crops used for producing cellulose; timber trees.

Standards	Target use
Lebanon 2010	I: Fruit trees and crops that are eaten cooked; parks, public gardens, lawns, golf courses and other areas with direct public exposure;
	II: Fruit trees; lawns, wooded areas and other areas with limited public access, roadsides outside urban areas; landscape impoundments: ponds, water bodies and ornamental streams, where public contact with water is not allowed;
	III: Irrigation of cereals and oleaginous seeds, fiber and seed crops; crops for canning industry, industrial crops; fruit trees (except sprinkler-irrigated); plant nurseries, ornamental nurseries, wooden areas, green areas with no access to the public.
Iran 2010	A: Irrigation of crops likely to be eaten uncooked, sport field, public parks;
	B: Irrigation of cereal crops, industrial crop, fodder crops, pasture and trees;
	C: Localized irrigation of crops in category B if exposure of workers and the public does not occur.
Jordan 2006	A: Cooked vegetables, parks, playgrounds and roadsides within city limits;
	B: Fruit trees, roadsides outside city limits and landscape;
	C: Field crops, industrial crops and forest trees.
	No name: Cut flowers;
Saudi Arabia 2006	Unrestricted irrigation;
	Restricted irrigation
Palestine 2003	A: High water quality;
	B: Good water quality;
	C: Medium water quality;
	D: Low water quality.
Morocco 2002	A: Crops likely to be eaten raw, field sports, public gardens;
	B: Cereal crops, industrial and forage crops, orchards and pastures;
	C: Crops of category B if they are irrigated under drip irrigation and if agricultural workers and farmers are not exposed.
Syria 2002	A: Irrigation of cooked vegetables crops and public areas;
	B: Processed food crops, fruit trees and other urban areas;
	C: Industrial crops and forestry.
Kuwait 2002	One water category
Oman 1995	A: Vegetables likely to be eaten raw, fruit likely to be eaten raw and within two weeks of any irrigation;
	B: Vegetables to be cooked or processed, fruit if no irrigation within two weeks of cropping, fodder, cereal, seed crops, pasture no public access.
Tunisia 1989	Only one crop category

SOURCES: EPA 2012; WHO 2006a; UNEP 2005; WHO 1989; RSB 2018 (Abu Dhabi); ECP 2015 (Egypt); FAO 2010 (Lebanon); Shoushtarian and Negahban-Azar 2020 (Iran); Official Standard JS 893 (Jordan); Al Jasser 2009 (Saudi Arabia); Official Standard MF 742/2003 (Palestine); MEDAWARE 2003 (Morocco); JICA 2008 (Syria); Abusam and Shahalam 2013 (Kuwait); Shoushtarian and Negahban-Azar 2020 (Oman); Official Standard NT 106.002/1989 (Tunisia).

tries have set more stringent microbial limits for food crops than those recommended by the 1989 WHO guidelines for the same use category (1,000 bacteria/100 mL) (Figure 5.3). Both Lebanon and Jordan have opted for 200 *E. coli*/100 mL.[10] This is the most stringent threshold recommended by the WHO (1989) for the irrigation of public spaces (Figure 5.4). The same

[10]Different bacterial indicators are used. See notes in Figures 5.3 and 5.4.

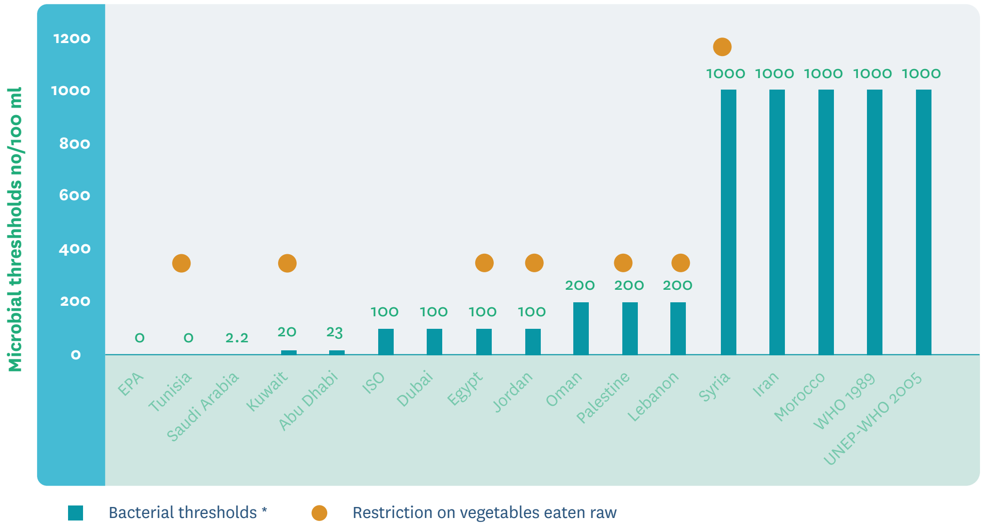

FIGURE 5.3 Microbial threshold and crop restrictions for food crop irrigation.
SOURCES: EPA 2012; ISO 2015; UNEP 2005; WHO 1989; RSB 2018 (Abu Dhabi); ECP 2015 (Egypt); FAO 2010 (Lebanon); Shoushtarian and Negahban-Azar 2020 (Iran); Official Standard JS 893 (Jordan); Al Jasser 2009 (Saudi Arabia); Official Standard MF 742/2003 (Palestine); MEDAWARE 2003 (Morocco); JICA 2008 (Syria); Abusam and Shahalam 2013 (Kuwait); Shoushtarian and Negahban-Azar 2020 (Oman); Official Standard NT 106.002/1989 (Tunisia).
NOTES: *Microbial indicators are different from one standard to another: EPA, WHO. Lebanon, Iran, Saudi Arabia, Morocco, Syria and Oman use fecal coliforms, while Palestine, Jordan and Egypt use *E. coli*; WHO-UNEP, Abu-Dhabi uses both indicators equivalently. Kuwait uses either fecal coliforms or total coliforms. The latter has a threshold of 400/100 mL.

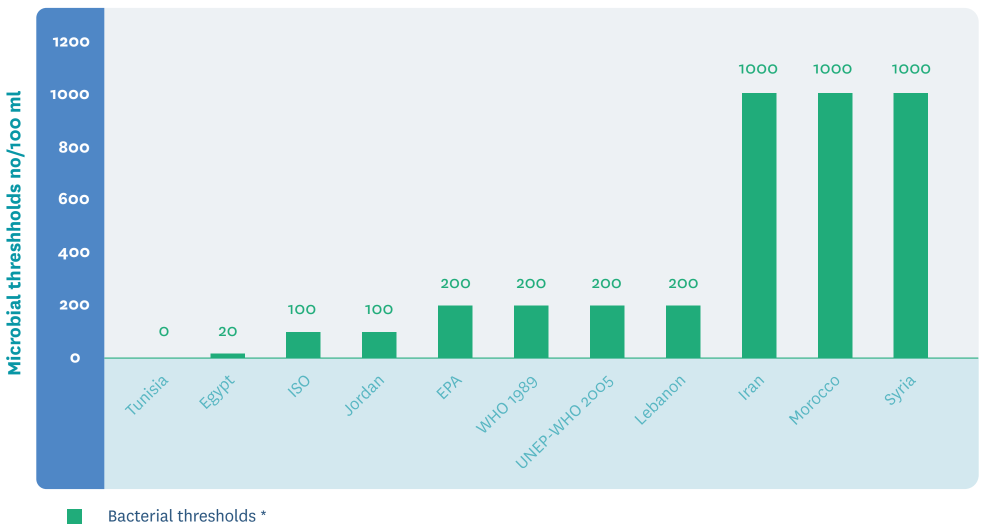

FIGURE 5.4 Microbial thresholds for public parks and landscape irrigation.
NOTES: *Microbial indicators are different from one standard to another: EPA, WHO Lebanon, Iran, Morocco and Syria use fecal coliforms, while Jordan and Egypt use *E. coli*; WHO-UNEP uses both indicators equivalently. SOURCES: EPA 2012; ISO 2015; UNEP 2005; WHO 1989; ECP 2015 (Egypt); FAO 2010 (Lebanon); Shoushtarian and Negahban-Azar 2020 (Iran); Official Standard JS 893 (Jordan); MEDAWARE 2003 (Morocco); JICA 2008 (Syria); Abusam and Shahalam 2013; Official Standard NT 106.002/1989 (Tunisia).

threshold was adopted for the same category in the Mediterranean guidelines (UNEP 2005) while thresholds for food crops were the same as those recommended by the 1989 WHO guidelines. Egypt has set the limit at 100 fecal coliforms/100 mL (the same as Oman) and Tunisia at 0 bacteria, which is more stringent than Saudi Arabia, Kuwait and Abu Dhabi and closer to the Californian Model. Morocco is the only country adopting the 1989 WHO-recommended threshold for food crops.

Furthermore, only Morocco allows irrigating vegetables that can be eaten raw, while the four others completely forbid it. GCC countries are less restrictive in terms of allowed end-uses, particularly concerning vegetable-eaten-raw irrigation. Three out of four of the latter countries (Kuwait being the exception) allow for irrigating vegetables that can be eaten uncooked, which makes them less restrictive in terms of irrigating food crops.

As noted in the next sections, crop restriction is hard to enforce in practice and often leads to informal reuse. When formulating the Mediterranean guidelines, this topic "has been the subject of so intense controversies among the experts" (UNEP 2005; p.21). It was finally decided that "Vegetables to be eaten cooked, such as potatoes, leeks, beans, etc. and not exclusively grown for the canning industry, are included in the same category as vegetables to be eaten raw, for they are often grown in the same fields, irrigated with the same water (UNEP 2005; p.21).

Restrictions on irrigation systems

The five countries' regulations (guidelines in the case of Lebanon) have introduced restrictions on irrigation techniques as an on-farm management barrier. Egypt allows using "small sprinklers with a horizontal angle of no more than 11 degrees" for irrigating public spaces (Category A), food crops including vegetables to be cooked and processed and fruit trees (Category B). Sprinklers are restricted in categories C and D (seedlings and non-food crops). Lebanon allows the use of sprinklers only for categories II and III water, which include fruit trees but exclude vegetables and only if a "buffer zone of 300 m" is respected between excluded crops. Jordan, Tunisia and Morocco restrict the use of sprinklers for all categories. The WHO (1989) and the Mediterranean guidelines (UNEP 2005) both provide freedom for countries to allow for the use of sprinklers (Table 5.5).

5.4.2. Physicochemical parameters

The main physicochemical parameters have been compiled for the first category of water for 12 MENA countries' official regulations or guidelines (Lebanon) and are presented in Table 5.6. Generally, it shows that countries did not adopt the same physicochemical parameters to monitor and have different thresholds for the same parameters. Biological oxygen demand (BOD5) and total suspended solids (TSS) are adopted in 11 countries' standards (except Morocco for BOD5 and Tunisia for TSS), chemical oxygen demand (COD) is adopted in seven standards, the COD in six standards, turbidity (NTU) in five standards and the dissolved oxygen (DO) only in one standard (Jordan).

Our five countries of interest have various levels of stringency regarding the different parameters. The highest limit value for BOD5 has been set by Tunisia and Jordan (30 mg/L) and the lowest for Egypt (15 mg/L). Other governments in MENA such as Abu Dhabi, Saudi Arabia and Oman register lower thresholds (10, 10 and 15 mg/L, respectively) which can be explained by the higher level of treatment in these countries (Choukr-Allah 2008). The COD parameter is only monitored in three countries (Lebanon, Jordan and Tunisia) with Lebanon having the

TABLE 5.5 Main standards and restrictions for pathogens control.

Country	Category	Bacteria (no./100 mL)*	Intestinal nematodes (eggs/L)	Vegetables eaten raw allowed	Sprinkler irrigation allowed
WHO 1989	A	≤1,000 for food crops; 200 for public spaces	≤1	Yes	Yes, if conditions allow
	B	No standard recommended	≤1	No	No
	C	Not applicable	Not applicable	No	No
Mediterranean-Guidelines UNEP 2005	I	≤ 200	≤ 0.1	Not applicable	Yes
	II	≤ 1,000	≤ 0.1	Yes	Yes
	III	<10-5	≤ 1	No	Yes except for fruit trees
	IV	Not required		No	No
Egypt	A	20	≥1	No	Yes (Small sprinklers with a horizontal angle of no more than 11 degrees)
	B	100	_	No	Yes (Small sprinklers with a horizontal angle of no more than 11 degrees)
	C	1,000	_	No	No
	D	_	_	No	No
Jordan	A	100	≤1	No	No
	B	1,000	≤1	No	No
	C	_	≤1	No	No
	D	<1.1	≤1	No	No
Lebanon	I	≤ 200	<1	No	No
	II	≤ 1,000	<1	No	Yes (Buffer zone of 300 m must be respected)
	III	_	<1	No	Yes (Buffer zone of 300 m must be respected)
Morocco	A	< 1,000	0	Yes	No
	B	_	0	No	No
	C	_	0	No	No
Tunisia			1	No	No

NOTES: * Microbial indicators are different from one standard to another: WHO, Lebanon and Morocco use fecal coliforms, while Jordan and Egypt use E. coli; UNEP uses both indicators equivalently. *SOURCES*: UNEP 2005; WHO 1989; ECP 2015 (Egypt); FAO 2010 (Lebanon); Official Standard JS 893 (Jordan); Al Jasser 2009 (Saudi Arabia); MEDAWARE 2003 (Morocco); Official Standard NT 106.002/1989 (Tunisia).

higher threshold (125 mg/L) followed by Jordan (100 mg/L) and Tunisia (90 mg/L). GCC countries have either higher or lower threshold values. Amongst the 12 countries, Morocco adopted the highest limit value for TSS and is the only standard providing two different values according to the used irrigation technique (100 mg/L for sprinkler and 200 mg/L for gravity). It is followed by Lebanon (60 mg/L), Jordan (50 mg/L), Iran and Syria (50 mg/L) and Palestine (30 mg/L). As for the BOD5 parameters, Egypt's TSS threshold is closer to GCC countries' standards (15 mg/L like Kuwait and Oman). This can be related to Egypt's national objective of implementing high-level treatment technologies.

TABLE 5.6 Physicochemical parameters for the best category of treated effluents in different regulations.

	Target use/ Water Category	BOD5 (mg/L)	COD (mg/L)	DO (mg/L)	TSS (mg/L)	Turbidity (NTU)
EPA (2012)	Category A	10			5	2
WHO-UNEP (2005)	Category I				≤ 10	
Abu Dhabi	Unrestricted irrigation	10			10	5
Egypt	Category A	15			≤ 15	≥ 5
Lebanon	Crops of Category I	25	125		60	
Iran	Category A	21			40	
Jordan	Category A	30	100	More than 2	50	10
Saudi Arabia	Unrestricted irrigation	10			10	5
Palestine	Crops irrigated from high quality water	20	50		30	
Morocco	Category A				100 (sprinkler); 200 (gravity)	
Syria	Category A	30	75		50	
Kuwait	Unrestricted irrigation	20	100		15	
Oman	Category A	15	150		15	
Tunisia	One category	30	90			30

SOURCES: EPA 2012; UNEP 2005; RSB 2018 (Abu Dhabi); ECP 2015 (Egypt); FAO 2010 (Lebanon); Shoushtarian and Negahban-Azar 2020 (Iran); Official Standard JS 893 (Jordan); Al Jasser 2009 (Saudi Arabia); Official Standard MF 742/2003 (Palestine); MEDAWARE 2003 (Morocco); JICA 2008 (Syria); Abusam and Shahalam 2013 (Kuwait); Shoushtarian and Negahban-Azar 2020 (Oman); Official Standard NT 106.002/1989 (Tunisia).
NOTES: BOD5 (biological oxygen demand) indicates the amount of oxygen which bacteria and other microorganisms consume in a water sample during the period of five days at a temperature of 20°C. The COD (chemical oxygen demand) value measures how much oxygen the chemical purification processes in the wastewater consume. The higher the value, the less effectively the water is purified. DO (dissolved oxygen) is the amount of oxygen that is present in the water and is a direct indicator of an aquatic resources' ability to support aquatic life. TSS (Total Suspended Solids) is a measurement of the total solids in a water or wastewater sample that are retained by filtration. Turbidity is the measure of relative clarity of a liquid. It is an optical characteristic of water and is a measurement of the amount of light that is scattered by material in the water when a light is shined through the water sample.

5.4.3. Agronomic parameters and trace elements

The compilation of agronomic parameters showed a wide variety of regulatory approaches amongst countries where different classifications were adopted and varying numbers of parameters (Table 5.7). As per the classification adopted by FAO (1992), Lebanon and Jordan identified three degrees of restrictions on use (none, slight and severe). Egypt identified two types of use, 'long term' and 'short term' and other countries such as Morocco did not distinguish between level of restriction on uses. The highest number of parameters to monitor was adopted by Jordan (11) while Lebanon, Egypt and Morocco specify nine parameters to monitor.

TABLE 5.7 Classification and agronomic parameters adopted to regulate crop production in MENA.

MENA countries	Approach used to identify risks	# of agronomic parameters	Specified Parameters
FAO (1992)	Classified into three categories according to 'degree of restriction on use' (none, slight, severe)	14	pH; EC; TDS; SAR; Na^+; Cl^-; Cl_2; HCO_3^-; B; H_2S; Fe; Mn; TKN Threshold values of Na^+ and Cl^- differ according to irrigation system (sprinkler lower than surface)
Abu Dhabi (2018)	Same categories as for key parameters (Unrestricted; restricted)	9	pH; EC; TDS; SAR; Na^+; Cl^-; HCO_3^-; Res Cl_2; B
Egypt (2015)	Classified into two categories 'Long-term use' and 'short-term use'	9	TDS; SAR; Na^+; Mg^{2+}; Ca^{2+}; HCO_3^-; PO_4; SO_4; B
Lebanon (2010)	Classified into three categories according to 'degree of restriction on use' (none, slight, severe);	9	pH; EC; TDS; SAR; Na^+; Cl^-; TKN; HCO_3^-; Res Cl_2; B; Threshold values of Na^+ and Cl^- differ according to irrigation system (sprinkler lower than surface)
Iran (2010)	One category	10	pH; EC; TDS; SAR; Na^+; Cl; NH_4; HCO_3; PO_4; B
Jordan (2006)	Classified into three categories according to 'degree of restriction on use' (none, slight, severe)	11	pH; EC; TDS; SAR; Na^+; Cl; NO_3; HCO_3^-; PO_4; Res Cl_2; B
Saudi Arabia (2006)	Same categories as for key parameters (Unrestricted irrigation; restricted irrigation)	5	pH; TDS; NO_3; Res Cl_2; B
Palestine (2003)	Same categories as for key parameters (A, B, C, D)	6	pH; TDS; Cl (different values according to irrigation system); NO_3; HCO_3; Res Cl_2
Morocco (2002)	Only one category	9	pH; EC; TDS; Na+; Cl; NO_3; HCO_3^-; SO_4; B Threshold values of Na+ and Cl differ according to irrigation system (sprinkler lower than surface)
Syria (2002)	Same classification as for key parameters (A, B, C, D)	14	pH; TDS; SAR; Na^+; Mg; Ca; Cl; NO3; NH_4; HCO_3^-; PO_4; SO_4; Res Cl_2; B
Kuwait (2002)	Only one category	8	pH; EC; TDS; TKN; NH_4; PO_4; Res Cl_2; B
Oman (1995)	Different then for key parameters (food crops; non-food crops)	11	pH; EC; TDS; Na^+; Mg^{2+}; Cl; TKN; NO_3; NH_4; PO_4; B

SOURCES: EPA 2012; FAO 1992; UNEP-WHP 2005; WHO 1989; RSB 2018 (Abu Dhabi); ECP 2015 (Egypt); FAO 2010 (Lebanon); Shoushtarian and Negahban-Azar 2020 (Iran); Official Standard JS 893 (Jordan); Al Jasser 2009 (Saudi Arabia); Official Standard MF 742/2003 (Palestine); MEDAWARE 2003 (Morocco); JICA 2008 (Syria); Abusam and Shahalam 2013 (Kuwait); Shoushtarian and Negahban-Azar 2020 (Oman); Official Standard NT 106.002/1989 (Tunisia).

5.5. Implementing risk management approaches: practices and challenges

While MENA countries are deploying efforts in improving water quality regulations, adaptive risk management approaches recommended by international guidelines (such as WHO 2006a and EPA 2012) were found to be poorly adopted. The issue of informal (thus unsafe) reuse practices is generally not addressed in regulatory efforts, which remain focused on the 'formal' sector (Tawfik et al. 2021). In existing reuse schemes, restrictive approaches are still privileged with insufficient incentives or support for farmers to adopt the imposed practices. The following section illustrates these problems and attempts to explain the institutional and social processes that lead to non-adaptive regulations.

5.5.1. A poor adoption of risk management orientations

The regulatory measures adopted in the five countries show that efforts are focused at regulating effluents discharged from existing treatment plants while unsafe practices remain poorly addressed. Egypt is an archetypal example where polluted water is tapped informally in the Nile Delta drainage system to irrigate all types of crops, including vegetables to be eaten cooked and raw (Loutfy 2010). While the government is implementing large treatment plants in other parts of the country with plans to expand 'safer' crops (timber trees), Egypt's largest agricultural areas remain irrigated with poor quality water. The management of the risk of informal reuse does not seem addressed in Egypt new water regulations (2015).

While 'best practices' (risk-reduction measures) are found in most regulations and guidelines, they come under the form of recommendations and are accompanied with restrictive compulsory measures such as complete restriction on crops and irrigation techniques. On the other hand, capacities of enforcement are low and alternatives not always feasible for farmers. In Tunisia, the government substituted freshwater with treated effluents in several irrigation schemes. In one of the reuse schemes (Cebala), restrictions on irrigating vegetables pushed farmers to keep large portions of land uncultivated; and in Ouzarah and in Al-Resalah, farmers requested authorities to reallow the use of freshwater (Abu-Madi 2004). The same practices were recently observed in Jordan nearby 'Al Kherbe Al Samra' WWTP. There, contracts between the water company and farmers impose cultivating fruit trees and forage crops, but many farmers were seen to be informally planting vegetables.[11]

In Lebanon, treatment volumes are low and organized reuse systems are still lacking.[12] In the Bekaa Valley, the pollution of the Litani River has induced serious health impact on residents and the implementation of conventional treatment plants accumulated tremendous delays (Eid-Sabbagh et al. 2022). Informal reuse is widespread but alternative or complementary risk management measures (e.g., unconventional treatment, pathogen control points at farmer or consumer levels as recommended by WHO) are poorly considered in planning and regulations. On a national level, areas with 'reuse potential' typically include leafy vegetables as

[11] Interview with a Jordanian researcher in January 2022.

[12] The exception is in Ablah where a small reuse system was implemented by an EU project in 2015 (see Eid Sabbagh et al. 2022).

shown by a recent IWMI study (Eid-Sabbagh et al. 2022). Conversely, the guidelines promulgated in 2010 completely forbid irrigating vegetables eaten raw as well as the use of sprinklers. The Lebanese Agricultural Research Institute (LARI) conducted efforts to empirically test on-farm risk management practices in the Bekaa but such efforts are done on project level, are dependent on external funding[13] and are not systematically linked to the formulation of new regulations. Furthermore, their translation into risk management plans is yet another challenge given the multiplicity of administrations and the fragmented planning in the Lebanese wastewater sector (Eid-Sabbagh et al. 2022; see Chapter 3).

5.5.2. Parallel planning and lack of institutional leadership

The Jordanian experience illustrates the institutional challenges of implementing the risk management approach promoted by WHO. In 2014, the Ministry of Irrigation developed the Irrigation Water Quality Guidelines using the WHO (2006a) concepts of risk assessment, health-based targets and health protection measures. For instance, the formulated guidelines allow irrigating vegetables eaten raw under specific measures which is a forbidden practice in the official standards. According to Kassab (nd), these guidelines were not incorporated in the recent Agriculture Law of 2016 due to institutional disagreements. A Jordanian researcher involved in water quality regulation processes in the country explains that implementing such multi-stakeholders' plans cannot be done without a political decision from the central level such as the Council of Ministers. In her view, a 'higher' authority should institutionalize such plans so that administrations have a legal framework and a political incentive to implement the different 'control points' of the multi-barrier approach (see Section 3, Chapter 4).

Institutional fragmentation, an issue commonly underlined in MENA (Choukr-Allah 2008; Ait-Mouheb et al. 2010) further complicates stakeholder coordination. For example, the planning process of treatment plants is often undertaken by agencies which scope or expertise does not encompass irrigation and agricultural reuse. In Jordan and Tunisia, for instance, wastewater treatment facilities were long designed in compliance with environmental standards (discharge in the environment) rather than those formulated for reuse (Abou Madi 2004). This has improved in Jordan where administrations in charge of operating treatment plants are now directly responsible for establishing subscription contracts with users. However, monitoring of crops is under the responsibility of the Ministry of Agriculture, whose staff is geographically distant from the field.[14]

In Lebanon, the administrations responsible for planning or operating treatment plants were found to follow environmental discharge standards and are rarely aware about the existence of the issued reuse guidelines (FAO 2010).[15] Moreover, while the design of new treatment plants starts to include reuse outlets, overall planning is not coordinated with administrations concerned with irrigation management, municipalities or users (Eid-Sabbagh et al. 2022). In Morocco, despite the governmental efforts deployed to integrate sanitation and

[13]Research experiments were conducted in 2019 and 2020 as part of ReWater MENA project. LARI researchers performed the trial and published research papers.

[14]Interview with a Jordanian researcher in January 2022.

[15]Personnel observation.

reuse in unified plans, some studies suggest that there is no "formally agreed-upon process for formulating and designing new [reuse] projects" (Ait-Mouheb et al. 2020). Further to this gap between treatment design and reuse policies, studies regularly mention an issue in treatment plants' performance due to under-staffing, lack of technical expertise and institutional fragmentation, which should be resolved to comply to regulations (Choukr-Allah 2008; Ait-Mouheb et al. 2020).

5.5.3. The technocratic tradition of formulating regulations

Favoring 'strict' regulations is also explained by the socio-institutional framework in which standards are formulated. Setting standards often happens through 'technical committees' formed by representatives of ministries (of health, environment, water and irrigation depending on the countries). They are usually mid-level officials coming from a technical background (e.g., chemists, agronomists and biologists) and aiming for the best possible conditions for health safety or crop productivity. In such settings, the discussion is more often focused on standards and parameters as 'absolute values' (EPA 2012) rather than framed in the larger socio-economic and institutional context. Institutional considerations such as administrative capacities and enforcement, or questions of farmers' practices and incentives, are not systematically brought on the table. In Jordan and Lebanon, these meetings are organized by the respective 'Standard Institution' of each country. In Lebanon, the main committee members invited are mostly water quality experts and agronomists with limited experience in institutional aspects of the wastewater sector (planning, institutional mandates and mechanisms), practical questions of WWTP operation or farmers' practices and challenges[16]. The context seems to be similar in Jordan, where officials involved in such discussions are poorly aware of the practical challenges of enforcing regulations[17]. In both Lebanon and Jordan's case, farmers or communities' representatives are not part of these committees, which means that issues of agricultural practices, or wider questions of pollution impact are hardly discussed with users. In Jordan, "farmers can attend if deemed adequate, but they don't have the right to vote on decisions".[18] This shows that concepts of the 'Learning Alliance' (Evans et al. 2010) promoted by international organizations, remain poorly institutionalized and translated to practice. While projects aim at forming multi-level stakeholder's platform, they are often conditioned by the choice of representatives of the ministries, whose backgrounds are not always consistent with the discussion.

5.5.4. Social perceptions and institutional responsibilities

Relaxing microbial thresholds is often perceived as 'irresponsible' or even an 'unethical' decision. In Tunisia, officials meeting to set new health-risk assessments are described as having a traditionally protective approach toward human health risks (Caucci et al. 2018). In Lebanon, a high-level official invited to a discussion on revising FAO guidelines based on the 'WHO-multi barrier approach' said that "more research needs to be done since relaxing

[16]Personnel observation of the main author.

[17]Interview with a Jordanian researcher in January 2022.

[18]Ibid.

standards has an impact on peoples' health."[19] Protective approaches have been described in one of our interviews as a sterile strategy of "passing the buck" where "officials go for decisions that are less risky but turn a blind-eye on questions of capacities of enforcement." As deplored by a key informant, "Strict thresholds often remain just a number on papers. This is not a responsible attitude in my opinion because removing the responsibility from one's shoulder does not mean safety will improve."[20]

5.6. Conclusion

This chapter analyzed the regulations and guidelines adopted by five MENA countries (Egypt, Jordan, Lebanon, Tunisia and Morocco) to manage the safety of water reuse in irrigation. It specifically focused on human health protection regulations and assessed countries' efforts and challenges in developing context-based regulatory approaches as recommended in recent international guidelines such as the WHO (2006) and EPA (2012).

It showed that the five countries still follow a standardized model targeting the formal wastewater sector where treated effluents need to comply to a fixed set of standards to be considered safe for reuse. Four countries (Egypt, Jordan, Lebanon and Morocco) adopted the model developed by WHO (1989) and three of them (Morocco being the exception) have adapted it with more stringent microbial thresholds and a complete restriction on vegetables to be eaten raw. Tunisia, despite many attempts to issue more adaptive regulations, still adopts its 1989 standards, which are closer to the 'zero risk' Californian Model.

Overall, the five countries adopt a top-down approach to controlling safety with complete restrictions on certain crops and irrigation techniques. Enforcement is often ineffective with farmers having poor incentives or support to find alternative practices. Furthermore, regulations are only applied to planned reuse projects while informal reuse remains poorly located and risks left unmitigated.

The WHO multi-barrier approach issued in 2006 has been widely promoted in the region but is not reflected in countries' regulations. While some initiatives such as in Jordan and Tunisia developed guidelines based on the concepts of 'health-based targets' and 'risk management,' those remain indicative and were not translated in risk management plans or adaptive regulations. Several factors hinder the design and implementation of such adaptive approaches such as the lack of institutional leadership on coordinating the tasks of diverse and sometimes competing administrations, the technocratic institutional processes of formulating standards and reluctance to take decisions that might be perceived as unethical or entail additional responsibilities.

[19]Minutes of Meeting, LIBNOR (November 31, 2021). This meeting was supported by IWMI and LARI researchers, where LARI presented the results of its field trials and the impact of on-farm practices on pathogen reduction was part of the discussion.

[20]Interview with a Jordanian researcher in January 2022.

On a more positive note, the study identified several research initiatives and field experiments aiming at studying risk management measures with the goal to propose guidelines adapted to local conditions. Knowledge should be shared with decision-makers in appropriate institutional settings, given visibility and supported to influence regulations and policy practices.

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Section 2
Thematic guidelines

Introduction

Javier Mateo-Sagasta

Section 2 provides thematic guidelines for different audiences based on lessons learned from international experiences, the case studies in Section 3 and the ReWater MENA project activities in Lebanon, Jordan and Egypt.

There are multiple international guidelines to improve environmental quality and food safety in water-food systems (Figure S2.1). There are numerous guidelines for water pollution control from different sources and guidelines for health, environmental and agronomic protection when using marginal quality water to produce, process or prepare food (for example, see FAO 2013; Mateo-Sagasta et al. 2018; UNEP 2004; WHO 2006, 2015, 2019). There are also technical guidelines about direct water reuse for different purposes (for example, see US-EPA 2012). But these guidelines seldom address in-depth issues such as adopting financial models for cost recovery, gender integration, barriers to acceptance and governance frameworks. This section provides specific guidance on these niche topics, which are poorly covered in the existing literature.

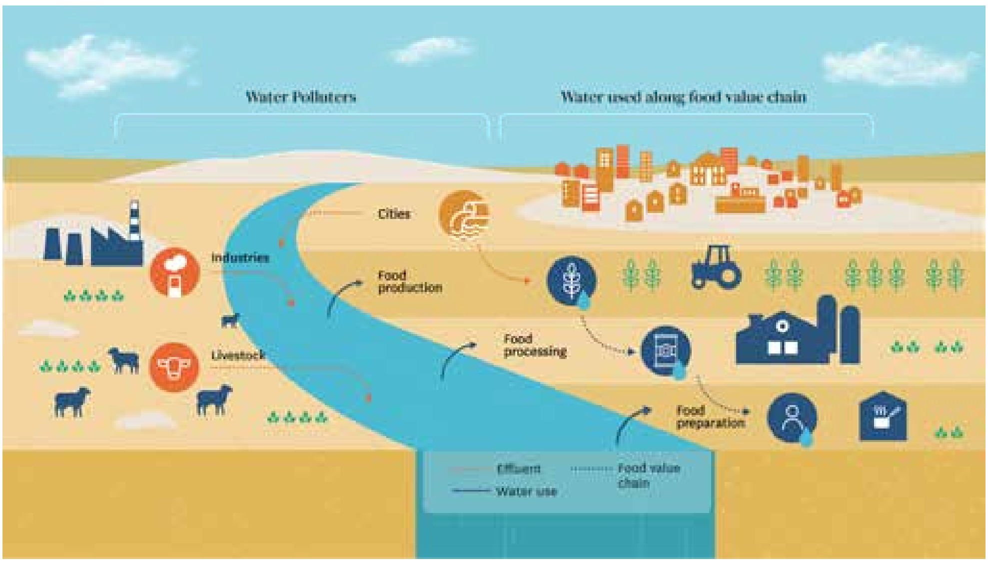

FIGURE S2.1 The waste-water-food value chain.

Chapter 6 provides guidelines for developing bankable water reuse models. These guidelines present an outline that can be used to develop bankable water reuse models in MENA. It supports the public and private sectors such as wastewater treatment operators, water utilities, ministries of agriculture, ministries of water and irrigation, and forestry commissions as well as investors and donors interested in developing wastewater reuse models in a particular location and context. The guidelines are developed based on IWMI's research on water reuse and business models development.

Chapter 7 proposes some guidelines for gender mainstreaming in water reuse. These generic guidelines enable project designers and implementers to understand and address the differences between and among women, men, girls and boys in terms of their relative ownership, distribution and control over resources, opportunities, constraints and power across the project cycle. These guidelines offer an introduction to core gender concepts and a framework for gender mainstreaming in water reuse based on the project planning cycle and the gender mainstreaming approach as suggested by the Swedish International Development Cooperation Agency. These guidelines further provide a brief section on why we need to move towards gender transformative approaches (GTAs). GTAs aim to address the root causes of gender inequality and aligns with Sweden's feminist foreign policy approach for a gender-equal humane world. GTAs also enhance the ability of women and girls to become influential actors who can individually and collectively exercise their rights and claim their entitlements equally with men.

Chapter 8 explores how to improve acceptance of water reuse. Technology and good practices already exist to manage reclaimed water projects and meet or exceed health-based targets. However, good practices and adequate technical capacity are not enough to guarantee the success of water reuse interventions in terms of community buy-in. Understanding the issues and concerns around perceptions and acceptance and addressing these with timely, effective communications and stakeholder engagement can significantly help to build trust and improve and support of reclaimed water use initiatives. A comprehensive communication plan targeting key stakeholders is essential to the success of water reuse projects or policy decisions. This chapter provides a greater understanding of the issues that hinder acceptance of water reuse across the MENA region, and tools and strategies to overcome them.

Chapter 9 presents some guidelines and practices that can lead to harmonious planning and governance of agricultural water reuse projects in MENA. This chapter is solution oriented and provides stepwise guidelines, tools and examples for consensus building. It shows that governance problems are often rooted in deeper socio-political structures that cannot simply be changed by implementing participatory processes and social engineering tools. Some examples identified in MENA are cited to draw the attention on this type of challenges and to open the debate around the difficult question of reaching 'good water reuse governance' in the region.

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Chapter 6

A guideline for developing bankable water reuse models

Solomie Gebrezgabher and M. Ragy Darwish

Guidelines at a glance

To develop a bankable water reuse model, these guidelines suggests a stepwise approach consisting of five main phases:

- Step 1: Identify potential water reuse options
- Step 2: Develop a business model for the water reuse option
- Step 3: Identify innovative partnership and financing options
- Step 4: Identify risks and opportunities
- Step 5: Develop an implementation plan

6.1. Introduction

In the MENA region, the existing imbalance between available water supply and demand is expected to widen due to population growth, greater urbanization and higher water consumption. The largest use of water in MENA countries is for agriculture, which forms the foundation of the economies of many of the countries. For example, Egypt uses 86% of its total renewable water for agriculture, while Jordan and Lebanon use 65% and 60% of the total renewable water for agriculture, respectively (Qadir et al. 2009).

We need alternatives such as circular economy (CE) approaches to supply water in view of the water scarcity and climate change challenges and the need to ensure water security in urban and rural areas. One of the essential dimensions of a CE is the creation and capture of value remaining in waste materials and maximizing that value to promote sustainable development. Recovering the water, energy, nutrients and other materials embedded in wastewater is a key opportunity. This notion of wastewater recovery is gaining more attention in water-scarce countries as a way to meet the demand as non-conventional water resources can be used for irrigation in agriculture, industrial use and groundwater recharge.

Despite the prevalent water scarcity in the MENA region, the adoption of water reuse technologies has been uneven and slow (see Chapter 2). For example, in Egypt there has been significant progress in water reuse for afforestation. However, the institutional and regulatory set-up and missing incentives impede the implementation of water reuse (Otoo and Drecshel 2018). In Jordan, fruits and other cash crops are grown through the reuse of water in the Jordan Valley where about 80% of the agricultural water consumption depends on blended wastewater (World Bank 2016).

In general, the development and implementation of water reuse strategies across the MENA region is challenged by factors such as a lack of water reuse cost recovery mechanisms, low pricing of irrigation water, need for creating financial incentives for safe water reuse and lack of understanding among the public about the perceived environmental benefits of wastewater treatment and reuse (Otoo and Dreschel 2018; World Bank 2011).

Wastewater treatment projects have historically been established as a means to maintain health and environmental standards with no potential for financial or monetary rewards. Central and local governments have perceived them as liabilities rather than assets. Water reuse projects, if adequately planned and properly implemented, can provide opportunities for sound investments and financial rewards (see Chapter 4). However, the perceptions of the public, investors and decision-makers must be changed. To ensure sustainability of water reuse, we need to develop bankable water reuse models by instituting cost recovery or revenue generation mechanisms. This can be achieved through the recovery of different resources but also through innovative financing, cost recovery and partnership approaches.

These guidelines present an outline that can be used to develop bankable water reuse models in the MENA region. It supports the public and private sectors such as wastewater treatment operators, water utilities, ministries of agriculture, ministries of water and irrigation, and forestry commissions as well as investors and donors interested in developing water reuse models in a particular location and context. The guidelines are developed based on a plethora of research such as Dreschel et al. (2015) and Otoo and Dreschsel (2018) on water reuse and business model development work done by IWMI in several other projects.

6.1.1. Who should use this guideline

- *Investors and financiers*: Public and private investors; water users associations and agricultural cooperatives; donors and lending agencies
- *Planners, designers and decision-makers*: Policy-makers; ministries such as irrigation/water; agriculture; industry
- *Water reuse systems implementers and operators*: Water and wastewater systems operators; relevant public bodies such the local government, metropolitan assemblies and their waste management departments
- *Beneficiaries and end-users*: End-users of various reuse products and services such as farming, industries, cooling and recreation

6.1.2. Concepts and principles

In the context of water reuse, the term *bankable* should not be confused with the more traditional use of the term *bankable*, which refers to projects that have sufficient collateral, future cash flow and a high probability of success to be acceptable to commercial lenders (World Bank 2019). Bankable, in the context of water reuse, should be understood as wastewater projects that demonstrate a high likelihood of receiving public or private financing based on their value propositions[1] and other factors that indicate that the wastewater project is likely to be sustainable. While it is important that the water reuse project should be sustainable, sustainability in this context does not necessarily imply profit maximization but could imply a cost recovery target, especially given that the wastewater sector offers many opportunities for social business models aiming at improved living conditions or reduced environmental pollution (Otoo et al. 2016).

[1]Value proposition is the added value that end- or target users derive from the products and services offered.

6.2. Practical steps to develop a bankable water reuse model

Wastewater offers a variety of options for recovering resources. Studies on developing bankable water reuse models, and on the potential of implementing water reuse models, must first identify and set priorities in terms of the target area. This priority setting is essential to identify potential water reuse models that have high relevance and a likelihood of success for the local context. To develop a bankable water reuse model, this guideline suggests a stepwise approach consisting of five main phases:

- Step 1: Identify potential water reuse options
- Step 2: Develop a business model for the water reuse option
- Step 3: Identify innovative partnership and financing options
- Step 4: Identify risks and opportunities
- Step 5: Develop the implementation plan

Step 1: Identify potential water reuse options

The treatment and reuse of water offers not only environmental and public health benefits but also a range of opportunities for transforming wastewater into multiple value propositions. A variety of value propositions and options for cost recovery from wastewater treatment and reuse to the recovery of water for irrigation to potable water can be developed (Figure 6.1).

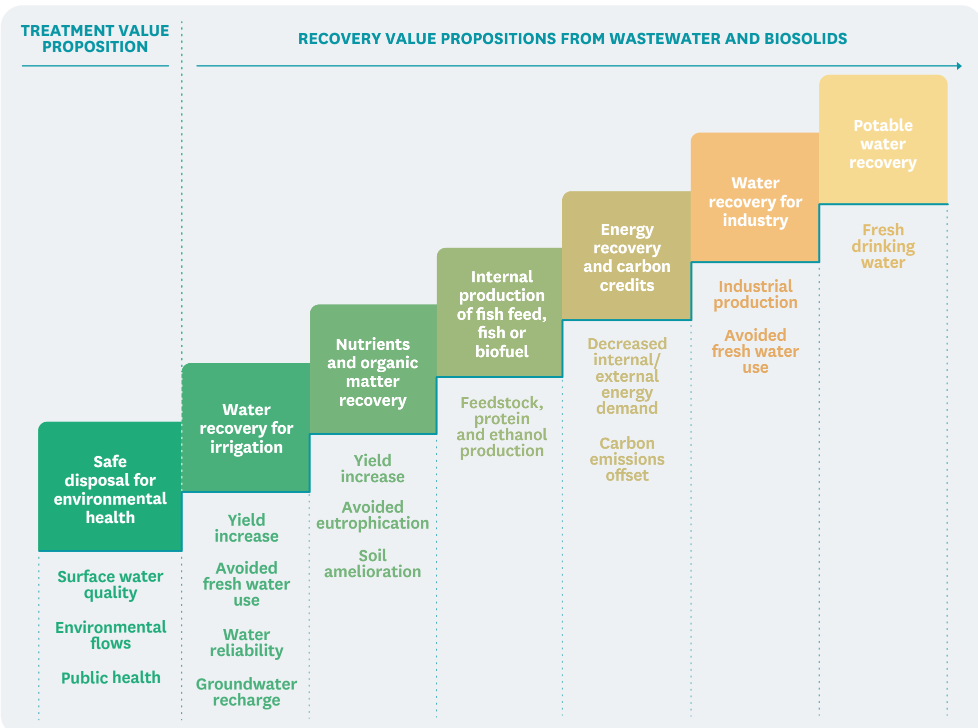

FIGURE 6.1 Ladder of increasing value propositions related to wastewater treatment based on increasing investments in water quality and/or the value chain (Drechsel et al. 2015).

Even if there is no reuse, wastewater treatment has an economic value for safeguarding environmental and public health, but no direct financial value. The recovery of other resources can add new value streams to the proposition (GWI 2010).

Water reuse implementers can select from a wide range of options depending on the existing wastewater collection and treatment infrastructure, the technology used for treatment, the available financing and the target end-use (Box 6.1). Several MENA countries have sewerage systems with more coverage in urban areas than rural. For example, 74% of households in urban areas of Egypt are connected to sewerage system while only 18% of households in rural areas are. Similarly, in Jordan the coverage is 67% in urban and 4% in rural areas. Thus, the first step for implementing a water reuse model is to identify which reuse pathway will be most suitable given the local context and target end-users.

There are various technical options and business models for implementing a water reuse model. A key step is to narrow the option down to those with the highest probability of success and buy-in by the local stakeholders. Stakeholder participation in this process is imperative to understand which water reuse options resonate best with them (Otoo et al. 2017). Thus, from a planning perspective, the implementation of water reuse projects should be demand driven. For example, in Morocco, a partnership was developed between the golf courses of Agadir and the water agencies who supply them with continuous treated wastewater based on the demand expressed by the golf courses (World Bank 2011).

BOX 6.1 Basic questions to guide in identifying potential reuse models

- How much wastewater is generated in the specific locality?
- What treatment technologies are in place?
- Given the local context, what resources could be potentially derived from wastewater?
- Is there demand for the wastewater-derived resources?
- How much are different users willing to pay for treated wastewater?
- Are there any legislations/regulations that could prevent a water reuse model?
- Are there any institutions (public, private) that could qualify as business owners and partners and be interested?

Step 2: Develop a business model for the water reuse option

Having identified the water reuse option that has potential given the local context, we move on to developing a water reuse business model. A business model describes the rationale of how an organization creates, delivers and captures value in economic, social, cultural or other contexts (Osterwalder and Pigneur 2010). It consists of four core elements, which describe an organization's:

- *value proposition* that distinguishes it from other competitors through the products and services it offers to meet its customers' needs;
- *customer segment(s)* that the firm is targeting, which are the channels a firm uses to deliver its value proposition and the customer relationship strategy;
- *infrastructure* which contains the key activities, resources and the partnership network that are necessary to create value for the customer; and
- *financial aspects* (costs and revenues) which ultimately determine a firm's ability to capture value from its activities and break even or earn profit.

The business model is a simple tool that enables implementers to think through the different building blocks and how they relate to each other. It provides a breakdown of major considerations impacting a business.

As noted in the introduction, the term 'business' does not necessarily imply that the water reuse models are profit oriented or able to achieve full cost recovery through their value proposition. This is more relevant in the case of water reuse in agriculture since revenues from selling treated wastewater are small, given that freshwater prices are often highly subsidized. However, additional value propositions could be added to improve cost recovery (Box 6.2).

BOX 6.2 Cost recovery through water reuse for fruit trees in Tunisia

The Ouradanine wastewater treatment plant, managed by the National Sanitation Utility (ONAS), treats domestic wastewater from about 3,400 households. The secondary treated wastewater is used by nearby tree plantations managed by 40–46 private farmers producing olives, peaches and pomegranates.

Another public institution, Commissariat Regional de Development Agricole (CRDA), manages downstream irrigation infrastructure. CRDA receives the water from ONAS free of charge and sells it to the farmers at a subsidized price as an incentive for reuse of the treated wastewater. The treatment plant also supplies biosolids on demand as soil conditioner free of charge. Through this reuse model, ONAS recovers 40% of the operation and management cost of the treatment plant.

Step 3: Identify innovative partnership and financing options

Innovative partnership options

The promotion of water reuse models requires innovative business models, which are embedded in innovative partnership and financing schemes. Various types of partnerships can be formed among different types of organizations. Similarly, value creation in the water reuse sector can go beyond the traditional focus on private sector value creation toward models where private entities, government entities, civil society, NGOs and other types of entities can work together in cross-sector alliances to create new products and services, improve the quality of existing products and services, and create economic and social values.

Innovative cross-sector partnership formats are the vehicles through which new business models are developed and new products and services are generated (Dehan et al. 2010).

The public-private partnership (PPP) is the most common type of partnership in which government and private companies assume co-ownership and co-responsibility for the delivery of services. Through these partnerships, the advantages of the private sector such as access to finance, knowledge of technologies, managerial efficiency and entrepreneurial spirit are combined with the social responsibility and environmental awareness aspects of the public sector. Based on the social and environmental benefits of wastewater treatment, most water utilities in the MENA region are publicly financed and operated. Private finance models such as build-own-operate-transfer (BOOT) and build-own-operate (BOO) are also used (Otto and Drechsel 2018). For example, in Tunisia, several partnerships have been established with the private sector in the operation and maintenance of wastewater treatment plants, which contributed to the increase in the number of treatment plants. In 2009, the private sector operated 17 WWTPs in Tunisia (World Bank 2011).

One of the key factors that determines the success of a partnership is the partners' motivations. Differences in motives between the partners are believed to derail the collaboration especially during the formation of the partnership. Thus, the first step for designing a business model that leverages resources and expertise of the partners is to define the business objectives for partnering (Chesbrough and Schwartz 2007). Moreover, the extent to which each partner's business models are aligned is essential in choosing partners and in designing partnership models (Box 6.3). Aligned business models are complementary, are more likely to benefit each partner and can be sustained in the long term (Chesbrough and Schwartz 2007).

BOX 6.3 Steps to consider when establishing partnerships

- Clearly define the motives and business objectives for partnering
- Assess the resources and capabilities required and what each partner is bringing
- Determine the degree of business model alignment with partner

Financing options

Project financing is a means of obtaining funds for industrial projects, long-term infrastructure and public services. The main sources of finance include equity, debt and government grants. Financing from these alternative sources have important implications on the project's overall cost, cash flow, ultimate liability and claims to project incomes and assets. One of the main challenges for the sustainability of public projects in general, and water and water reuse projects in particular, is the inadequate and/or the interrupted inflow of funds and revenues received during the project's operational years. Consequently, a critical challenge for water reuse projects is the ability to cover operational costs and achieve cost recovery. Figure 6.2 and Box 6.4 show pathways or approaches for improving cost recovery in water reuse.

FIGURE 6.2 Approaches for improving the cost recovery of water reuse models.
SOURCE: Lazurko et al. 2018.

Community contributions such as user fees, household investments, community-based savings and cost sharing are some of the major sources for financing sustainable sanitation and water management products and services. Cost sharing is becoming one of the most applied techniques to ease financial burdens in water and water reuse management (Table 6.1). Cost sharing is a mechanism for deciding which agents should be served by a public project and how much each of them should pay. It includes all contributions, including cash

TABLE 6.1 Advantages and disadvantages of a cost-sharing mechanism.

Advantage	Disadvantage
Effective since different stakeholders are involved making different contributions	Time consuming for collecting information on all stake-holders and their contributions
Improves the sense of community ownership and thus improving sustainability of project	Requires constant control of the stakeholders fulfilling their tasks
Benefits local communities	The issue of further operation and maintenance after completion of the project
Increases assurance of commitment and dedication for the project by various stakeholders	Conflicting self-interests amongst stakeholders
Increases the project transparency	Problems of ‘Free Riders’

BOX 6.4 Financing options

Collect smart fees: In order to achieve cost recovery, water reuse projects should set water tariffs, user fees or taxes based on the local context. The water tariff can be set on the volume of water used or based on the type of users such as for agriculture, landscaping or industry.

Diversify revenue streams: Water reuse projects have the potential to achieve cost recovery by offering multiple value propositions such as reuse of water for agriculture, aquaculture and energy production. Furthermore, carbon offsets present opportunities for greenhouse gas emission reductions, bringing in revenue from carbon markets.

Improve cost effectiveness: In addition to diversifying of revenue streams and collection of smart fees, it is important to examine the daily operations of the water reuse project to optimize value and reduce costs.

Focus on value chains: Water reuse relies on an upstream supply of wastewater and downstream reuse of wastewater. Cost recovery of water reuse models can be improved by effectively managing the entire value chain from collection, treatment and final reuse. This calls for considering the entire wastewater value chain as a system to be managed holistically rather than managing each stage of the value chain in a silo.

Government support: Governments can also support water reuse projects through favorable fiscal policies such as tax incentives or holidays to incentivize private sector participation and create intersectoral collaborations among public and private entities. Thus, implementers of water reuse projects should be aware of and benefit from such incentive mechanisms in the region where they operate.

and in-kind, that a recipient makes to an award. Different types of expenses can be allocated among different stakeholders (such as labor cost, material cost and cost of using equipment).

Step 4: Identify risks and opportunities

Public and private entities/entrepreneurs in the water reuse sector that explore opportunities of creating and capturing value from wastewater are driven by both external and internal factors. External factors that drive public and private entities include regulatory and market pressures while internal driving factors include new profit opportunities or cost recovery mechanisms and environmental sustainability (Figure 6.3).

Policies, regulations and institutions play important roles in the deployment of water reuse projects. Different instruments such as fiscal incentives and industrial and product quality standards can be implemented. The presence of a policy framework on its own, while sufficient, is not adequate to provide an enabling environment that promotes water reuse. A conflicting policy environment, an inadequate policy or an adequate policy environment but without enforcement mechanisms can all act as negative drivers to the development of

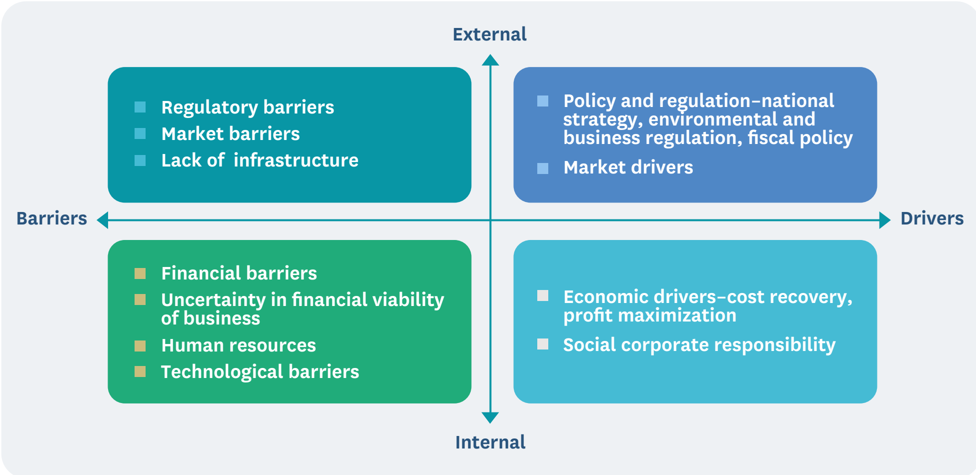

FIGURE 6.3 Internal and external drivers and barriers to water reuse models.

water reuse sectors that operate under such frameworks. Thus, it is important to understand existing institutional, legal and policy frameworks to identify opportunities and risks as well as mitigation measures.

Water reuse models should seek to identify, analyze and minimize other risks such as market risks, competition risks in input and output markets, as well as technology performance risks. While these risks are context or location specific, they must be analyzed and minimized. For example, for market risks, the key factors that could be considered are changes in supply and demand, as well as likely sources of competition. Technological performance risks are related to whether the technology is commercially proven and if there are anticipated challenges with local repair and maintenance. One of the simplest ways to understand the internal and external risks and opportunities of a business model is through the SWOT analysis.

The SWOT analysis

The SWOT analysis performs an assessment of internal (strengths and weakness) and external (opportunities and threats) factors of the business model. The SWOT analysis:

- assesses a business's strengths (S) and weaknesses (W) for achieving business objectives;
- assesses the business environment's opportunities (O) and threats (T) for achieving business objectives;
- assesses the current position and imagine possible future positions; and
- informs business objectives and action plans.

Once the SWOT analysis is completed, you can highlight key findings and then develop a strategy to mitigate risks and take advantage of opportunities (Box 6.5).

BOX 6.5 From SWOT analysis to strategy

- **S-O** strategy: How can you use your strengths to take advantage of the opportunities?
- **W-O** strategy: How can you use your opportunities to overcome the weaknesses?
- **S-T** strategy: How can you take advantage of your strengths to avoid real and potential threats?
- **W-T** strategy: How can you minimize your weaknesses and avoid threats?

SOURCE: Based on Otoo et al. 2018.

Step 5: Develop an implementation plan

Wastewater offers a variety of options for recovering resources (Figure 6.2, above), so a detailed feasibility study should precede the development of an implementation plan. The feasibility study will seek to determine which water reuse option has the highest probability of success in the local context. The feasibility study will inform the development of an implementation or business plan[2] for the most promising water reuse model. However, if the feasibility study ends with a choice of options, local stakeholders must set priorities and choose, according to their objectives, the most preferred option and location.

A business model provides a snapshot of a business idea, whereas a business plan is a finely tuned business model for the planned investment size and local opportunities or constraints. A business plan is more detailed and sets objectives, defines budgets, engages partners and anticipates problems before they occur. It helps you start and keep the project on a successful path. Key investors or financial institutions will want to look at the business/implementation plan before providing capital. To make the most of the planning, a water reuse project should give careful thought to the strengths and weaknesses of its water reuse model and the opportunities and threats in the business environment, and develop strategies to improve its potential for cost recovery and improve overall performance.

The key components of a business plan include:

- *The Business Concept*: Describes the business, including its products and services.
- *The Marketing Plan*: Describes the target market for your product and explains how you will reach that market.
- *The Financial Management Plan*: Details the costs associated with operating your business and explains how you will pay for those costs, including the amount of financing you may need.
- *The Operations and Management Plan*: Describes how you will manage the core processes of your business, including the use of human resources.

[2]Implementation plan and business plan are used interchangeably in this report.

You should ask the following key questions when developing business plan:

Business concept: Vision and mission	What is the vision of the water reuse model? What is your purpose? How will your reuse model look in next one, two and three years?
Objectives and goals	What are your most important goals? What is your value proposition? And how do you measure success?
Marketing plan	Who is your target end-user? How are you going to position your products or services?
Operations and management plan	How will you manage the core processes of your business, including use of human resources – organizational structure, expertise/skills needed, personnel plan/ staffing requirement.
Financial plan	How do we define success in measurable terms? What should be the target for cost recovery or breakeven?
Risks and mitigation	Identify risks – market, technical, political, regulatory and other risks and put mitigation measures

6.3. Conclusion and recommendation for adoption

A sound and adequate policy, legal and institutional framework is essential in providing an enabling environment for public and private sector investments in the wastewater sector. Regulatory frameworks can be important drivers but also significant barriers in water reuse business development. Thus, for the effective adoption of this guideline, there is a need for a conducive policy and institutional framework to enable public and private sector investment in water reuse sector. Furthermore, there is a need to be aware of any conflicting interests between public and private interests.

Conflicts between public and private sectors (including end-users) may exist for different reasons. For example, conflicts may relate to who are the losers and winners of the proposed change. In addition to these, traditions, norms and religious constraints and awareness levels are factors that need to be considered when designing and promoting water reuse projects. This is especially important since most people in the MENA region may have a negative perception toward reuse of wastewater.

Stakeholder engagement, awareness creation among relevant stakeholders and developing effective incentive mechanisms are some of the strategies and means to mitigate such constraints and bring in a common view and objectives for successful adoption of water reuse models.

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Chapter 7

Gender mainstreaming guidelines

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Guidelines at a glance

These generic guidelines enable project designers and implementers to understand and address "the differences between and among women, men, girls and boys in terms of their relative ownership, distribution and control over resources, opportunities, constraints and power" (SIDA 2015, 2) across the project cycle. These guidelines offer an introduction to core gender concepts, and a framework for gender mainstreaming based on the project planning cycle and Swedish International Development Cooperation Agency's (SIDA's) gender mainstreaming approach. Reference is also made to the joint FAO and SIDA gender mainstreaming approach, which was developed for a SIDA-supported project implemented in seven countries of the Near East and North Africa.

These guidelines further provide a brief section on why we need to move toward gender transformative approaches (GTAs). GTAs aim to address the root causes of gender inequality and aligns with Sweden's feminist foreign policy approach for a gender-equal humane world. Sweden's feminist foreign policy is a transformative agenda, which aims to change social, cultural, economic, institutional, financial and political structures. It also enhances the ability of women and girls to become influential actors who can individually and collectively exercise their rights and claim their entitlements equally with men (MFA 2019: 11).

7.1. Introduction

7.1.1 Introduction to gender – beyond women

Mainstreaming gender equality and women's rights into the water reuse sector is central for infrastructural investment outcomes for both women and men. Socially inclusive water reuse approaches can address normative and structural barriers which result in unequal access to, use and control of water reuse interventions.

In most developing countries, women comprise the majority of the population (FAO 2011). In the case study countries of Egypt, Jordan and Lebanon, women are nearly half of their respective populations at 49.47%, 49.4% and 50%, respectively (World Bank 2022).

Addressing gender equality and women's rights and economic empowerment in development will significantly contribute toward the attainment of the Sustainable Development Goals (SDGs) (UNDP 2018). In the case of water reuse, gender dividends include greater impact from water investments through reaching women who would otherwise be left out. Sustainability can only be achieved when the water reuse system or model considers the requirements of both women and men in their design and operation. However, most development interventions often exclude women due to established gender-based social norms that are often biased against them.

An understanding of the core concepts of gender in development is key to appreciate the logic behind gender mainstreaming. While the word *gender* has become common jargon within the development field, it is also one of the most misunderstood. Often, it is assumed to be synonymous with *women* as most gender-related projects focus on women's issues because women tend to be more disadvantaged than men. However, *gender* refers to socially constructed identities, relationships, challenges and outcomes. Therefore, gender goes beyond *women* to embrace the entire community. It is an inclusive approach to development that sheds light on the intricate challenges faced by men, women, youth and other groups of a community.

7.1.2 Core concepts

These guidelines make a case for gender mainstreaming but also further demonstrate how to mainstream gender equality and women's rights into all phases of water reuse projects. Below are several core concepts in the discourse about gender in development.

Gender refers to socially constructed characteristics of women and men, such as the norms, roles and relationships that exist between them. It does not refer to the biological differences between men and women. Gender is the value society ascribes to people based on sex, age, caste, religion and other social variables. It does not reflect one's capability and needs but is a function of the differential power dynamics. For example, in some societies it is unacceptable for women to be engaged in irrigation activities while it is the norm in others. In many societies, this is due to the night shifts of irrigation when women are not supposed to contribute. The different roles of women in these contexts are not defined by their physical ability to irrigate their fields but by the roles ascribed to them by the society they live in. For the purposes of these guidelines, the focus will largely be on women, while recognizing that gender is much broader than women.

United Nations Women defines gender as referring to the roles, behaviors, activities and attributes that a given society at a given time considers appropriate for men and women (UN Women 2022). Furthermore, the social attributes and opportunities associated with being male and female and the relationships between women and men and girls and boys are all important elements for consideration in this regard. Gender also refers to the relations between women and those between men. These attributes, opportunities and relationships are socially constructed and are learned through the socialization processes. They are context/time specific and changeable. Gender determines what is expected, allowed and valued in a woman or a man in a given context and society.

As such, gender refers to the characteristics, behaviors, roles and attitudes of men and women, as well as the relationships between them as shaped by societal norms. Gender is thus culture specific and changes over time.

Gender roles are the 'social definition' of women and men's roles, which vary among different societies and cultures, classes and ages, and during different periods in history (FAO 2018; Mapedza 2008). For instance, women in the twenty-first century are far more active in social, economic and political affairs than they were in the eighteenth century. Irrespective of the differences, gender continues to play an important role in defining the principles for division of labor within families, communities and in the public arena. The roles are defined by societal norms including cultural and religious norms that lay out the boundaries guiding men and women's functions and responsibilities. Gender roles are thus socially constructed and learned. They are dynamic (change over time) and are multi-faceted as they differ within and between cultures.

Gender equality refers to equality between men and women, with respect to their rights and in legislation and policies. Gender equality is a basic human right. It ensures equal access to, and control over, resources and services within the family and society. It is the recognition that men and women often have different needs and priorities, face different constraints, have different aspirations and contribute to development in different ways. It acknowledges that men and women are biologically different *but* must have equal mechanisms and processes to seize opportunities.

Gender equity means fairness of treatment for women and men, according to their respective needs. This may include equal treatment or treatment that is different, but which is considered equivalent in terms of rights, benefits, obligations and opportunities. Is a set of policy measures/special programs that are corrective; targeting women (mainly, but this could be any vulnerable groups such as persons with disabilities, minority communities and neglected geographies) with the aim of compensating them for the historical and social disparities that deprived them of enjoying access to equal opportunities. Measures of positive discrimination and quota system are two examples of gender equality.

Gender-based constraints are barriers inhibiting either men's or women's access to material, non-material resources and opportunities of any type. These can be formal laws, norms, attitudes, perceptions, values or practices (cultural, institutional, political or economic).

Women's empowerment consists of the process of empowering women through the facilitation of women's articulation of their needs and priorities as well as the enhancement of their active role in promoting their interests and agency.

Agency can be defined as the ability to make strategic choices under constraints or an unsuitable environment (Yount et al. 2020). Kabeer (1999) further points out that agency includes the processes of decision-making itself, as well as the less measurable manifestations of agency such as negotiation, deception as well as manipulation.

Gender analysis is a methodology that explores the differences in gender roles and relations with respect to a specific target group. Gender analysis at the project level gives insight into how tasks and responsibilities are divided between household members: who does what and how it is done? Who has control over what? Who attends or contributes to which event? Who wins? Who loses? It gives information on the ways in which women's access to, and control over, resources such as land, income, inheritance and political influence relate to that of men. Ideally, gender analysis should be done before the start of a project. The analysis can be repeated later to capture changes induced by development interventions. In other words, gender analysis refers to the variety of methods used to understand the relationships between men and women, their access to resources, their activities and the constraints they face relative to each other (Kabeer 1999). Gender analysis is facilitated through the collection of **sex disaggregated data**, which consists of data that is cross classified by sex, presenting information separately for women and men, boys and girls. Sex-disaggregated data allows for observing the differences in opportunity and achievement between men and women. An important part of valuable information is lost by assuming that men and women have the same access, ability, control over resources and roles (Doss 2013).

Gender within intersectionality: The lived experiences are a result of the intersection of multiple factors, which include race, class, caste, language, culture, ethnicity, gender, age, ability, sexuality and education (Porter 2018). Intersectionality within gender is understood as how the various dimensions of inequality further intersect to compound the inequalities and disadvantages that men and women face (Viruell-Fuentes 2012). Black feminists of the United States challenged the notion of a universal gendered experience and argued that Black women's experiences were also shaped by race and class (Collins 1998; Collins 1990; MFA 2019; Viruell-Fuentes 2012) These inequalities include race and class ethnicity, which further compound the gendered disadvantages. According to Potter (2018):

> Intersectional lens helps in explaining how people experience inequality according to different – intersecting – aspects of their identity. No one, for example, is *just* poor, or *just* working class, or *just* a woman or *just* a disabled person. Each person experiences a combination of inequalities differently, and these will shape how each person responds in different situations.

Gender transformative approaches (GTAs)[1]: Consist of programs and interventions aiming at creating opportunities for individuals to actively challenge existing gender norms, addressing power inequities between individuals of different sexes and promoting positions of social, economic and political influence for women. Also viewed as a feminist perspective, GTAs argue that for meaningful gender changes, there has to be a change in the norms, values and the unequal power relationships that define gender roles (Kabeer 2001; Mukhopadhyay 2004; Cole et al. 2014; Mapedza et al. 2019; Kabeer 1994). GTAs argue that as long as the social structure promoting patriarchy and other inequalities are in place, gender disparities will remain. The approaches are informed by conceptual frameworks that explicitly recognize the potent influence of social relations on creating and perpetuating gender inequalities (Kabeer 1994; Locke 1999).

GTAs are much more empowering as they question the reasons that led to a specific situation. For example: Why are women doing most of the work? Why are women powerless to transform themselves? This approach challenges the social structure which defines roles and responsibilities for men and women. This approach challenges current division of labor

[1]GTAs are often viewed as a strategic gender approach as opposed to a practical gender approach that seeks to lighten the burden of women within the existing constraints. GTAs aim for gender equality as an end goal.

and challenges existing power relationships and dynamics. This approach focuses on triggering change and is linked to decision-making process and empowerment of women. It is about defining a new reality where women are much more equal than the status quo. Gender under the transformative approach entails a better understanding of the process as well as the outcome (O'Neil and Domingo 2016; Kabeer 2019). GTAs align well with SIDA's Feminist Foreign Policy, which aims for equality between women and men.

Gender mainstreaming means integrating a gender equality perspective at all stages and levels of policies, programs and projects. The concept was first introduced at the 1985 World Conference on Women held in Nairobi, Kenya. It is based on the recognition that men and women have different needs, different access to and control over resources and play different roles. These roles differ from one context to the other depending on the country, region, ethnic group or other determining factors that shape and organize societies.

Gender mainstreaming offers an alternative to the traditional ways of thinking that caters to the needs of the dominant group in a society and aims to intentionally bring the gender-based constraints, inequalities and biases into the mainstream thinking. Gender mainstreaming thus broadens the scope for designing and implementing inclusive projects and programs that enhance the well-being of both women and men and creates a more socially just and sustainable society. At a global level, addressing gender in development will significantly contribute toward the attainment of the SDGs (UNDP 2018).

Gender mainstreaming further develops tailored interventions that address women-specific priorities including through equity measures. These interventions addressed through policies, plans, projects/programs need to be backed by gender-responsive targets, indicators and budgets, which need to be monitored and evaluated for the impact they make on women's empowerment and gender equality. Further, gender mainstreaming must adopt a whole-of-government and whole-of-society approach with all relevant and related government ministries, sectors and stakeholder groups present on institutionally established multi-disciplinary mechanisms in a sustained manner. Most importantly, women and their organizations working at various levels on water reuse must be represented on these mechanisms at all stages of the policy process in leadership and decision-making roles. In particular, this must include gender-aware women and those affected by, and who are knowledgeable about, water issues and lack of appropriate reuse (as in the case of water reuse, for example).

7.2. Considering gender in water reuse

With increased demand for water resources, water reuse recycles water so that it may be used for domestic and agricultural purposes (see Chapter 2). The ongoing climate change and climate variability challenges will make the role of water reuse more important. It is strategic that gender mainstreaming is included in the water reuse opportunities.

According to the WorldBank (2019), service providers, wastewater treatment service providers need to engage diverse types of labor force, which include both men and women for efficient service provision:

> To meet these challenges, water utilities need to increase their productivity and become more efficient. This will require tapping into new approaches, technologies, and solutions, as well as renewing the water workforce to meet emerging needs and move away from business as usual. By hiring, managing, and training a more diverse mix of employees, new and fresh perspectives can help shape the water utilities of the future (World Bank 2019: ix).

This would entail hiring both men and women at all levels of wastewater treatment to bring in new perspectives within the utilities. Women bring in a unique dimension in water and sanitation which is lost through the current exclusion. Women comprise about 18% of all the water and sanitation service providers. Their numbers were even lower for more technical fields (World Bank 2019). The exclusion of women in more technical fields in the water sector is a reflection of the broader exclusion of women in such technical fields (IWA 2016; Das 2017). Evidence shows that over time, there is a slow increase in the number of women working in water and sanitation utilities.

7.2.1. Why consider gender in water reuse?

Gender is central for water and water reuse in terms of current roles and responsibilities of women and men, patterns of asset ownership including abilities and constraints to access, use and control resource, and differential benefits in the value chain. It is also important to consider the various institutions/actors involved and the roles and positions held by men and women in these institutions and associated value chains.

Firstly, in most developing countries women comprise nearly half of the population (FAO 2011). However, most development interventions often exclude women due to gender biases which have developed over a long period of time. Gender must be understood within water reuse for several reasons. Water reuse in agriculture offers an opportunity to make use of water several times and, in some cases, for different purposes. The purposes for reuse and the types of activities required for reuse often engage men, women or both depending on the context and existing social norms. It is thus important to understand the shifts in gender roles in line with shifts in reuse strategies and purposes, in order to respond to each need strategically. Using gender analysis tools will provide contextual information which offer an in-depth understanding of the constraints and opportunities for change, which in turn offers insight into how to effectively mainstream gender in project implementation processes and achieve set targets.

Secondly, water reuse in general, and especially in agriculture, requires strict adherence to set rules and regulations by the users of the water to ensure its safe use with minimal negative implications for humans, animals and the environment. These rules and detailed information on suggested modalities for reuse should be clearly and effectively communicated to all men and women users. Women form a majority of the agricultural labor force in the MENA region and are largely responsible for food preparation, water collection, use and provision. However, their needs and the challenges they face are often neglected in project planning, implementation and evaluation processes. Adequate and timely access to essential information, including procedures and protocols for reuse – which is dependent upon the type of crop grown, or additional steps needed in cooking the food – will give women an opportunity to be part of the process of identifying and deciding on appropriate reuse options and be in full compliance with the rules thereby protecting themselves, their household and the environment from harm. This is even more poignant where vegetables which may be eaten raw are to be prepared. Gender mainstreaming in water reuse projects is thus very important to ensure equitable access to information.

Thirdly, water reuse for agriculture is a sensitive issue in many countries. This is partly attributed to cultural and religious concerns, and lack of information to influence people's perception on its acceptability and safety for use. The more informed the users are, the better they will be equipped to manage risks. This is especially true for women who tend to have less access to technical information. In gender mainstreaming, it is critical to consider the intersectionality of the different dimensions (culture and religion) and sources of inequality (sex, race and ethnicity) that can exacerbate existing inequalities and put certain groups of the society at a more disadvantaged position. A heightened level of awareness of these issues will help project managers and implementers understand the complexities surrounding water reuse for agriculture, on the basis of which they can design targeted activities that meet the needs of the society as a whole – including men and women and facilitate acceptability and use of this important water resource. Women who are well informed can be a force to address current social acceptance barriers toward water reuse.

7.3. Practical steps for integrating gender in water reuse

The first part of this chapter looks at opportunities for mainstreaming gender within the generic water reuse sector in the context of a project cycle. The second part looks at employment opportunities within the water and sanitation sector which builds on a World Bank (2019) study. The core idea for focus on the latter, stems from the understanding that water reuse, which depends on investments that create alternative use for different qualities of water creates new employment opportunities for men and women. This section thus explores some of the approaches to increase women's employment within the water reuse sector.

7.3.1 Gender mainstreaming opportunities in the water reuse project cycle

This section offers practical steps for engaging women, men and youth along the core domains of a project cycle in general, and with focus on water reuse projects in particular (Figure 7.1). Gender mainstreaming calls for the disaggregation of all data by sex, and whenever possible by age, economic status, ethnicity and other core social differentiating factors to account for differences in challenges and opportunities among different social groups.

Collecting additional data on other intersectionalities including race, class, caste, sexuality, religion, ability and physical appearance is also useful to gain a deeper understanding of the challenges and opportunities faced by different social groups. The breadth of variables to be considered should depend on the scope of the project and the context within which gender-based inequalities persist. Guidelines, in the form of leading questions, are offered to explore different opportunities to mainstream gender in each aspect of the project cycle including planning and design, implementation, as well as monitoring and evaluation.

In these guidelines, gender is assessed using four approaches presented in the form of questions (SIDA 2015), which need to be addressed by water reuse project teams:

- How are the targeted measures aiming at ensuring, or at least increasing, participation of women in different water reuse programs?
- What are the integrated measures with focus on structures and systems that systematically reduce the gender gap and empower women within the water reuse program?
- What are the policy dialogue opportunities and challenges for men and for women to participate, lead, manage and benefit from water reuse investments?
- How are gender disparities and differences included as part of the applied methodology?

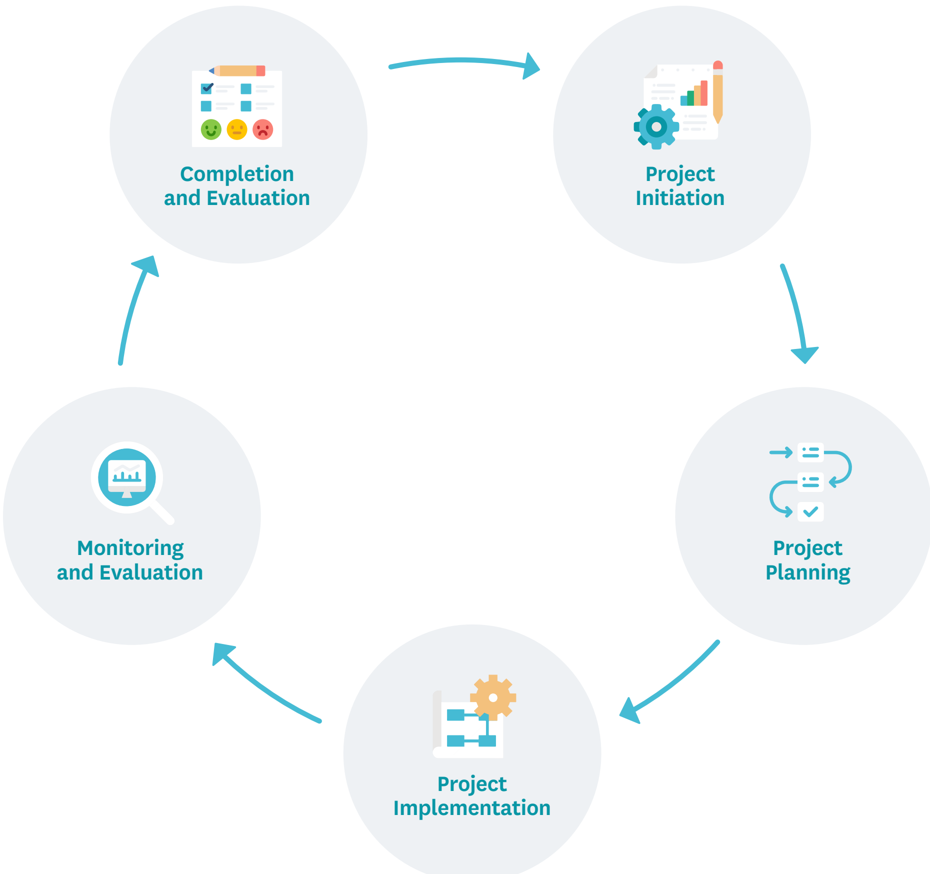

FIGURE 7.1 The project cycle in the water reuse context.

Stage 1: Water reuse project initiation

This is a preparatory stage of data collection and gender analysis through secondary data and active participation of women and men. It aims to better understand broader socioeconomic and political context on gender equality and women's rights and in water reuse so as to best address women's priorities in relation to water reuse in ways that will begin altering power relations between men and women. This stage will also surface risks and mitigation strategies to move a transformational gender agenda.

Project managers should ask the following questions:

- What are the current roles of men, women, and youth in water reuse, i.e., who does what, which occupation, activity, and task? Where – (community spaces, water treatment plant, home)? And how – (type, method, purpose)?
- What can the project learn from the stock of knowledge that men, women and youth have accumulated over the years concerning water reuse (types, methods, benefits and purpose)?
- Are there any differences in the perception of water reuse among men, women and youth?
- What are the challenges and opportunities for reuse for men, women and youth?
- Are there any gender-based constraints that present different opportunities/challenges to men, women and youth? And are they reflected in the problem analysis and prioritization process? Note: In this case, challenges and opportunities should be conceptualized in a broad context to include human, social, economic, physical and institutional challenges and opportunities.
- It is equally important to consider the whole value chain (input-production-processing-packaging-marketing) and use a broader view to account for various actors and institutions that are involved across multiple levels of the chain.
- Will the solutions/changes proposed by the project address women's practical water reuse needs, or both practical needs/priorities and a transformational gender agenda?
- What are the anticipated risks to women's empowerment and a transformational agenda in water reuse?
- What are the mitigation strategies?
- Which groups in the internal water sector/community environment and external environment beyond water reuse sector need to be advocated with for the change the project envisages to happen?

The initiation stage is essential to establish a good understanding of the overall bio-physical, institutional, political and socio-economic conditions, including gender norms and relations to inform the project planning phase of the project. Such information could be collected through desk reviews and key informant interviews with relevant stakeholders.

This stage will also allow project managers to identify potential partners, set realistic goals, identify potential risks and mitigating solutions, and set realistic assumptions.

Stage 2: Water reuse project planning

The planning process should:

- include consultation processes based on multi sector/stakeholder engagement approach, which ensures the active representation and participation of women and their priorities in project design;
- gauge the level of gender awareness of key institutions and include relevant activities to address gaps in awareness;
- ensure that the goals/objectives, outcomes, outputs, activities, have sufficient budget and human resources allocated to them to achieve set goals; and
- ensure that the project's theory of change reflects and pursues a transformational gender agenda.

Project managers and implementers should ask the following questions about opportunities for incorporating gender within the project cycle:

- Is the specific theory of change with related outcomes, outputs, activities, targets, indicators, budgets and suggested solutions inclusive of stakeholder consultation, and does it reflect the needs of men, women and youth?
- Are the institutions dealing with water/water reuse in relation to the project have gender sensitive corporate mandates, structures, standard operating procedures (SOPs), cultures, programs, budgets and accountability systems? Are the institutions and other stakeholders involved in the project inclusive/gender sensitive in their approach at the community, work site, household and state level (whichever is applicable)? If not, what can be done to ensure equitable delivery of goods and services?
- Has the project allocated sufficient resources to ensure that all activities addressing women's priorities and gender inequality in water reuse can be implemented as planned?
- Are the proposed solutions accessible and affordable for all groups of the community? If not, why not? And what can be done (targeted solutions) to meet the needs of minority groups or ensure equitable access and use by all? Note: The composition of marginalized groups can be different from one society to the other. While women almost always fall under this category, it is also important to keep in mind other factors for social differentiation including race, religion, ethnicity, etc. In such cases, it is advised to adopt an intersectionality approach to assess the combined effect of prevalent factors on a group's ability to access and benefit from the project.

Stage 3: Water reuse project implementation

Within the project implementation phase, project managers and implementers should ask the following questions:

- Are the required resources available – including capacities on gender, project implementers with required skills and qualifications, enough project staff and budgets?
- Has support been provided to engender institutional mandates, SOPs, organizational structure, programs, budgets and accountability systems?

- Are relevant institutions and stakeholders effectively sensitized and engaged to provide services equitably to men, women and youth?
- Is the baseline data (quantitative and qualitative) collected for the project disaggregated by age and sex, economic status and ethnicity?
- Do efforts for community mobilization/engagement/participation and training create equal opportunities and provide measures to ensure equal access to project benefits for men, women and youth?
- Does messaging and training content reflect women's priorities, rights and gender equality in water reuse?
- Do efforts to raise awareness, provide information, demonstrate or offer short-/long-term training equitably target men, women and youth to ensure that all equitably share from the benefits of the project?
- Does the project create equal opportunities and provide measures to ensure equal access to project benefits for men, women and youth?
- Is there a fair representation of both sexes in the project implementation team? Note: This is important both from the perspective of ensuring gender balance in the workplace, representation of gender experts, and to ensure the teams' ability to reach targeted communities in culturally sensitive manner. The latter is especially important in cases where women, due to cultural or religious reasons, can only work with women.
- Are relevant institutions and stakeholders effectively sensitized and engaged to equitably provide services to men, women and youth?
- What institutional training strategies will be employed? And does it consider the required needs for all staff (i.e., men and women) at all levels? Including management to build the knowledge and skills needed to mainstream gender equality and women's rights perspectives into their water reuse work?
- Are there accountability mechanisms in place to assess performance on gender responsiveness with corrective action for transgression?
- Are there mechanisms in place for exchange of information, monitoring progress, and evaluation and addressing challenges, and is this being implemented?
- Are there mechanisms in place for adjustment in strategies and actions, and is this happening?
- Are budgets adequate for the gender equality actions and are they being disbursed in a timely manner? Note: This is very important to ensure sustainability of project outcomes.

Stage 4: Performance monitoring of water reuse projects

Having gender-sensitive indicators and targets as part of a project's performance monitoring system is essential to track gender-related changes over time. The indicators are useful to highlight changes or the lack thereof against set gender targets, allowing project leaders an opportunity to timely address any concerns. Such monitoring and evaluation are significant as it allows tracking of progress and provides useful information to make timely adjustments during implementation. To achieve this, project managers should consider:

- Are there sufficient gender-specific performance indicators that are disaggregated by age and sex, economic status and ethnicity that can be measured either quantitatively or qualitatively over time (percentage and numbers)?
- What are the expenditures on women's priorities and gender equality actions?
  Examples:
  - Number of participants who received short-term training (disaggregated by sex and age)
  - Number of participants who are using recommended options for safe water reuse (disaggregated by sex and age)
  - Numbers of participants whose knowledge and conceptual understanding increased with trainings. (This can be measured by doing pre- and post-training surveys).
- What are the adjustments, revisions related to challenges in implementation and budget revisions that have been made?

Stage 5: Evaluation of water reuse projects

Project evaluations offer an opportunity to learn about what worked and what did not in gender mainstreaming throughout the project cycle. In addition to providing general recommendations for improvement, evaluations – when appropriately gendered – can also provide invaluable insight into gender transformations achieved as a direct result of the project. Questions to ask during an evaluation include:

- Was there rigor in the gender analysis from preparatory stage to evaluation?
- Was there rigor in addressing women's priorities and gender equality in design phase in relation to goals/objectives, methodology and theory of change?
- How did the project benefit or meet the needs of men, women and youth (primary and secondary beneficiaries)?
- How has the project influenced or led to changes in perceptions on water reuse among men, women and youth (primary and secondary beneficiaries)?
- How has the project influenced benefits related to meeting practical needs?
- How has the project influenced structural, institutional and gender-based changes? Particularly changes in gender roles/power dynamics/decision-making and overall social norms?
  Note: The change in this case could be negative or positive. For instance, an increase in the role of women in the management and reuse of water could be positive if it results in change in status or income, or negative if it only results in increased workload.
- Are the linkages between gender related outputs, outcomes and impacts clearly specified?
- Is the project's theory of change gender sensitive?
- What are some of the lessons learned from mainstreaming gender throughout the project cycle?
- Did the project contribute to long-term behavioral change that fosters gender equality?
- What institutional training strategies were employed, and did they take into account the required needs of all staff (i.e., men and women) at all levels? (Including management to build the knowledge and skills needed to undertake the mainstreaming strategies).

7.3.2 Gender mainstreaming approach guide

Figure 7.2 summarizes the gender mainstreaming approaches. Gender analysis is the first step, followed by identifying how men and women are impacted which then informs the gender aware dialogue, the targeted gender activities and the integration of gender equality leading to gender mainstreamed in water reuse. Gender mainstreaming is then practically situated within a water reuse project.

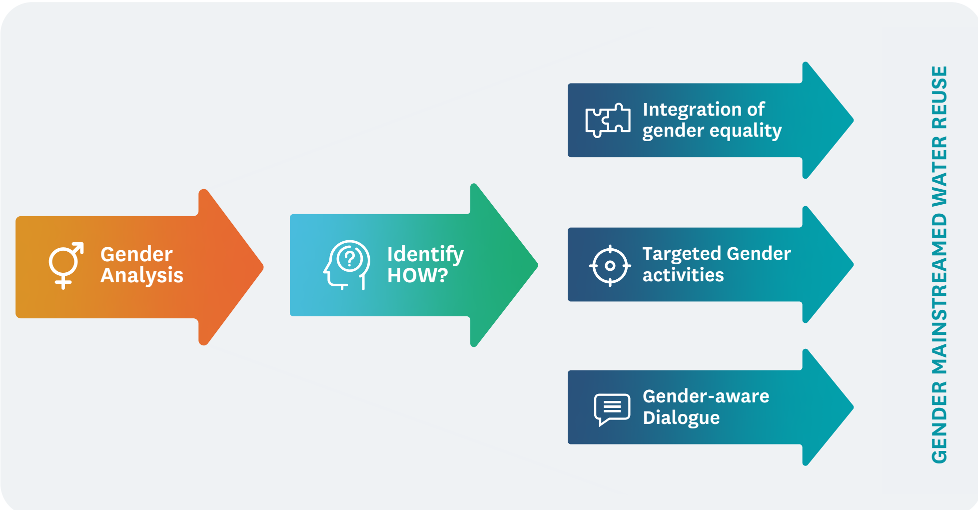

FIGURE 7.2 Gender mainstreaming in water reuse.
SOURCE: Adapted from SIDA 2015.

7.4. Gendered employment opportunities

7.4.1 Shifting modus operandi for water utilities

Historically, water and sanitation utilities were often top-down entities that saw themselves as offering an essential service based on their expertise. The business environment is shifting with the need to see citizens as customers whose needs must be addressed. This turning upside down of the hierarchical approach entails that citizens are viewed as clients or customers who must have a say in the way the service providers are managed. Women must not only be consulted, but they need to be represented at different levels of the service providers tiers and contribute to decision-making. In other words, the service providers need to reflect the society in which they are doing their business (WorldBank 2019).

7.4.2 Multiple benefits from women engagement in water and sanitation utilities

While the ultimate benefit to women lies on transformative changes that create enabling environments for equality among different social group, in the interim, women can still benefit from gender-focused interventions. Through engaging women, the World Bank(2019) argues that the benefits are multiple. First, the women who are engaged benefit through employment opportunities. Second, the community gains through having representation and input of its society members. Third, the water and sanitation service providers will benefit from an increased pool of talents with a potential of diversified inputs for more efficient and effective service provision to intended customers.

Studies have noted that including women in the design, operation and maintenance of water and sanitation facilities results in positive outcomes at different levels (WorldBank 2019; GWA 2011; Hunt et al. 2018; Thompson 2017). These changes, through time, will also have a cumulative effect that shifts norms and structures that hinder women's rights.

7.4.3 Removing constraints for women in water and sanitation sector benefits the broader economy

A more gender-inclusive approach within the water and sanitation sector has significant financial benefits to the nation (World Bank 2019). The inclusion of women has broader economic benefits in all sectors including the agricultural sector (FAO 2011; World Bank 2012, 2019). Excluding women in the economy costs USD 160.2 trillion of losses in human capital wealth globally (Wodon 2018). Within the Organization for Economic Co-operation and Development (OECD), a 50% male-female work ratio is projected to result in a 6% gain in the gross domestic product (GDP) by 2030 (OECD 2015).

7.4.4 Removing barriers discriminating women in water and sanitation providers

There is discrimination against women employment in the water and sanitation sectors at four stages: attraction, recruitment, retention and advancement (World Bank 2019).

Attraction

Social norms shape gender roles. Certain roles are socially perceived as male or female roles. Division of labor also see women not even exploring opportunities in the employment opportunities considered male 'type' labor. Science, Technology, Engineering and Mathematics (STEM) graduates are mainly males.

While there are initiatives to encourage female students to study science subjects, the number remains low, which already reduces their number from the available pool of science graduates. The last point contributes to the lack of role models in that most of the technical positions are occupied by males. Without role models, fewer women aspire to be in the technical fields. Some initiatives are using the few women who are in the technical fields to be mentors and also visit lower-level schools to inspire girls to aspire to technical fields.

Recruitment

Women face more barriers in the recruitment process for water and sanitation utilities. The World Bank (2019) Utility Survey over a 12-month period showed that only 20% of new hires were females. Some of the reasons for fewer women being recruited include biases in the recruitment process. The World Bank notes that even in advertisements there tends to be discriminatory language, which discourages women from applying. The study also shows that female STEM graduates were discriminated against in the hiring process. It is further noted that in some economies, women are specifically barred from being engaged in the water sector.

Positive directions would include gender-neutral advertisements and broader interview panels. Other initiatives include on-the-job training, placement programs, internships and apprenticeships, and incentives and diversity targets.

Retention

Retention of women in water and sanitation utilities is affected by a lack of gender-sensitive policies and a discriminatory work environment. Domestic chores, which remain a burden for women, have meant that it is a much bigger challenge for women to strike a healthy work-life balance as compared with their male counterparts. While society is changing, the burden of childcare remains the responsibility of women. This has meant that men will have an edge professionally as they are less restricted by domestic chores and childcare.

Family-friendly policies are progressing especially in developed countries. For instance, organizations that offer flexible working hours for their employees tend to retain more of their women staff. However, such policies lag for the rest of the world and working hours might be used as a basis for recruitment discrimination.

Fair wages are still one of the key issues as women most often earn less than men, even in developed countries. The work environment, especially in the water and sanitation arena, was largely designed with men in mind. This makes it difficult for women who would like to join the profession.

Sexual harassment is also a major concern mainly for women. The #MeToo movement has shed light on the silent women who experience sexual harassment, which is more pronounced in male-dominated fields such as the water and sanitation sectors.

The work facilities and amenities in a number of instances are designed without considering female requirements, which may be as basic as bathroom facilities and nursing rooms for mothers with babies and toddlers.

Advancement (gender differentiation in management)

Women in water utilities do not always have the same opportunities as men to advance their career. Sometimes, training opportunities are given to men due to their perceived minimal demands on their time from child rearing and domestic chores. Mentorship for men is easily available, while women have fewer people to mentor them. Networks and opportunities are usually targeted toward men. Events and opportunities are usually available through men's clubs and events. Sometimes senior management opportunities are discussed in such settings. This suggests that women, and sometimes young men, are also excluded from such key decision-making events, often held away from the workplace and sometimes during weekends or holidays.

7.5. Promising approaches in water and sanitation utilities

The section below highlights the different community engagement approaches, beginning with manipulation on one hand and ending with more inclusive citizen control.

Targeted interventions to increase female participation in water utilities. Women need to be targeted not only as employees but in decisions made about water and sanitation and water reuse specifically. This could be viewed in the context of Arnstein's ladder of participation, moving beyond non-participation and tokenism for women to real engagement of women in water and sanitation challenges and opportunities (Arnstein 1969) (Figure 7.3). Water reuse interventions must aim for citizen control as opposed to manipulation.

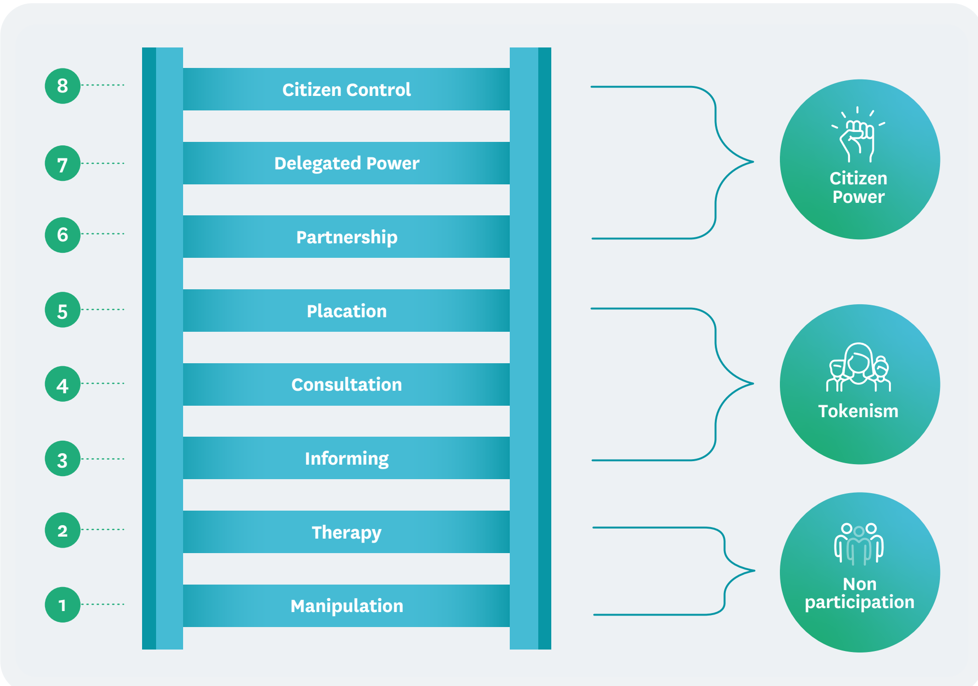

FIGURE 7.3 Arnstein's ladder of participation showing different levels of community engagement. *SOURCE*: Arnstein 1969.

Creating an enabling environment at national and subnational levels to facilitate positive gender practices at the local level. Several countries are signing up to the international conventions such as the Convention on the Elimination of All Forms of Discrimination Against Women of 1979 and the SDGs, which have gender equality and women's empowerment as a key aspect. Some countries are going even further by developing domestic laws, policies and strategies. One of the key challenges in most developing countries is translating 'good' policies into action on the ground. This is mainly due to the lack of understanding and the will to change; consequently gender is often thought as side-streamed rather than mainstreamed.

Gender norms. While gender stereotypes are certainly being played out in the water and sanitation sector, it is important to note that such gender stereotypes result from the socialization process. Some employers and interview panels do not reflect on their 'socialization' process and how it is bringing gender biases into the water and sanitation sector.

There is no 'silver bullet' solution for gender equality in water and sanitation utilities. The utilities need to learn from each other while simultaneously tailoring solutions for their own context. Each water and sanitation utility needs to address gender equality, otherwise the inequalities will continue under a business-as-usual mode.

7.6. Conclusion

These guidelines began by developing a common understanding of 'gender', which is not the same as 'women.' Gender is understood as a socialization process that ascribes values to men, women, youth and children based on who they are rather than what they can do. For instance, some parents would avail less educational opportunities to a girl as compared to a boy in the same household. In terms of employment opportunities, women face more hurdles even if they have the same qualifications as men.

Using SIDA's gender mainstreaming approach in the context of a project cycle, opportunities to integrate gender have been identified in the form of questions to ensure that gender reflection and action take place throughout the project cycle. Good gender mainstreaming is an important development that will positively impact men and women, as well as children, who are the citizens awaiting the benefits from socially inclusive water reuse interventions.

The guidelines further attempt to show project designers and implementers how to empower women in water reuse projects and ensure that reuse benefits everyone – men, women and youth. It is, however, important to note that gender mainstreaming is just a good start. The aim is GTAs, which strive to challenge and change norms and values while reconfiguring power relationships to enhance women's agency, thereby promoting equality between women and men. This is the ultimate aim for development interventions including in the water reuse sector.

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Chapter 8

Guidelines to improve acceptance of water reuse

Javier Mateo-Sagasta and Pay Drechsel

Guidelines at a glance

Good practices and adequate technical capacity are not enough to guarantee the success of water reuse interventions. Understanding the issues and concerns around perceptions and acceptance and addressing these with timely, effective communications and stakeholder engagement can significantly help to build trust and improve and support reclaimed water use initiatives. This chapter provides a greater understanding of the issues that hinder acceptance of water reuse across the MENA region, and tools and strategies to overcome them.

To improve acceptance of water reuse, project designers can:

- Encourage public participation and discourse
- Engage proactively in early and continuous communication to build trust
- Select messaging with the right terminology
- Communicate the benefits of water reuse and how risks are mitigated
- Address possible religious concerns
- Facilitate behavior change

8.1. Introduction

Water reuse is becoming increasingly important to water security in arid regions. Technology and good practices already exist to manage reclaimed water projects and meet or exceed health-based targets. However, good practices and adequate technical capacity are not enough to guarantee the success of water reuse interventions in terms of community buy-in. Understanding the issues and concerns around perceptions and acceptance and addressing these with timely, effective communications and stakeholder engagement can significantly help to build trust and improve and support of reclaimed water use initiatives.

A comprehensive communication plan targeting key stakeholders is essential to the success of water reuse projects or policy decisions. This chapter provides a greater understanding of the issues that hinder acceptance of water reuse across the MENA region, and tools and strategies to overcome them.

8.1.1. Understanding barriers for acceptance

Different communities and stakeholders can have very different degrees of acceptance of water reuse initiatives. The level of acceptance depends on many cultural factors but also on the type of use for the reclaimed water. Water reuse can trigger rejection, especially when resulting in a possible direct exposure. In a study in the southeast USA, respondents strongly disagreed with the use of reclaimed water for replenishing surface or groundwater for potable reuse or used within the household (Figure 8.1).

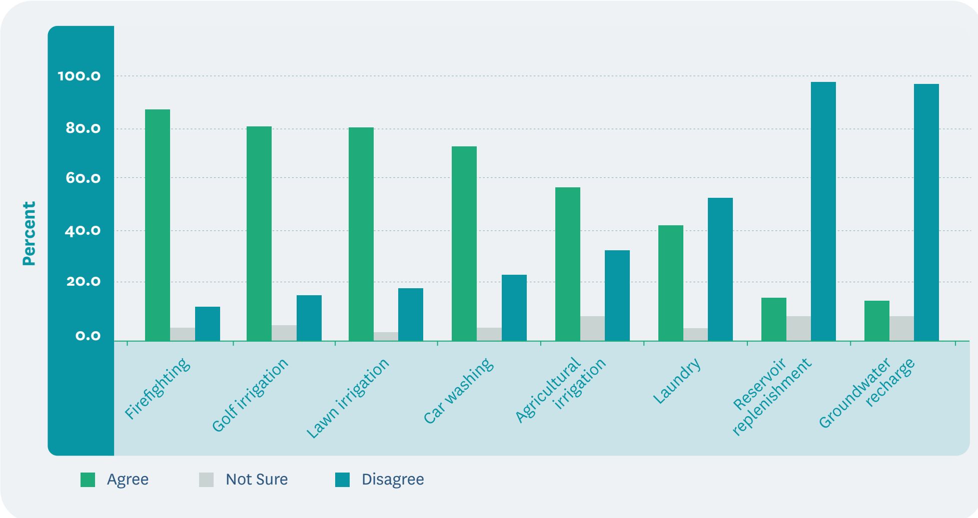

FIGURE 8.1 Attitudes toward water reuse options in southeast United States.
SOURCE: Robinson et al. 2005, cited in WHO 2006.

Irrigation of dairy pastures and edible crops including orchard and vineyard are usually accepted by farmers if agronomic risks are under control, but not necessarily well accepted by end-users of this product. There can also be concerns vis-à-vis import regulations if the produce is exported. Finally, water reuse to irrigate recreational parks, golf courses, gardens or pastures tend to have higher acceptance (Po et al. 2003; Khan and Gerrard 2005; Abu-Madi et al. 2009; Australian Water Recycling Center of Excellence 2014; Wester et al. 2015; Sharma et al. 2019). Direct exposure, social, religious, economic, health, political, freshwater scarcity and institutional framework can affect the acceptance of reuse projects (Al-Kharouf et al. 2008; Drechsel et al. 2015). These and other key factors that influence perceptions of water reuse could be grouped into the following categories:

- Health, environmental and agronomic risks
- Emotional, cultural and religious factors
- Financial implications, costs of technology and capacity to fund initiatives
- Freshwater scarcity
- Public involvement in decision-making

Public acceptance of reclaimed water is often the result of a combination of factors, including attitude, subjective norms, knowledge, trust in providers, perceived risk, cost and availability of alternatives. To improve the perceptions of water reuse, we need to understand, in any specific location, each of the locally expressed barriers to accepting reclaimed water and address these through effective communications.

8.1.2. Health, environmental and agronomic risks

The fear that reclaimed water may still contain even a small amount of pollutants such as pathogens, metals, drug residues and organic toxic compounds may trigger rejection. Both farmers and the public perceive the potential presence of these pollutants as environmental, health or agronomic risks. Even in cases where the risks are negligible or non-existent, the public perception of risk increases depending on the appearance, color and odor of reclaimed water, but can even more be steered by gossip, fear and misinformation. In the Australian case of Toowoomba, for example, public acceptance was strongly influenced by a political campaign building on 'yuck' and 'fear' factors than social and financial arguments by the supporters of the project (Drechsel et al. 2015).

The public tends to be more concerned with the health risks associated with the use of reclaimed water when they perceive that the quality of water is not guaranteed. Moreover, lack of trust in governing institutions and the authorities in charge of reuse safety could explain perceptions of risk resulting from system failure.

Farmers are more concerned with the long-term effects of water reuse and the accumulation of pollutants in soils, particularly when such pollution can affect crop yields or crop selection. They are typically concerned about salinity when reclaimed water is more saline that alternative water sources. Overall, farmers may see the benefits of having a reliable source of water all year round or the benefits of plant nutrients in reclaimed water; nevertheless, they tend to worry about the stigma associated with reuse and fear a potentially lower demand for their products or lower market prices for the same.

The end-users of reclaimed water (for example, farmers) and their decision to use it or not can promote or compromise any water reuse project or policy. The same applies to the consumers of the products who can jeopardize market demand or only show a low willingness to pay.

8.1.3. Emotional, cultural and religious factors

Acceptance of water reuse cannot be achieved simply by adopting technologies able to mitigate environmental and health risks. Water reuse will not be accepted only based on an economic justification (i.e., where the overall benefits of a project are larger than the expected costs). For a water reuse initiative to succeed, community attitudes need to be understood and addressed. It is necessary to consider instinctive and emotional responses that people have toward 'human excreta' and 'sewage.' Many people trust hearsay, or their own impressions of water quality, more than they trust medical and scientific evidence or advice. Once water has been in contact with contaminants, it can be psychologically very difficult for people to accept that it has been purified. Combined, these factors can create mental barriers to the acceptance of reuse water as a source of pure water.

The influence of instinctive responses of disgust against waste derived products is frequently referred as the 'yuck' factor. Connected with disgust are accompanying feelings of fear, which are often conserved during evolution to protect against risks. The yuck factor could therefore be said to serve a useful purpose. But this reaction of repugnance, distaste or disgust can overcome scientific evidence and rational arguments and become a barrier to water reuse, even when it is proved to be safe and economically justified.

When people are just beginning to learn about potentially controversial ideas, their reaction often depends on where their information comes from and how it is presented. A person who was once repelled by the thought of using recycled water might change their mind if reuse is supported by someone with shared cultural values. Also, not all types of organizations are equality trusted. Most trusted sources are usually scientists who do not have a stake in whether a technology gets adopted or not. The least trusted entities are typically corporations. Terminology and data also matter (see below). It is easier to appeal to sentiments with imagery, than it is to appeal to perceptions with technical information and data. Scientists must communicate so that the public hears and understand what they are saying.

Similarly, there is an association between religious beliefs and respondents' willingness to use treated wastewater. The religious obligation to use water has direct implications for accepting treated wastewater. Even though in 1978 a fatwa was issued decreeing that treated wastewater could be considered pure with proper treatment, some people still object to water reuse on religious grounds. The issue becomes of greater pertinence when there is a large diversity of users and religious beliefs, which when not understood, leads to high levels of resistance and concern. Thus, the design of treated wastewater facilities can make water reuse more acceptable in countries that have religious taboos (i.e., letting the sewage effluent move underground after recharge) (Warner 2001).

8.1.4. Financial implications, costs of technology and capacity to fund and sustain projects

For the farmers and traders, it is important to know if the use of reclaimed water is financially viable from their perspective. In the case of use of recycled water for irrigation, for example, crop acceptance by the consumer (buyer) remains the most crucial criterion. Assuming the source of the crop is known to the consumer, their decision to buy or not to buy a crop produced with reclaimed water is determined by public views, knowledge and perceptions (Drechsel et al. 2015; Abu-Madi et al. 2009).

There may also be significant costs associated with funding, and operation and maintenance of water reuse projects. Equitable distribution of costs among key stakeholders is critical to acceptance, with consideration for their capacity to pay. This should consider the economic benefits of the reuse project in terms of food supply, water savings, health and livelihoods, which should be internalized to justify subsidies. Various subsidies and incentives are required for most water reuse projects as cost recovery through users cannot be guaranteed. Capital investment is financed in most cases with state funds and by international donors. High-income countries are better positioned to subsidize or recover project costs of operation and maintenance.

8.1.5. Freshwater scarcity

Reuse projects can easily fail if there are still alternative water sources. In Tunisia, the willingness of fruit tree farmers to pay for treated wastewater near Ouardanine is mostly undermined by their ability to fall back on groundwater use, which is free of charge if found above a depth of 50 m. However, extraction of groundwater is increasingly unsustainable, and there are now options to regulate extractions such as electricity charges for pumping (Drechsel and Hanjra 2018).

In Windhoek, Namibia, which lacks affordable water alternatives, up to 35% of the city's wastewater is treated and blended with other potable sources to increase the drinking water supply (Lahnsteiner et al. 2013). Singapore, on the other hand, has still enough freshwater; the public has rejected all attempts to use perfectly purified wastewater. As a result, only a small portion (2.5% in 2011) of NEWater has been blended with Singapore's freshwater during periods of drought (Lim and Seah 2013). Where an alternative freshwater source is a crucial disincentive to the adoption of reuse in agriculture, as was reported also for Jordan or Spain (Molinos-Senante et al. 2010; Brahim and Duckstein 2011), restrictions on the use of freshwater could be set and enforced.

8.1.6. Public involvement in decision making

As summarized by Drechsel et al. (2015), a consensus is that to achieve general acceptance of planned water reuse schemes, especially in a social environment with the power to influence the implementation process, it is important to ensure active public involvement from the planning phase to full implementation (EPA 2012; WHO 2006). Public involvement begins with early contact with potential users, and can involve the forming of an advisory committee, and public workshops on reasons, benefits and risks of reuse. The exchange of information between authorities and public representatives should ensure that concerns from perceived health or environmental impacts to lower property values have been shared and addressed (Crook et al. 1992; Helmer and Hespanhol 1997). The two-way dialogue and learning process should build on mutual trust to provide the right climate for negotiation and conflict resolution.

8.2. Practical steps for improving acceptance of water reuse

Initial reactions to new technologies or controversial ideas often depend on where the information originated, how it was presented and who was involved. There are key strategies and tools available to overcome barriers to the acceptance of water reuse, which include:

- Public participation
- Early and continuous communication
- Careful messaging and terminology
- Communicate the benefits of water reuse and how risks are mitigated
- Addressing possible religious concerns
- Facilitating behavior change

Jordan has succeeded in informing its population about the importance of water reuse in agriculture by implementing an active educational campaign with strong community outreach (EMWATER 2004). A program component included the distribution of newsletters and guidebooks, coverage of water issues in newspapers and on television and radio, websites, public educational places and the education of land-use decision makers. Additionally, educational materials were distributed to schools, universities and libraries.

In Jordan, Tunisia and Kuwait religious concerns were expressed but are not among the top reasons for farmers' rejection or hesitation to use reclaimed water for irrigation (Abu-Madi et al. 2008; Alhumoud and Madzikanda 2010). In view of potable water reuse, no fundamental religious objections appear to exist either internationally or locally, as a multi-level survey in Durban showed (Wilson and Pfaff 2008).

The recommendations below assume that the water reuse project is safe for people, crops and the environment, does not pose an economic burden, and benefits the environment and society.

8.2.1 Encourage public participation and discourse

Research confirms that communication and engagement with stakeholders increase acceptance of water reuse (Drechsel et al. 2015). Creating a sense of ownership through public involvement increases that support and involves a series of activities to inform and obtain input, not only a single event. Participation provides the public and stakeholders an opportunity to influence decisions that affect them. Project managers should consider recruiting local advisory councils to allow for comment, tours and open houses (Box 8.1). Site visits to existing water reuse projects have also proven to be a positive influence on acceptance. Studies have shown that although individuals accept experts' opinions on reclaimed water quality, they tend to rely more on their personal impressions and tested benefits (OECD 2002; Ait Mouheb et al. 2018).

8.2.2. Engage proactively in early and continuous communication to build trust

Once a negative narrative on water reuse has been voiced, it is difficult to overcome. Communication on water reclamation projects should begin early to build trust over time and complement the broader resource planning effort. Communication activities should include information to community organizations, the media and local leaders on decision-making processes and benefits; distributing brochures to utility customers; and hosting information booths and sessions at public events. A successful communication plan contains strategies that allow stakeholders to study the evidence and draw their own conclusions, seeing both the decision-making process and the decisions themselves through transparency. Project monitoring and accountability are key. Information on developments, positive or negative, should be first heard from project managers. It should be possible to identify a problem when an incident occurs and be able to trace the root cause of the problem to take early action in the future.

BOX 8.1 Learning alliances, action research and scaling up innovation in water reuse

Learning Alliances are a specific type of multi-stakeholder involvement. The name itself already suggests that learning plays a major role in this format. This refers to both learning in terms of the water reuse issues at stake, and also learning about the interaction between the stakeholders.

The Learning Alliance approach is a response to the failure to address complex societal issues involving natural sciences and technical engineering without incorporating social sciences and learning. Examples of research and action through Learning Alliances can be found in agricultural and urban water management (http://www.switchurbanwater.eu/la_intro.php) (Lefore 2015).

Learning Alliances have many similarities with other stakeholder formats; however, they also have some features that make them stand out, including:

- Key role of research and knowledge organizations, which are often the ones to facilitate the alliance as impartial and evidence based 'honest brokers'.
- Systematic observation of learning process. In parallel to researching actual water reuse issues, the process of interaction between the stakeholders and their progress in learning is also monitored and documented. Their achievements and failures in working together are equally important as improvements in wastewater and reuse management itself.
- Social inclusion. Learning Alliances put strong attention to those stakeholders who are normally not included in the official discourse on public matters. These groups include: women household and agricultural users, small-scale farmers, aquaculture producers, cattle owners, other water users, small- to medium-scale investors, etc.

8.2.3. Careful messaging with the right terminology

The concept of water reuse is relatively new for society. Its value must be presented in simple, compelling terms, avoiding technical language and emphasizing benefits and low risks of reclaimed water. Choice of words and terminology can overcome negative reflexes. Consider each audience as messaging is developed: what may resonate with investors will be different to what moves end-users. Terms like 'reclaimed water', 'recycled water' and 'water reuse' improve acceptance, compared to terms such as 'wastewater.' Water should not be judged by its history but for its quality. Once reclaimed, wastewater is not a waste anymore, and the term 'waste' should be avoided in water reuse projects. Water security for the MENA region is a primary concern and shaping positive messages on alternative water supplies will continue acceptance of water reuse to address serious, long-term water shortage issues. Health and safety should be promoted as the most important concern and highlight the safety record in the region.

BOX 8.2 Participatory simulation of scenarios and role-playing games

When designing a water reuse project, it is important to be able to anticipate potential problems that can occur during its implementation. This feedback can help adapt the project at the design face and prevent issues. To reach common understanding, and potential agreement on reuse solutions, stakeholders (e.g., farmers) must be put in the shoes of the others (e.g., policymakers) and vice versa.

Participatory simulation of scenarios and role-playing games allow a group of stakeholders to simulate an existing or future situation or problem and to explore its potential solutions. Participants are placed in a decision-making situation in a controlled and safe virtual environment. They can play various roles different than their own, explore different scenarios and test solutions. During a debriefing phase at the end of the process, the participants have an opportunity to explain and analyze their choices in order to draw conclusions for real-life situations.

Role-playing games make it possible to simulate complex situations where power asymmetries are central. It's also a reference tool for exploring hidden knowledge (hidden strategies, illegal usages, etc.), since role-playing allows participants to step back in a secure environment.

While inadequate and negative terminology can impede clear communication, positive images and terms that enhance knowledge and understanding of water and wastewater can enhance the likelihood of success (Macpherson and Slovic 2008).

8.2.4. Communicate the benefits of water reuse and how risks are mitigated

Water reuse holds significant benefits for cities and rural agricultural areas and should be promoted. It improves water quality and increases its availability, benefiting the environment, especially aquatic ecosystems. Where possible, benefits for end-users and stakeholders should be quantified and preferably with an economic justification. This will provide tangible targets and set expectations. It is also valuable to communicate risk. A successful communication plan will include details on how risks are being mitigated. Communication between organizations and stakeholders builds trust and has a major influence on the level of support for water reuse projects.

BOX 8.3 Gender and water reuse

Thoughtful safety interventions must be gender sensitive. In many cultures, women carry the main responsibility for hygiene and health, and also with regard to water reuse, as reported in Jordan (Boufaroua et al. 2013), Vietnam (Knudsen et al. 2008) and Tunisia (Mahjoub 2013). The strong connection between water use at a household level and women offers a significant potential for innovative training approaches to improve the social acceptance of safe water reuse as recently demonstrated in Jordan (Boufaroua et al. 2013).

Gaining public acceptance is easier when the public is suffering from water scarcity and the need to conserve high-quality water sources for domestic purposes is established. In a sense, water reuse becomes a solution to a problem, rather than a problem (Fawell et al. 2005). However, good timing alone is not a guarantee of success, as the Toowoomba example showed. It will also require a sensitive approach to avoid a polarization of stakeholders in favor and against reuse.

8.2.5. Addressing possible religious concerns

Religious concerns were mentioned in surveys carried out in Islamic countries. The attitudes of Islam can be considered as an incentive for irrigation with reclaimed water although some farmers and rural dwellers might not be aware of this (Abu-Madi et al. 2009). In 1978, the Council of Leading Islamic Scholars (CLIS) in Saudi Arabia stated that treated wastewater can be used if its treatment included advanced technical procedures that remove impurities related to taste, color and smell (Faruqui et al. 2001). According to Farooq and Ansari (1983), there are three ways in which impure water may be transformed into pure water:

- self-purification of the water (for example, removal of the impurities by sedimentation);
- addition of pure water in sufficient quantity to dilute the impurities; and
- removal of the impurities by the passage of time or physical effects (for example, sunlight and wind).

It is notable that the first and third of these transformations are essentially similar to those achieved by wastewater treatment processes.

8.2.6. Facilitating behavior change

In many cases, increased education and risk awareness will not be sufficient to motivate the desired changes in behavior toward the adoption of, for example, safety practices. Economic incentives might be helpful in motivating farmers who are usually engaged in cash crop production, while consumers might respond better to social marketing, which aims to respond to inner desires, fears and motivations (Scott et al. 2007). Successes with social marketing, trigger studies and nudging have been reported to support the adoption of best practices (Drechsel et al. 2022). The need to change attitudes and behavior calls for a strong integration of social science research and related strategic partners and stakeholders in the

BOX 8.4 Odor and color matter

The physical properties of water are related to its appearance: color, temperature, turbidity, taste and odor. To be better accepted, water must be free from impurities that are offensive to the sense of sight, taste or smell. One very important physical characteristic that should be encountered when discussing water quality is turbidity – the amount of cloudiness in the water.

dialog with communities to balance the strongholds of engineering and public health experts to address possible adoption barriers and opportunities. In particular, these concern:

- public perceptions and group dynamics which can easily jeopardize any reuse project;
- educational levels which might be too low to understand risks and related responsibility; and
- the lack of economic or social incentives for changing practices (Drechsel et al. 2015).

8.3. Conclusion

Figure 8.2 presents a flowchart for establishing programs for stakeholder involvement along four phases of a planned reuse project from the first plan of study to the final implementation. All interactions are two-way communications, where the project is learning in the same way as the community members and have continuously to adapt the training to the feedback received to make this participatory process as successful as possible.

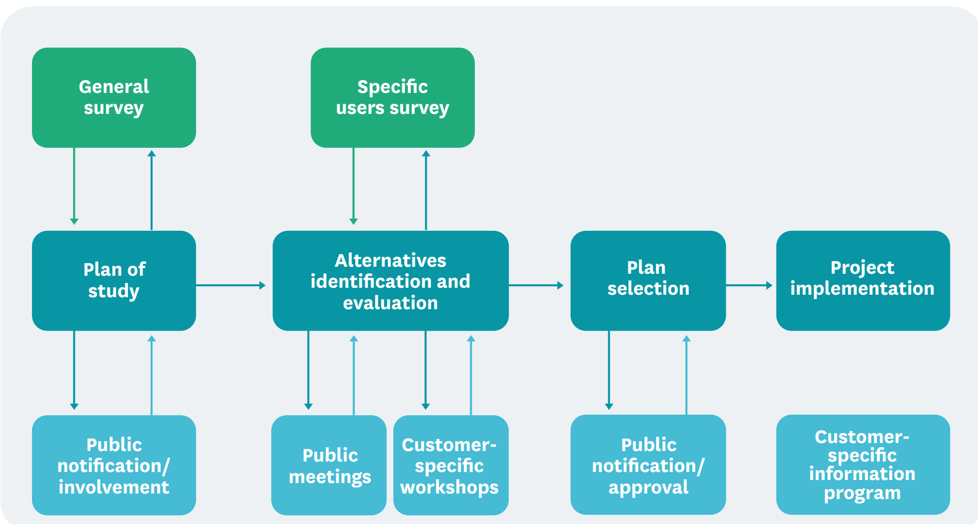

FIGURE 8.2 Strategy for public participation in planned water reuse.
SOURCE: Modified from WHO 2006; based on Crook et al. 1992 and Helmer and Hespanhol 1997.

The participatory process needs to be professionally facilitated. Facilitators may or may not be subject matter experts, but in any case, in their role as facilitators they should suspend their judgment. When facilitators act as water reuse specialists they should avoid providing technical advice on reuse. In the facilitation role, one should demonstrate the total opposite. Even though a facilitator may think to know, they are not supposed to show. Facilitators should ask and show interest in an honest way to get the best knowledge of individual participants in the group, and all of them equally, even though the facilitator may not even feel close to some. Facilitators should:

- adopt a two-way communication process to learn from the community how far adoption barriers can be addressed through information or require more customized approaches; like workshops analyzing, e.g., reasons for certain attitudes and behavior, to address them;
- use a positive terminology showing that reuse is solving community problems and not creating them;
- be sensitive to gender roles and religious arguments; and
- give due attention to national and international research ethics and obtain 'informed consent' from all participants taking part in interviews, focus group discussions or household surveys.

With due attention to research ethics, personal identifiable information should be kept protected and all responses anonymized. This should be explained while obtaining 'informed consent' and allow participants to express freely their thoughts. Thus, any data sharing from interaction with potentially vulnerable community members with third parties or in publications (including videos) is only permitted if the data are anonymized. This can be different for responses from public officials.

Participation and effective communication take time and resources but project designers need consider both when formulating and planning any water reuse project. These short-term investments will result in long-term dividends and lead to better acceptance and sustainability of the water reuse intervention.

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Chapter 9

Toward a more harmonious planning and governance of agricultural water reuse: Guidelines, practices and obstacles

Marie-Hélène Nassif and Mohamed Tawfik

Guidelines at a glance

- Ensure buy-in by the key national players around clear goals
- Establish multi-stakeholder platforms and welcome epistemic communities to facilitate
- Conduct a stakeholder mapping exercise
- Understand roles and responsibilities, gaps and overlaps
- Analyze stakeholders' influence and interest
- Clarify roles and responsibilities along six areas of prerogatives
- Establish central coordination and regulatory institutions
- Allow for flexibility in operation and cost-recovery mechanisms
- Empower stakeholders with existing know-how and political leverage
- Understand and re-negotiate local water rights
- Ensure access to information and data sharing between stakeholders
- Create a climate of trust and collaboration
- Develop the capacity of public utilities and local institutions

9.1 Introduction

Planning and managing agricultural water reuse projects come with an inherent complexity. They require harmonizing a multiplicity of decision-making processes and activities performed by stakeholders with different and often conflicting jobs, goals and interests.

The first challenge is that of water allocation among sectors/users. A wastewater treatment and water reuse system is part of the larger hydrosocial cycle, which connects different economic, social and cultural activities via waterflows (Boelens et al. 2016). The quantitative and qualitative access to water for existing users is impacted by treating wastewater discharged into waterways and reallocating it for reuse impacts.

Planning reuse projects or policies involves making difficult choices, which can disrupt existing water rights or political legitimacies linked to state authorities, municipalities, farmers or other social groups (Beveridge et al. 2017).

Secondly, like hydraulic systems, reuse projects can only work if socially accepted, technically reliable and profitable for farmers. This requires strong links between central administrations (and their donor partners) and local stakeholders to analyze local practices, develop appropriate infrastructure and negotiate adaptive management arrangements (Figure 9.1).

Thirdly, a reuse system creates an interdependency between two usually separate activities: wastewater treatment and crop production. These activities need to be synchronized, which requires negotiation and coordination between managers and users, often daily (Maaß and Grundmann 2018).

Finally, reusing treated effluents comes with concerns over the quality of the treated water and its potential negative impacts on health and ecosystems. It implies the intervention of health, agronomic and environmental institutions, which need to collectively develop regulations, monitor and enforce compliance and make trade-offs between safety and enforceability (see Chapter 5). In short, when planning and managing a reuse system, stakeholders will have to collaborate and find consensus – often for the first time – around and across different fields and scales.

In the MENA countries, water reuse projects and policies have been developing for few decades (see Chapter 1). Depending on their own institutional and political history, countries developed different institutional modalities for governing water treatment and reuse (see Chapter 3). Although considerable differences are noted between countries, administrations are generally found to be fragmented, competing and/or excessively centralized with weak involvement of local users (see Chapter 3; Ait-Mouheb et al. 2020; Eid-Sabbagh et al. 2022) and regulations unduly stringent and poorly enforced (see Chapter 5). Drawing from literature from international and MENA sources on water and water reuse governance, the following guidelines intend to guide MENA countries stakeholders toward more coordinated and inclusive planning, implementation and governance of agricultural water reuse systems.

This chapter is solution oriented and provides stepwise guidelines, tools and examples for consensus building. On the other hand, it shows that governance problems are often rooted in deeper socio-political structures that cannot simply be changed by implementing participatory processes and social engineering tools. Some examples identified in the MENA region will be cited to draw the attention on this type of challenges and to open the debate around the difficult question of reaching 'good water reuse governance' in the region.

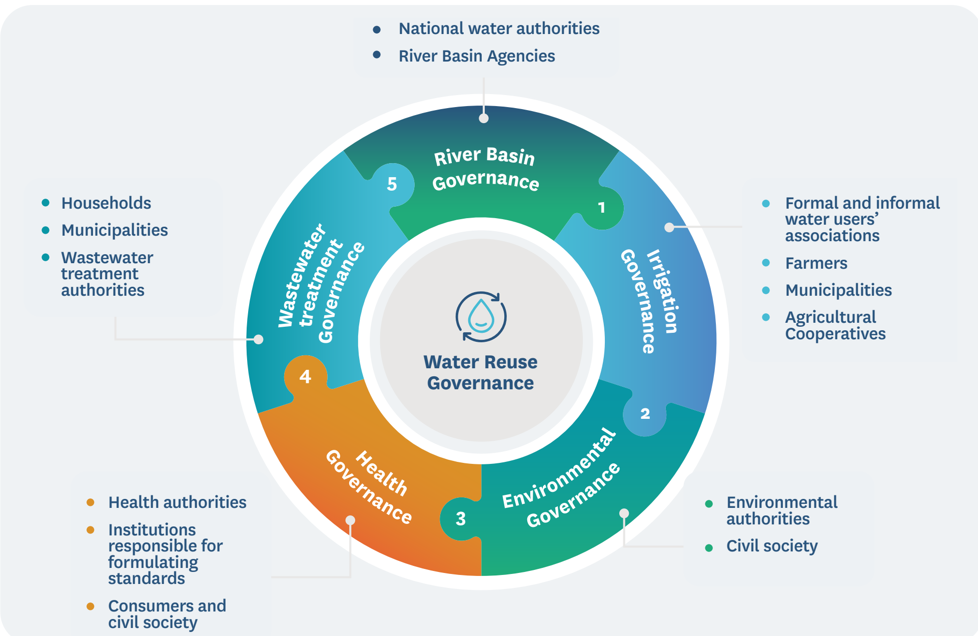

FIGURE 9.1 The large array of stakeholders involved in the governance of agricultural water reuse systems.

9.2 Practical steps in planning and governance of water reuse

9.2.1. Ensure buy-in by the key national players around clear goals

Planning a reuse project and initiating regulatory or institutional change related to water treatment and reuse can be a complex process. It involves many players with different jobs, interests and technical backgrounds. It often entails shifting patterns of quantitative and qualitative access to resources, adding new responsibilities on institutions or losing old competencies. This implies gains for some stakeholders and losses for the others, which can come with contestation, resistance and opposition (Beveridge et al. 2017). Hence, implementing water reuse projects or policies inevitably implies initiating discussions and negotiations at early planning and design stages among the various stakeholder groups at the different governance scales (Evans et al. 2010; Nassif et al. 2022).

At the very beginning, key players need to be willing to sit at the same table and work toward the same goal. There should be a clear intention to deploy efforts and resources to collaborate and eventually reach consensus. Hence, any such initiatives need to at least be supported by the legitimate national administrations.

This very first step is often the most challenging especially when projects are stimulated by external donor organizations, which is often the case in the region. National players may not be willing to collaborate simply because a project is virtuous or when political leadership is contested. An illustrative case was encountered in Lebanon when the International Water Management Institute (IWMI) proposed to facilitate a dialogue to develop agricultural reuse around the Sour/Tyr WWTP to reallocate the use of freshwater for drinking water use (Eid-Sabbagh et al. 2022). The planning institution (Ministry of Energy and Water) was supportive of the project, but this was not the case with its administrative subordinate the Litani River Authority (LRA). The LRA's opposition to the project and its capacity to block decisions can be explained by the fragmentation of power in the country and its reflection on state administrations (Nassif 2019).

If incentives can be created to bring stakeholders to collaborate, as we suggest in this paper, this is often constrained by deeper power contestations entrenched in societal structures. The following steps are to be read bearing in mind that instituting 'good governance' can be beyond the capacities of projects. Lobbying for better policies cannot be done without being aware of the political nature of water management (Molle et al. 2019). It is a long-term process which should start by bringing into light these types of challenges.

9.2.2. Establish multi-stakeholder platforms and welcome epistemic communities to facilitate

A multi-stakeholder platform (MSP) is a popular participatory practice that typically gathers stakeholders from diverse groups, willing to collectively work on water projects, policies or regulations (Warner 2005, 2006). It is conceptualized as a privileged space for multi-stakeholder input, debates and negotiation and can be conducive to consensus-building and conflict resolution (Cleaver 2001, 2017). MSPs can be established to gather the multiple stakeholders that need to coordinate around the development of water reuse projects and policies (Evans et al. 2010). When adequately designed and facilitated, MSPs can help projects avoid future stalemates through democratizing and legitimizing the decision-making process (Warner 2005, 2006; Graversgaard et al. 2017).

As seen above, institutional leadership and political legitimacy are important for such initiatives to take place. On the other hand, epistemic communities, or "communities of techno-scientific experts working to inform policy through their knowledge" are encouraged to facilitate or contribute to such participatory platforms (Bukowski 2016; Mabon et al. 2019). Furthermore, dialogues can be more successful when led by independent facilitators that bring together different stakeholders with divergent background and/or interests, a practice that has been growing in environmental projects around the world (Dionnet et al. 2017). While such expert-based leadership should not be regarded as always neutral or uncontested (Stone 2017), examples show that epistemic communities can lead effective policy building in adequate circumstances. For example, such initiatives were found to be successful with favorable historical context of locally led environmental science research, personal investment of the epistemic community members and regular dialogue between the epistemic community and local society (Mabon et al. 2019).

In Lebanon, Jordan and Egypt, several modalities of participatory initiatives are taking place around different topics related to water reuse projects and policies. In Jordan, the Royal Scientific Society (RSS), comparable to an epistemic community, was able to facilitate negotiations between the Ministry of Water and Irrigation and farmers to incentivize the use of a state-led water reuse project (Box 9.1). In Lebanon, IWMI supported the formulation of an MSP backed by national administrations to design adaptive qualitative water reuse regulations (Box 9.2). In Egypt, different focus groups were facilitated by the project and its partner, the International Center for Agricultural Research in the Dry Areas (ICARDA), to build consensus around the choice of direct and indirect reuse models. Other forms of local participatory platforms were also facilitated through ReWater MENA in Lebanon and Jordan to assess the cost and benefits and design different types of water reuse models.

9.2.3. Conduct a stakeholder mapping exercise

The processes of stakeholder engagement start with a thorough analysis of the existing actor networks. The first step is known as 'stakeholders mapping' and consists of an inventory of stakeholders either formally (legally) or informally in charge of the different aspects of wastewater treatment and reuse planning and management. In the MENA region, formal institutional frameworks tend to focus on state administrations and formal organigrams while in practice, community and private stakeholders are also key actors at many levels but are frequently unknown or not officially recognized (Cleaver 2002; Tawfik et al. 2021). These actors should be identified and ideally represented in the MSP in order to have a full view of the sector's governance and identify local knowledge and technical practices as well social dynamics.

BOX 9.1 The Royal Scientific Society of Jordan dialogue with the Ministry of Water and Irrigation with farmers

In the Northern Jordan Valley, the Royal Scientific Society (RSS), a local non-governmental research organization gathering a group of Jordanian researchers and experts, recently facilitated a dialogue between the Jordanian Ministry of Water and Irrigation (MWI) to incentivize indirect water reuse supplied by the 'As-Samra WWTP. The goal was to convince farmers to use the treated effluents instead of freshwater planned to be reallocated to domestic uses as per the Jordanian water substitution policy.

As an outcome of the facilitation process, it was agreed that the MWI will publish on regular basis water quality tests on a digital platform accessible to farmers, as water quality was found to be a major factor of concern for users.

BOX 9.2 A multi-stakeholder platform for qualitative standards in Lebanon

In Lebanon, the dispersion of prerogatives and lack of leadership for setting quality regulations for water reuse is some of the factors that constrain the development of official reuse standards. Recently, the Lebanese Norms Institutions (LIBNOR), a semi-autonomous public administration, took the lead of developing such standards as part of its mission of setting norms for the use of different products and economic services. Based on a thorough stakeholder's analysis, ReWater MENA helped set up an MSP different than the 'technical committee' usually engaged by LIBNOR. The group gathered specific representatives from different national ministries and regional water authorities and, importantly, local lab technicians and operators of WWTPs that were able to discuss the practical possibility of following the discussed thresholds for qualitative parameters.

A senior researcher from the Lebanese Agricultural Research Institute (LARI) was one of the MSP's important stakeholders and has been informing the debate with results of experimental field trials that brought local evidence on the possibility of irrigating vegetables with treated effluents from a WWTP located in central Bekaa. Research conducted by IWMI on local farming practices in the Bekaa Valley guided the discussion on the capacity of enforcing crop restrictions.

Identifying informal/socially embedded arrangements requires interviews and field work. It can be done through collaboration with public officials in local offices, civil society and community leaders. Since those arrangements occur at the intersection points with formal ones, local officials are often the ones working closely with the 'informal' actors to facilitate the implementation of their tasks (Barnes 2017; Cleaver 2002) or vice versa. In the Nile Delta in Egypt, for example, many types of informal treatment technologies were found to be built in collaboration with public officials living there (Reymond et al. 2010). In the Bekaa Valley of

Lebanon, officials from the regional state authority borrowed some equipment from municipalities to repair water networks (Nassif 2019).

9.2.4. Understand roles and responsibilities, gaps and overlaps

Mapping the different stakeholders is followed by analyzing their roles and responsibilities with relation to the planned water reuse practice (stakeholder analysis). Who is in charge of each of the different activities? Do some of the responsibilities overlap and how? Are there important activities that no one performs or where responsibility is not clear? It is also necessary to understand the stakeholders' administrative boundaries: at what scale do they intervene (e.g., national level, watershed, municipality, regional, local)? How do these scales overlap? These are important questions to address in order to anticipate how each stakeholder will be impacted by an intended policy or project intervention (e.g., 'plan a water reuse project', 'design an implementation plan for the management of a reuse system', 'formulate qualitative standards for water reuse').

Many methods and tools were developed to help decision-makers, planners and researchers conduct stakeholders' analyses of the water sector. A recent analytical tool was developed specifically for water reuse (see Chapter 3) adapted from Tawfik et al. (2021). The framework is divided into strategy and policy formulation, wastewater management activities (i.e., collection, treatment, discharge or transfer); water reuse management (i.e., license, approval and allocation); codes and standard and monitoring (Figure 9.2). Its purpose is to help identify existing gaps and overlaps between stakeholders (formal or informal) at the same governance scale (horizontal) and between institutions at different governance scales. It is recommended to complete this framework with different types of informed stakeholders to avoid assumptions or misunderstandings particularly in complex institutional contexts as in Lebanon and Egypt.

Wastewater management and reuse activities	**Strategy and policy formulation**	**Wastewater management (collection, treatment, discharge or transfer)**		**Water reuse (license, approval and allocation)**			**Codes and standards**	**Monitoring**
		Infrastructure development	Operation and maintenance	Industry	Agriculture	Urban (e.g., landscaping)		
Responsible institution								

FIGURE 9.2 Institutional mapping of governance activities.
SOURCE: Tawfik et al. 2021

9.2.5. Analyze stakeholders' influence and interest

Participatory processes often include a range of trade-offs among stakeholders. Therefore, it is important to analyze who may be better-off or worse-off as a result of the intended intervention and what are the relationships between the 'winners' and the 'losers'.

Project managers need to comprehend the influence, interest and power relations of stakeholders in addition to their technical roles and responsibilities. LISODE, a French-based consultancy service, proposed a simple way of studying actors' relations during the training for public participation provided to Lebanon public officials in the framework of ReWater MENA. It is a simple tool that allows the mapping of stakeholders in a diagram according to their 'Interest' and 'Influence,' where their position on the 'Interest' axis relates to how much the topic is important for them, while their position on the 'Power' axis shows their ability to influence the decision-making process (Figure 9.3) (Eden and Ackerman 1998). Other useful tools for stakeholders' analysis can be found in the online *Guide to public participation and facilitation* that helps designing participatory processes around the management of environmental resources management (Dionnet et al. 2017).

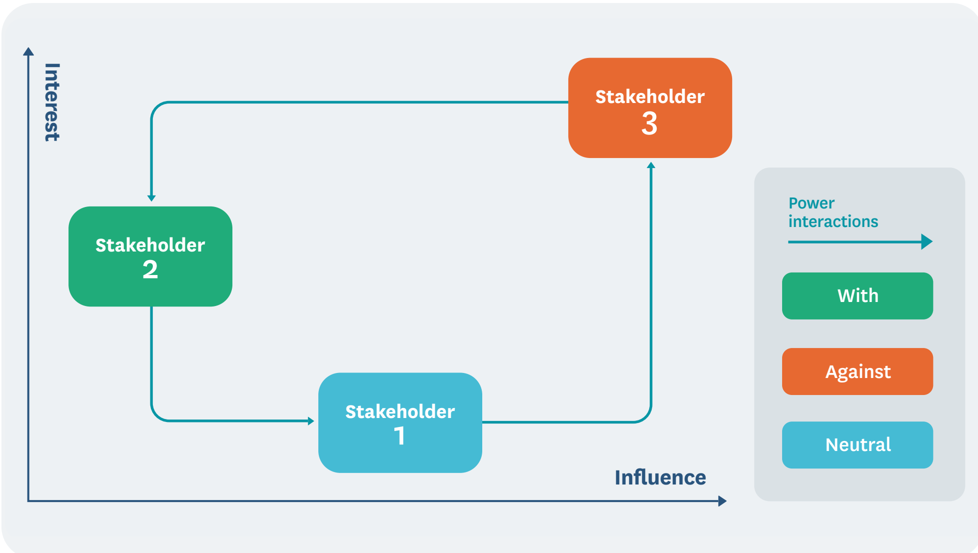

FIGURE 9.3 Analytical tool to assess stakeholders' interest, influence and power relations.
SOURCE: Adapted from LISODE 2019

9.2.6. Clarify roles and responsibilities along six areas of prerogatives

As simplified by Ait-Mouheb et al. (2020), ideally at least six management areas should be clearly assigned to specific stakeholders to ensure success of reuse projects and policies:

- who proposes and designs the basic socio-physical parameters of the project (i.e., location, surface area, beneficiaries, mode of water reuse);
- who authorizes the project after assessing its social desirability and whether it complies with existing regulations;
- who decides who pays what in upfront investments, operation and maintenance;
- who operates and maintain the project;
- who subsequently monitors water quality and its impact on soil, crops and human health; and
- who assumes responsibility of any unintended dispersion of contaminant?

There are many references on water reuse in MENA that document how project failure comes from the duplication and/or or gaps in institutional frameworks. Responsibilities overlap and accountability mechanisms are lacking, which leads to competition around some tasks and/or others being left unperformed (see Chapter 3; Ait-Mouheb et al. 2020; Choukr-Allah 2010; FEMIP 2009). Several political and economic factors can lie behind such (often depoliticized) institutional problems: competition around power, scale and resources, typically in infrastructure building and planning (e.g., between Ministry of Energy and Water [MEW] and Council for Development and Reconstruction [CDR] in Lebanon); inconsistency of donor-stimulated reforms (e.g., Egypt and Lebanon); lack of local legitimacy to levy fees and ensure system's operation (e.g, the case of the regional water establishments in Lebanon); and political protection of certain administrations from assuming legal responsibility over quality control of infrastructure or processes (in Lebanon) (see Chapter 3).

9.2.7. Establish central coordination and regulatory institutions

An independent arbitrator with sufficient political legitimacy to make things happen is required to develop sound decision-making between institutions, enhance integrated planning, and ensure mandates and regulations are adequately designed and implemented.

A researcher on the issue of implementing sound risk management safety plans in Jordan stated: "If there is no strong decision and follow-up from the Council of Ministers, administrations have no incentives to implement these extra tasks." Other experts recommend establishing independent regulatory and monitoring bodies to ensure good governance of water reuse and synchronizing the work of different administrations (Ait-Mouheb et al. 2020; EPA 2012).

Different types of regulatory bodies and mechanisms were institutionalized in MENA countries, often under donor-conditioned reforms. In 2004, the Egyptian government established the Egyptian Water Regulatory Agency (EWRA) for the regulation, monitoring and evaluation of all activities related to water supply services and wastewater disposal (Ménard 2022).

In Lebanon, the new, long-awaited 2018 Water Code proposed a Higher Water Council meant to coordinate the work between different ministries and involve municipalities and civil society (Riachi 2013; Eid-Sabbagh 2015; Nassif 2019). In Morocco, where institutions are also influenced by donor-oriented agendas (Tanouti 2017), a High Water and Climate Council and an inter-ministerial committee were established to ensure coordination and monitoring (Molle and Tanouti 2017).

Creating such legal entities does not guarantee their functionality. For instance, in Morocco, those two bodies were deemed largely ineffective (Molle and Tanouti 2017) In Egypt, the role of EWRA was hindered by the current overlapping responsibilities in the water sector and was found to be more 'ceremonial' than executive (see Chapter 3). In Lebanon, the High Water Council has been modified by parliamentarians to keep the power centralized in the hands of a few ministries (Eid-Sabbagh 2015). As rightly stated by a high-level official interviewed at the Ministry of Energy and Water, "Coordination is not complicated but there should be a will to coordinate" (Eid-Sabbagh et al. 2022).

9.2.8. Allow for flexibility in operation and cost-recovery mechanisms

Clear roles and responsibilities do not imply a rigid governance framework. Rather, it is important for the governance structure to be flexible enough to match the dynamic nature of water institutions especially in countries where community practices around water and wastewater management are longstanding. As proposed by Cleaver (2017), the "uneven patching together of old practices and accepted norms' would be a good framework for thinking about institutional design in MENA." This is particularly relevant for the tasks of operating small- to medium-sized decentralized reuse systems but can be extended to other tasks such as rule enforcement. While central/regional administrations need to be involved in large-scale planning, high-budget funding or issuing legal standards, planning and managing a reuse project (operation of a WWTP, fee collection, distribution of irrigation water) can be performed by different categories of stakeholders (regional authorities, municipalities, civil committees and private sector) and through a variety of institutional arrangements (EPA 2012).

In the MENA region, top-down oriented, state-centered approaches to water and wastewater management are still dominant (see Chapter 3). Planning, management and cost recovery are assigned to national or large-scale regional water authorities (regional water establishments in Lebanon, Water Authority of Jordan in Jordan, Holding Company for Water and Wastewater in Egypt) who often fail to levy tariffs, to guarantee a reliable operation and enforce regulations. In practice, other stakeholders such as municipalities or local water committees often take the lead in operating utilities, or even in securing funds and implementing infrastructure (Table 9.1). Building on the role that such actors already play or involving other community leaders has the potential to strengthen the governance of water reuse systems.

TABLE 9.1 Common community arrangements for wastewater and reuse management found in MENA.

Water Reuse System/ Wastewater treatment plants	De-facto performance of operation and maintenance (O&M)	Funding and cost-recovery mechanisms (de facto)	Official responsibility
Ablah Wastewater Treatment and Reuse Scheme – Lebanon	Municipality of Ablah through a local engineer closely cooperating with farmers	Infrastructure building funded by donor projects	Bekaa Water Establishment through wastewater tariff subscriptions
Fourzol, Ablah, Aitanit, Hammana and other municipal wastewater treatment plants – Lebanon	Municipality of Fourzol through local engineers	Municipalities use municipal taxes and funds	
Egypt decentralized sanitation systems in the Delta	Residents in collaboration with local officials with technical knowledge	Residents put funds in common to fund infrastructure and operation	Holding Company for Water and Wastewater (HCCW)

SOURCE: Eid-Sabbagh et al. (2022) for Lebanon; Reymond et al. (2014) for Egypt.

9.2.9. Empower stakeholders with existing know-how and political leverage

Planning the governance of a reuse system should build on existing practices in terms of technical know-how, local leaderships and more broadly collective action around water and wastewater management and reuse. Different factors should be considered to decide on the most effective institutional arrangements. It is important to consider institutions with political leverage and to build on existing historical expertise. For example, additional responsibilities may be assigned to different groups depending on their historical roles and technical and managerial expertise (EPA 2012). In the Settat Reuse Scheme of Morocco, the management of a reuse irrigation system was assigned to a water user association under the leadership of a local leader (Mayaux and Massot 2019).

Nevertheless, one should not fall into the 'local trap' that assumes that building on local institutions will naturally lead to the expected social and ecological outcomes (Purcell and Brown 2005). Empowering local actors should be studied with care and well accompanied. It should rely on an in-depth understanding of the existing social structures not to compound the vulnerability of certain groups, or delegate tasks undesired by local communities, as discovered in the case of the Settat scheme (Mayaux and Massot 2019).

Equally important, the involvement of local actors depends on the willingness of state authorities to share power and delegate some of their prerogatives (Pretty 1995). In several MENA countries, decentralization or participation in water management is often pushed by international donors' agendas and in different cases, it was seen that state authorities seemingly abide by these agendas but are often reluctant to institutionalize decentralization. This has been reported in Lebanon (Nassif 2019), Egypt and Morocco (Ghazouani et al. 2012) in the case of irrigation management transfer. Reluctance of state authorities to involve local communities in planning WWTPs was also seen in Lebanon (Eid-Sabbagh et al. 2022) and in Jordan, it was found that farmers have only a 'consultative' role in technical committees that design standards (see Chapter 5).

9.2.10. Understand and re-negotiate local water rights

Involving users and local leaderships is particularly important when planning water reuse and reallocation schemes among sectors and/or users/beneficiaries. Treating and redistributing effluents through a new reuse system need to be negotiated at multiple scales. While in this case consensus between key water authorities is a must, it is equally important to reach this consensus at the community level. This is particularly important where a reuse system would lead to changes in the current irrigation system, crop patterns and the economic feasibility of agricultural sector (Tawfik et al. 2021). In many documented cases in Lebanon, conflicts were identified between upstream and downstream farmers disputing access to treated water discharging from a WWTP into developed rivers. Old 'water rights' – in this case, local water allocation rules (legalized in the 1920s under French Mandate) – were used as an argument to justify priority to use the 'new' water (Eid-Sabbagh et al. 2022), although water allocation irrigation areas had substantially changed with the development of pumping and groundwater use (Nassif 2019). Similar arguments around the allocation of treated effluents in developed river irrigation systems have been identified in Settat and Marrakech in Morocco (Ait Mouheb et al. 2020; Mayaux and Massot 2019) and in Jericho in Palestine (Al-Khatib et al. 2017).

Analyzing how water is physically managed and socially perceived prior to reaching consensus around new allocation mechanisms were two substantial steps for designing a local reuse system in central Bekaa, Lebanon (Box 9.3). Different tools can be used to accompany users toward building consensus around shared environmental resources such as role-play games that simulate water use in the targeted river or sub-river basins and help farmers understanding their mutual perspectives and impacts of the problem (Figure 9.4).

FIGURE 9.4 Board of the role-play game prepared to design reuse systems around Zahleh and Ablah WWTPs. *SOURCE*: LISODE 2020.

BOX 9.3 Consensus-building around water allocation mechanisms to design a local water reuse system around Zahleh WWTP (Lebanon)

Zahleh WWTP (25,000 m^3/day) is located in the largest agricultural plain of Lebanon in a heavily exploited river basin where irrigation systems exist for centuries. Zahleh WTTP's tertiary-treated effluents discharge in the Litani River Basin and are now partially and informally reused by large land and well owners that pump it in the summer to reduce the cost of vegetable irrigation from deep wells.

Storing and distributing the WWTP's effluent in an organized system has the potential to provide supplementary irrigation for around 100 farmers and 500 ha of land. However, many community-based irrigation system co-exist in the command area and different farmers claim their 'water right' to use the effluents.

The co-design of a water reuse system was one of ReWater MENA's local pilots in Lebanon. A three-year participatory study allowed the mapping of the socio-technical arrangements around the WWTP and proposal of different scenarios to redistribute the effluents. In November 2021, the various farmer groups, as well as WWTP operators, Zahleh municipality and other stakeholders met around these different scenarios and reached a consensus. The treated effluent would be distributed to downstream farmers in the spring irrigation season and pumped in the summer to Zahleh farmers.

9.2.11. Ensure access to information and data sharing between stakeholders

Public participation in decision-making processes can only be meaningful in the presence of full access to relevant information. The *Manual on the human rights to safe drinking water and sanitation for practitioners* recommends sharing all relevant technical details of water and sanitation services, not only related to water quality, but also related to costs, budgets and operation of treatment facilities (Bos 2016). The manual recommends that details and procedures of data sharing be incorporated in the regulatory frameworks as well as contractual agreements between public authorities and/or service providers, including aspects of rights and responsibilities of individuals and institutions.

9.2.12. Create a climate of trust and collaboration

Coordination is based on trust and is only meaningful if stakeholders regularly communicate and work together. Success stories from other countries showed that a day-to-day, less formal means of collaboration builds trust between actors. For example, it was found that formal and informal engagement activities centered on risk management of a reuse scheme in London supported the development of common understandings, built important inter-stakeholder relationships and helped maintain trust (Goodwin et al 2017). In Braunschweig (Germany), informal discussions and negotiations between employees distributing reclaimed water on the field and farmers was also found to be crucial to adjusting water schedules (Maaß and Grundman 2018). This was also found in the case of a reuse scheme in the Bekaa Valley of Lebanon where, even in the absence of a formal governance framework for reuse, water schedules are decided jointly by the technician working at the WWTP and farmers (Eid-Sabbagh 2022).

9.2.13. Develop the capacity of public utilities and local institutions

Finally, funds and efforts need to be directed to strengthen both community-based (municipalities, farmer committees, etc.) and state institutions at different scales and with different expertise. While non-party stakeholders (NGOs, epistemic communities and private sector) can stimulate and/or contribute to different components of policy and project design and management, this cannot be effective if public administrations are not financially, institutionally and technically equipped. For example, the Private Public Partnerships (PPP),[1] attempted in the sector to fill technical and efficiency gaps in public utilities were often unsuccessful because of a lack of proper monitoring from the side of the governmental agencies (see Chapter 3; Reymond 2020; Eid-Sabbagh 2022). Moreover, many governance tools proposed in this chapter can only be truly useful if incorporated and transferred through long-term institutions anchored in society with legal or social legitimacy to lead more collaborative and accountable forms of governance.

[1] PPPs were not addressed in this paper but this type of governance mechanism, which is widely promoted in MENA deserves, to be critically assessed.

9.3. Conclusion

To harmoniously plan and manage reuse policies and projects in MENA and beyond, various central ministries, regional authorities and community institutions need to develop coordination instruments across different fields and scales. These guidelines provided a framework for action to improve stakeholder engagement, collaboration and consensus-building and documented past and current participatory practices around different policy or project design initiatives. They illustrate that thinking and practices linked to stakeholder participation are expanding in the region, essentially fueled by research and development projects.

Many multi-stakeholder platforms and participatory processes have recently been established to design context-based water quality standards, negotiate water allocation mechanisms and create incentives for farmers to use new reuse projects. While these initiatives are undoubtedly useful, they often encounter resistance. They were constrained by inter-administrative competition, technocratic decision-making, lack of knowledge of local practices and reluctance to involve users in policymaking processes.

By nature, power structures and social histories constrain social engineering approaches. To be useful, we recommend that such types of initiatives be duly documented and critically analyzed. This is an important step, we argue, toward opening the debate around the socio-political factors underlying the often-deplored institutional fragmentation in MENA countries.

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Section 3
A selection of outstanding water reuse cases in MENA

Introduction

Javier Mateo-Sagasta

The MENA region has been proactively investing in water reuse in the last decades. According to the ReWater MENA database the number of water reuse projects has doubled every decade since the 1990s. In the 19 MENA countries that were analyzed the number of reuse projects has specifically grown from 40 in 1990, reusing a total quantity of 0.421 billion cubic meters (BCM); to 97 projects in 2000 (0.655 BCM directly reused); 200 in 2010 (with 1.249 BCM); and finally, 409 in 2020 (with 2.275 BCM) (Figure S3.1). In the last decade, the growth in the number of projects of direct water reuse has been particularly high in countries like Saudi Arabia, United Arab Emirates, Qatar, Oman, Egypt, Algeria or Morocco.

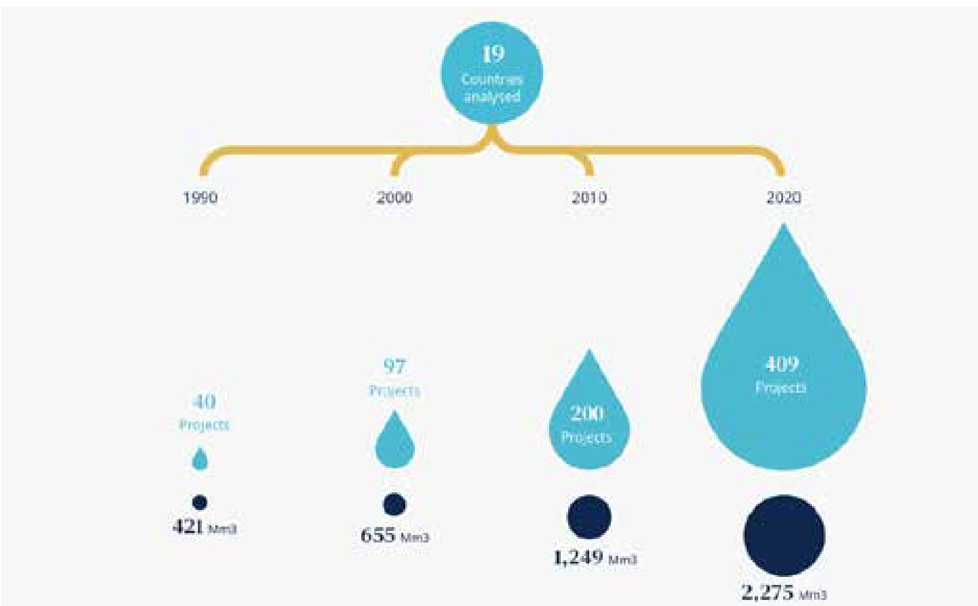

FIGURE S3.1 Evolution of direct water reuse in MENA; the number of reuse projects.

Nevertheless, the spread of projects on direct water reuse is uneven across the MENA region even though the region is one of the most arid and water-scarce regions in the world. Some countries, such as Jordan and Tunisia, promote wastewater treatment and reuse as an integral component of their water management strategy. Other countries, such as Lebanon, have not given priority to wastewater treatment or reuse.

Although water reuse in the region is currently limited, there are noteworthy water reuse success stories at different scales. Factors that contribute positively are political will and support, participatory stakeholder processes, economic and finance models, flexible reuse safety plans, effective policies, innovative partnerships, technologies and cost-effective investments that promote reuse. This body of knowledge provides opportunities for cross-learning to find solutions for common regional reuse challenges.

The dominant uses of reclaimed water are for forestry, agriculture and landscaping, including irrigation of parks and gardens. Each country of MENA has invested in different typologies of water reuse that best suit its needs and constraints. Forestry and agriculture are the dominant users of reclaimed water for example in Egypt, Tunisia and Jordan while landscaping is the preferred option in countries like Morocco, United Arab Emirates, Oman and other GCC countries. The pattern in other areas is not so clear with a more mixed project portfolio. These patterns are a consequence of different factors, including perceptions about reuse, the quality of the effluents and the different policies and legislations that have been shaped across the region.

The presence of water reuse projects for other purposes such as industrial use, non-potable urban use, aquifer recharge or environmental restoration are scattered and much less frequent.

In this section we have characterized in detail several key water resource projects from Morocco, Tunisia, Jordan, the West Bank and United Arab Emirates (Figure S3.2). The objective of this task is to make a full characterization of selected reuse cases, document the key factors that made them a success and the lessons learnt when things did not go well.

We selected nine case studies out of the 409 projects that ReWater MENA identified. The nine case studies met the following criteria:

- Have operated at scale for at least two years
- Have sufficient data available and accessible
- Are financially sustainable
- Generate positive social externalities
- Ensure human health protection and
- Generate positive environmental externalities

The selection also considers a balanced geographical distribution of cases that capture the regional differences and socioeconomic contexts.

Case studies 1 and 2 examine wastewater treatment plants (WWTP) in Morocco. The first study examines a WWTP which serves a million inhabitants of Marrakech. The WWTP has made it possible to use recycled water in novel and innovative ways including to irrigate golf courses, green landscaped areas, the palm grove and 26 gardens and parks in Marrakech city. It has been successful in offsetting a water deficit in the Tensift basin and alleviates pressure on conventional water sources. The reuse of this water, which is treated to a very high standard, is contributing to the health of the people and the environment.

The second case study in Morocco looks at the Boukhalef WWTP, which was constructed to increase capacity in wastewater treatment and to provide irrigation water for green spaces in Tangier city. Operational since 2015, the plant saves nearly 3 million m^3/year of water and improve the health and living environment of residents and bring additional benefits for promoting tourism.

Case studies 3 and 4 present examples of WWTPs in Tunisia. The Sfax Sud WWTP serves a population of around 526,800 people and is located 6 km south of Sfax city. Water from the WWTP is used to irrigate the public irrigated perimeter of El Hajeb, an agricultural area of 444 hectares.

The second case study in Tunisia is similar to the first as recycled water from the Ouardanine WWTP is used in the Ouardanine public irrigated perimeter. The 74 hectares of the perimeter is owned by 42 farmers. The Ouardanine perimeter is an active location for scientific research and studies on irrigated agriculture in Tunisia and the first at the national level to use sludge as organic fertilizer.

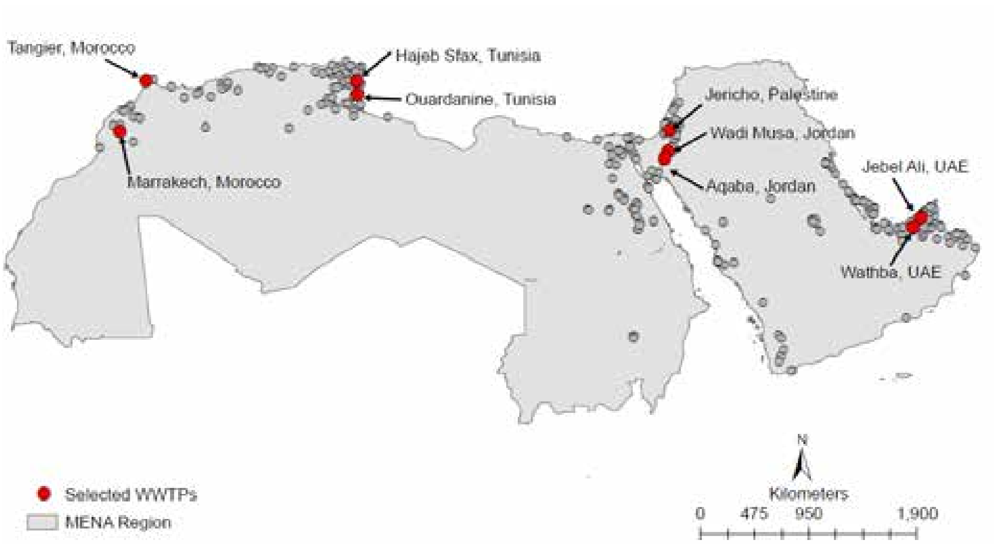

FIGURE S3.2 Selected cases of water reclamation and direct reuse for productive purposes in the MENA region.

Case study 5 provided an in-depth analysis of the Jericho WWTP in Palestine. The Jericho WWTP started operations in June 2014 with the dual purpose of treating wastewater generated in the area and providing recycled water as a new source of irrigation water for date palm cultivation. The Jericho WWTP provides an attractive new non-conventional water resource that is already almost fully utilized for supplementary irrigation on date palm farms, representing 8–25% of the total irrigation water used for date palm cultivation in Jericho.

Case studies 6 and 7 are from Jordan. Tala Bay WWTP started operations in 2005 to supply recycled water from the plant for use around the Tala Bay Hotels and Resorts complex to irrigate the landscaped spaces, for example, green areas and gardens. The water is pumped from the storage tank to be reused in different ways around the resort such as for the sprinkler systems to irrigate the green areas in the resort or to the drip network to irrigate the trees. Some of the recycled water is pumped to nearby hotels such as the Mövenpick Resort and Spa.

The Wadi Musa WWTP in the southern part of Jordan, close to the historic city of Petra, is owned by the Aqaba Governorate. It started operations in 2001 to serve 20,000 inhabitants and treat collected wastewater from hotels in Petra and nearby residential areas. The recycled water is used to irrigate an area used to grow alfalfa. It is the first community-based project established in Jordan.

Case studies 8 and 9 look at WWTP in the United Arab Emirates. In 2011, two new treatment plants and facilities were constructed to boost wastewater treatment services in Abu Dhabi city and the surrounding areas. The Al Wathbah-1 and Al Wathbah-2 WWTPs were designed to fill gaps in existing treatment facilities caused by the increased volume of wastewater and to produce recycled water to use as irrigation water for farms, parks, green areas and similar around Abu Dhabi as part of sustainable water resource management activities. The catchment area for Al Wathbah-2 is below sea level. This has led to seepage of seawater into the collection network and results in high levels of salinity which is reflected in the salinity levels of water produced at the plant.

The Jebel Ali WWTP is the largest state-of-the-art plant in the United Arab Emirates and is located close to the city of Dubai. Water treated at the plant can be reused for non-potable applications across the Emirate of Dubai, with tertiary treated water mainly used for agricultural purposes. When combined with existing facilities, Jebel Ali WWTP will be providing sewage treatment for more than half of Dubai's 3.5 million population.

Case Study 1: Morocco

Marrakech wastewater treatment plant and urban landscaping

Brahim Soudi and Adil Daoudi

Acronyms

ABH	River Basin Agency
PNE	National Water Plan
RADEEMA	Water and Electricity Distribution Authority of Marrakech

History and project justification

The Water and Electricity Distribution Authority of Marrakech (RADEEMA) has invested in efforts to collect and treat wastewater and exploit its reuse including from the Marrakech Wastewater Treatment Plant (Marrakech WWTP). Faced with a water deficit in the Tensift basin and to alleviate pressure on conventional water sources, this investment has made it possible to use this recycled water in novel and innovative ways including to irrigate golf courses, green landscaped areas, the palm grove and 26 gardens and parks in Marrakech city. The reuse of this water, which is treated to a very high standard, is contributing to the health of the people and the environment having achieved a water pollution control rate of more than 95%.

The reuse project is located 13 km from Marrakech while the Marrakech WWTP, which serves 947,331 inhabitants of Marrakech city, is located northwest of the city, on the left bank of Tensift River (Figure 1.1). The plant has been operational since 2010 and has undergone several phases of development since its inception (Table 1.1).

Reuse case description at a glance

The Marrakech WWTP started operations in 2010 and serves almost a million inhabitants of Marrakech city. In 2020, it had a capacity of 102,186 m^3/day achieved through a wastewater collection and transport network of over 3,000 km, which uses a mix of gravity and pumping stations – there are 21 pumping stations in total.

The plant uses an activated sludge treatment system and treats the water to a tertiary level. The recycled water it produces is used to irrigate green spaces and golf courses around Marrakech City (Figure 1.2).

FIGURE 1.1 Map showing Marrakech WWTP and reuse project areas.
SOURCE: Google Earth Marrakech WWTP: 31° 41' 46'' N, 8° 03' 36'' W (14/12/2015).

A solar sludge drying station was set up in May 2018 (Image 1.1). It includes 40 greenhouses (each one is 1,440 m²). Twenty-eight of the greenhouses for solar drying are equipped with high-precision equipment for turning and aerating sludge, enabling the dryness of the extracted sludge to reach 80%. Using solar power saves 5 MW of thermal energy daily.

The reuse network was initially designed to serve 20 golf courses in Marrakech and the palm grove. Currently it serves 14 golf courses, providing 8 million m³/ year of recycled water (Image 1.2). The total volumes guaranteed by RADEEMA are 84,000 m³/ day.

National institutional and policy environment

The current policy framework in Morocco is supportive of this water reuse project, including its replication and scaling as part of a strong promotion of water reuse, which is included in

TABLE 1.1 Chronology of the development of the Marrakech WWTP.

Period	Installed structures and expansion components
1998	RADEEMA takes over management of the liquid sewerage network
2000–2008	Master plan studies carried out. Restructuring, re-installation and rehabilitation of the sewerage network. Removal of all raw discharge points into the natural environment. Construction of the Marrakech WWTP (Primary Treatment) with a capacity of 117,940 cubic meters (m³)/day equivalent to a population of 1,300,000
2009–2015	Continuity of restructuring work, re-installation and rehabilitation of the sewerage network. Realization of the secondary and tertiary treatments. Construction of the reuse network comprising five pumping stations and a total distribution network of 80 km
From 2018	Continuation of work on the restructuring, re-construction and rehabilitation of the sewerage network. Expansion of Marrakech WWTP to a capacity of 143,606 m³/day equivalent to a population of 1,750,000. Realization of a solar drying unit of sewage sludge with a treatment capacity of 205 tonnes/day of sludge collected at 22% dryness

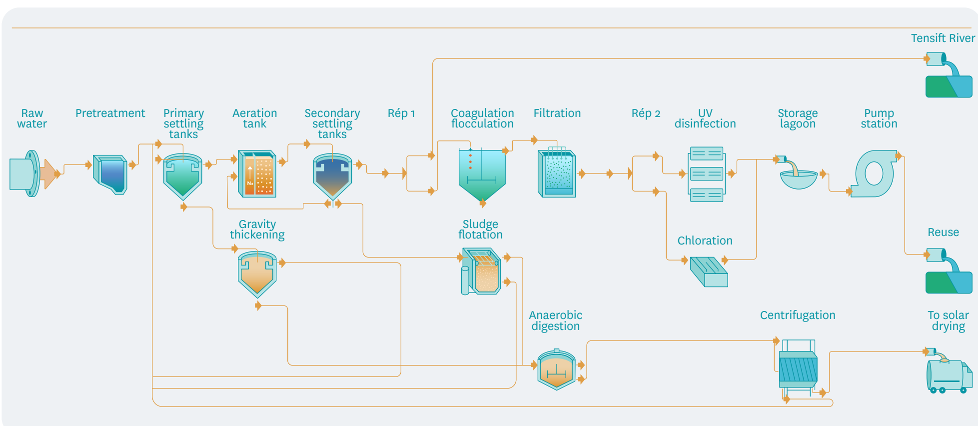

FIGURE 1.2 The Marrakech WWTP and water reuse project: Schematic diagram.
SOURCE: B. Soudi, Institute of Agronomy and Veterinary Medicine.

many policies, plans and programs (the National Water Strategy, the National Water Plan, the National Shared Sanitation Plan and the Emergency Drinking Water Supply and Irrigation Program (2020–2027). In addition, national integrated water resource management plans integrate reuse on the scale of river basins.

However, the governance of the project faces some difficulties (Figure 1.3), particularly in terms of intersectoral coordination and regulatory gaps. These include the definition of standards for sewage sludge recovery and the risk of non-financial viability of public partnership contracts agreed between the municipality and RADEEMA, the sanitation operator. From a technical point of view, these contracts do not clarify the sharing of responsibilities, in partic-

IMAGE 1.1 Solar sludge drying station.
SOURCE: RADEEMA.

IMAGE 1.2 Distribution of golf course irrigation and implementation progress.
SOURCE: RADEEMA.

ular concerning the quality of the recycled water used to irrigate golf courses which is prone to deterioration.

Other ministerial departments including the Ministry of Health and the Ministry of the Environment, as well as several water commissions, are also connected to this institutional scheme with territorial and regional representative entities including the National Office of Electricity and Drinking Water (ONEE-Water Branch), public service operators such as RADEEMA for Marrakech and private concessionaires.

Water recovery and reuse are also subject to regulatory compliance (Table 1.2).

Stakeholders involved and management model

As noted above, the guidelines issued at the national level encourage the use of unconventional water resources, particularly in water basins with a water deficit, as in the case of the

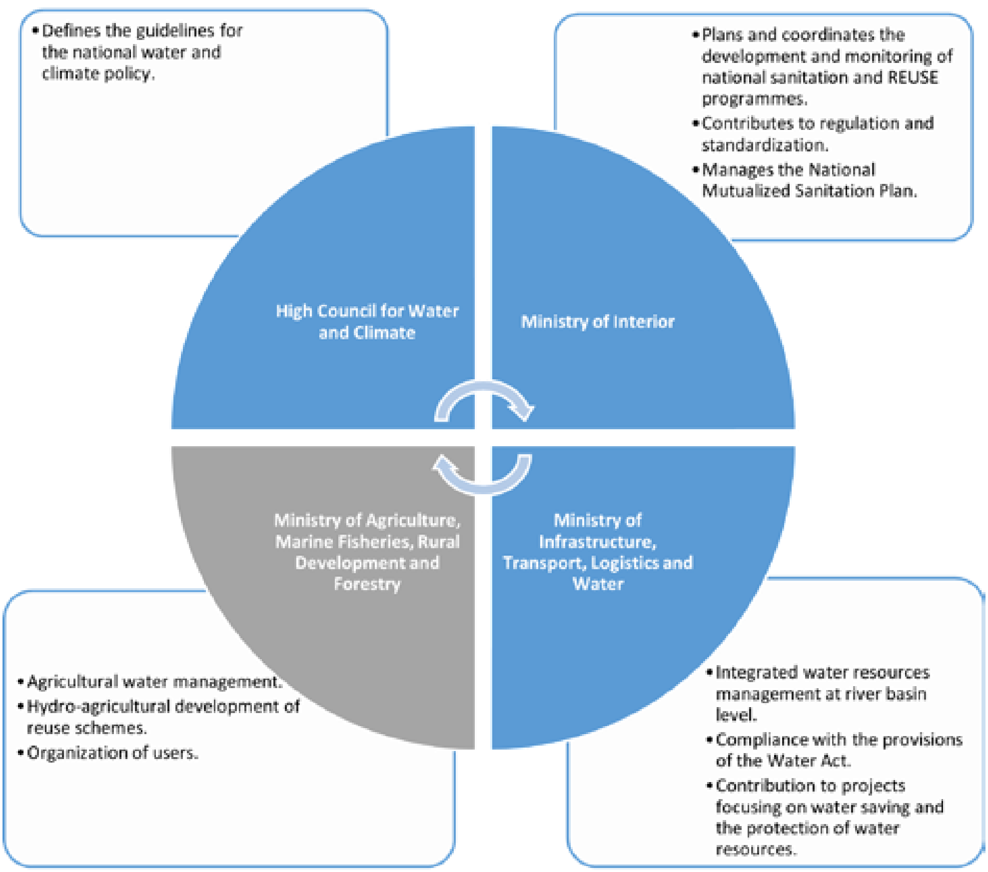

FIGURE 1.3 Key institutional players for wastewater treatment and reuse.
SOURCE: B. Soudi, Institute of Agronomy and Veterinary Medicine.

Tensift Basin. This strong policy framework has resulted in the strong commitment and mobilization of all stakeholders involved in the project.

The case of Marrakech is presented as two components (Figure 1.4): the first presents the irrigation component of golf courses, which is already operational, while the second presents the component of green landscaped areas and palm groves, which are under the process of operationalization.

The public-private partnership agreement is between RADEEMA (the public partner) and the golf course promoters (the private entities) whose roles are specified below. The Wilaya (the territorial administrative division) approves this partnership agreement, which includes a requirement for a monitoring committee made up of the Wilaya, representatives of RADEEMA and the Regional Investment Centre.

RADEEMA manages both wastewater treatment and wastewater distribution ensuring that it meets quality standards. Four other entities participate in the financing of the reuse project including the municipality of Marrakech, which is in charge of the management of the green landscaped areas and the palm grove. Three other institutions (Mohamed VI Foundation for the Protection of the Environment; the Directorate of State Domains and the Observatory of

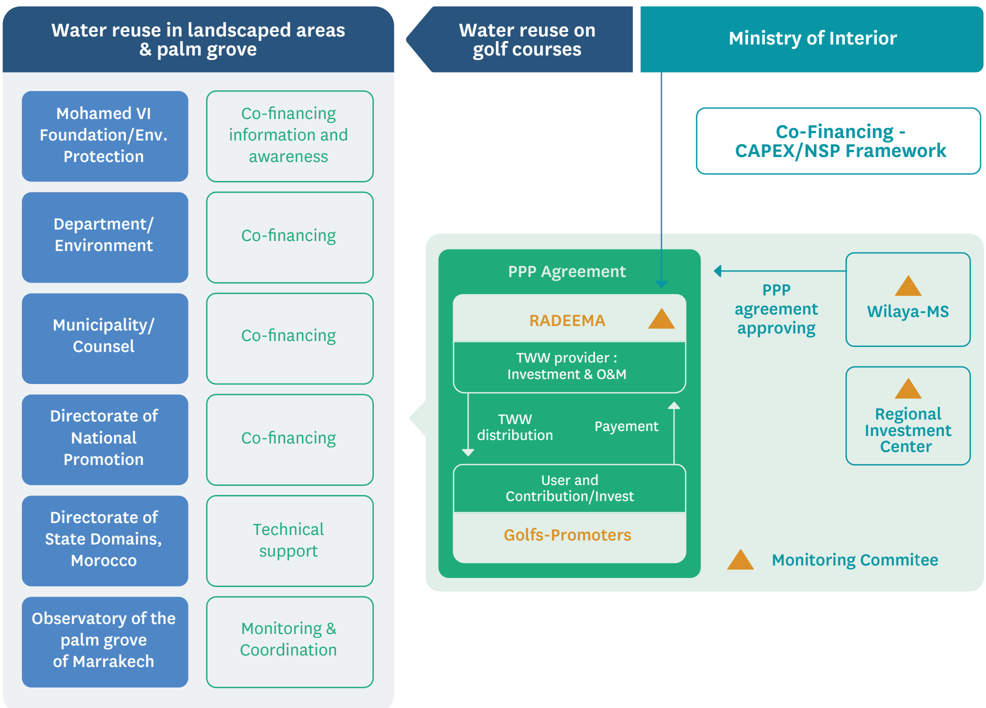

FIGURE 1.4 Stakeholders and management model.
SOURCE: B. Soudi, Institute of Agronomy and Veterinary Medicine (according to the stakeholders' engagements in PPP agreement).
NOTES: Marrakech SAFI (MS), National Sanitation Plan (NSP), Operations and maintenance (O&M), Public-Private Partnership agreement (PPP), Treated wastewater (TWW).

the Palm Grove of Marrakech) are responsible for information awareness, technical support, and monitoring and coordination, respectively.

In this configuration, it is important to note that the Regional Council of Tourism for Marrakech is not included in the partnership even through it promotes golf for tourism as it was not part of the stakeholder group when the original projects were started.

Funding and financial outlook and cost recovery

Since 2000, the Marrakech Wastewater Treatment Plant and Urban Landscaping Water Reuse project has been carried out in three main stages at a total cost of USD 252 million. The first phase, consuming 32% of the total cost of the project, was dedicated to the master plan of the city, including the realization and extension of the collection network and the initial construction of the treatment plant. The largest part of the total amount was dedicated to the second part of the project, to complete the treatment process of the plant and the water distribution network to enable the reuse of the recycled water. The remainder was invested in the extension of the treatment plant and the reuse network, as well as the solar sludge drying unit. The Ministry of the Interior co-financed the entire project within the framework of the National Sanitation Plan (Table 1.3).

TABLE 1.2 Regulatory texts relating to the recovery and management of wastewater in Morocco.

Law, decree or order	Arrangement
Decree n°2-05-1534 du 21 Chaoual 1426 (November 24, 2005) on the terms and conditions for the preparation and revision of the PDAIREs and the Nation Water Plan (PNE). Official Bulletin No. 5562 of 20/09/2007. Included in the new law 36-15.	The preparation of the draft master plan for the integrated development of water resources (PDAIRE) is entrusted to the River Basin Agency (ABH) of each basin in consultation with the other stakeholders in the field of water. Among the components of the master plan are the plan of its financing and the action plan for monitoring its implementation. The draft of the PNE is drawn up by the Minister responsible for water in consultation with the other ministerial departments and institutions that are members of the Higher Council for Water and Climate under the conditions specified in numerous articles of the same decree.
Decree n°2-05-1533 du 14 Moharram 1427 (13 February 2006) on autonomous sanitation. Official Bulletin No. 5404 of 16/03/2006 (Article 4).	Any installation of an autonomous sanitation system in rural areas is to be declared to the technical services of the municipality.
Decree n°2-97-224 du 21 Joumada II 1418 (October 1997) laying down the conditions for the artificial accumulation of water. Official Bulletin No. 4532 of 06/11/1997.	Articles 2 and 3: Artificial accumulation of raw wastewater shall be permitted only if it is an integral part of a system for treating such water, approved by the water basin agency concerned. The application for authorization is addressed to the corresponding ABH.
Decree n°2-97-875 du 6 Chaoual 1418 (04 February 1998) on the use of wastewater. Official Bulletin No. 4558 of 05/02/1998 (under revision) Articles 1; 2; 10; 11 and 12.	It is forbidden to use wastewater unless it is declared treated in accordance with the standards. It is also forbidden to use wastewater, even if treated, for drinking, preparation, packaging or preservation of products or foodstuffs. The conditions of application and the criteria used to benefit from the financial assistance are regulated and the application is filed with the ABH.
Joint Order n°1276-01 du 10 Chaabane 1423 (17 October 2002) setting standards for the quality of water intended for irrigation. OB No. 5062 of 05/12/2002 (under revision).	Treated wastewater whose reuse is thus authorized must meet the quality standards set by this Order laying down the quality standards for water intended for irrigation.

In 2014, the operating expenditure (OPEX) was USD 1.2 million and fluctuated between USD 2–2.2 million between 2014 and 2018. Cost recovery is secured through sanitation tax integrated into the drinking water and electricity bill. Additionally, golf promoters have agreed to pay USD 0.25 (MAD 2.5)/m³ of recycled water used on their courses to cover part of the OPEX that relates to tertiary and complementary treatments. Capital expenditure (CAPEX) includes sources of investment coming from a combination of subsidies and public-private investments (Tables 1.4 and 1.5).

TABLE 1.3 Funding and financial outlook and cost recovery.

Period	Installed structures and expansion components	CAPEX	Stakeholder that delivers the service	Co-funding
2000–2008	Carrying out master plan studies. Restructuring, re-installation and rehabilitation of the sewerage network. Removal of all raw discharge points into the natural environment. Construction of the wastewater treatment plant (Primary Treatment) to a population capacity of 1,300,000.	USD 82.5 million	RADEEMA	Government/Ministry of Interior
2009–2015	Continuity of restructuring work, re-installation and rehabilitation of the sewerage network. Realization of the secondary and tertiary treatments. Construction of the reuse network comprising five pumping stations and a total linear network of 80 km.	USD 0.16 billion	RADEEMA	Ministry of Interior in the framework of the National Sanitation Plan
From 2018	Continuation of work on the restructuring, re-construction and rehabilitation of the sewerage network. Expansion of the WWTP to a population capacity of 1,750,000. Realization of a solar drying unit of sewage sludge with a treatment capacity of 205 tons/day of sludge at 22% dryness.	USD 9.92 million	RADEEMA	Ministry of Interior in the framework of the National Sanitation Plan

TABLE 1.4 Sources of funding 2009–2018.

Sources of investment	Budget (USD Million)
State subsidy under the NAP (National Sanitation Plan)	16.5
Financing by RADEEMA	65.45
Golf Promoter Funding (2012–2016)	53.46
Total	135.41

SOURCE: Soudi, B. (For SWIM-H2020). Data provided by the RADEEMA (2018).

Socioeconomic, health and environmental benefits and impacts

The project has put in place the infrastructure to reuse 24 million m^3/year of recycled water from wastewater treatment plants. This represents the amount of drinking water needed in a city of 700,000 inhabitants, and as such contributes significantly to reducing the water deficit of the Tensift basin, estimated at 200 million m^3/year.

The water reuse project has also created jobs in the field of sanitation and boosted the economic activities of businesses and tourism through increased investments, for example, in golf courses in Marrakech.

Climate and environmental benefits include a reduction in greenhouse gas emissions equivalent to 80,000 tons of carbon dioxide through the use of biogas generators and solar energy to dry the sewage sludge, which saves 120 MW/day. Sewage sludge is also recovered during the cement manufacturing process of which 50 t/day is used in its dried form to replace 18 t/day of petroleum coke in the cooking line of the clinker – the equipment which is used to make cement.

Gender equality

Over the past decade, Morocco has made considerable progress in terms of gender-sensitive democratic governance, which was institutionalized in 2014. Its government has recognized women's economic empowerment is a key pillar for achieving gender equality, considering women's economic, social and political empowerment as one of the foundations of the rule of law. To this end, on the path of modernization and democratization, the Ministry of Economy,

TABLE 1.5 Contributions to infrastructure for green landscaped areas and palm grove reuse.

Partners	Contribution
Mohamed VI Foundation for the Protection of the Environment	USD 0.71 million (with a deduction of 4% for the financing of information and awareness-raising campaigns)
Wilaya of the Region of Marrakech – Safi	Administrative supervision, technical follow-up and coordination
Direction Générale des Collectivités Locales (DGCL from the Ministry of Interior)	USD 0.55 million of which USD 0.25 million is paid to RADEEMA on the signing of the agreement
Department of Environment	USD 0.27 million of which USD 0.1 million is paid to RADEEMA on the signing of the agreement
City Council of the city of Marrakech	USD 0.38 million
RADEEMA	USD 0.84 million
Directorate of National Promotion	USD 1.35 million
Directorate of State Domains, Morocco	Technical support and land
Observatory of the Palm Grove of Marrakech	Monitoring and coordination
Total	USD 4.07 million

SOURCE: Soudi, B. (For SWIM-H2020). Data provided by the RADEEMA (2018).

Finance and Administration Reform has made great efforts to institutionalize gender equality in the public service.

At RADEEMA, there is a program that targets groups including women, young people and children, to raise awareness about career opportunities in the treated wastewater sector. In March 2021, a new woman Director General of RADEEMA was appointed, providing a strong role model for other women.

Resilience to COVID-19

Overall, the impact of the COVID-19 pandemic on the Marrakech WWTP and water reuse project was limited with water treatments including chlorination ensuring that any water reused in green areas and golf courses could not contain the living virus. In addition, multi-barrier measures related to the treatment and storage provisions of the treated wastewater were put into place to further reduce the risks of contamination. In terms of sewage sludge treatment, the risk of contamination by COVID-19 is also non-existent as the virus would be deactivated during the treatment process.

For staff and end-users, safety provisions already in place for handling treated wastewater were adherent to guidelines recommended by the health authorities to prevent COVID-19 spread such as wearing a mask and frequent hand washing.

However, the impact of the pandemic on the quantity produced and delivered was strong enough to force a few courses to close during the pandemic. Due to the near absence of tourism, the production of raw wastewater has significantly decreased, which in turn has decreased the volume of recycled water that can be delivered for the reuse project. However, as all the main tourist activities including golfing were closed, the managers of the golf courses, as an adaptive measure, watered just the most sensitive parts of the course, in particular the greens, and decreased the frequency of watering on the other parts less important for the game, such as the fairways.

Scalability and replicability potential

This Marrakech project is already being scaled up and is also being used as a model to replicate and scale in other major Moroccan cities, notably Agadir, Rabat, Tangier and Tetouan. This type of water reuse is extensively developed in Morocco in line with the guidelines of the Moroccan Water Policy. RADEEMA, in collaboration with the regional council and the river basin agency, aims to extend the reuse scheme to all golf courses and new green spaces.

SWOT analysis

Table 1.6 summarizes the strengths, weaknesses, opportunities and threats (SWOT) of the Marrakech WWTP and green space and golf course reuse project.

Key factors for success along the project and lessons learned

During the design, construction and operation of the project, key factors of success included:

- Implementation efficiency in terms of the quality of the treatment and distribution works, due to the technical and managerial competency of RADEEMA.
- Collection, treatment and pollution remediation targets were met over the period 2008–2018.
- RADEEEMA was able to finalize and scale up the required level of treatment and distribution network to transport recycled water to the reuse sites.

TABLE 1.6 Marrakech WWTP and green space and golf course reuse project: SWOT analysis.

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ■ Competence and professionalism of RADEEMA ■ Financial contributions from partners in the reuse project as a whole ■ Funding under the National Mutualized Sanitation Plan ■ Financial solvency of users compared to reuse in agriculture ■ Environmental certification of RADEEMA ■ Strong mobilization of actors at the regional level ■ An innovative project in Africa	**WEAKNESSES** ■ Under-recovery of treated wastewater ■ Funding gap by golf course promoters ■ Unclear responsibility of developers for water quality inside golf courses
EXTERNAL FACTORS ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ■ Objectives to promote reuse in policies, plans and programs ■ Marrakech city is committed to becoming a sustainable city ■ Water scarcity due to climate change creates a great opportunity for the fast deployment of water reuse expansion in North Morocco ■ Leverage policies on gender integration to reinforce the contribution of women in program development	**THREATS** ■ Inadequacy of efficiency in the use of treated wastewater ■ Economic crisis for the tourism sector (as was the case during the COVID-19 pandemic) that could reduce the demand for wastewater treated by golf course developers ■ Risk of financial non-viability of Public-Private Partnership contract ■ The reluctance of golf course developers and users of conventional water in the event of firm non-prohibition measures

- The solar sludge drying model is innovative and could be replicated especially in large installations and those located in sensitive areas.
- In comparison with agricultural recovery, this model for a reuse project is financially viable. In this case, the golf courses are contributing irrefutably to cost recovery by paying up to 40% of the total cost of investment and significantly higher rates for each cubic meter reused (USD 0.25) than the cost of other water resources previously used.

Methods and resources

The methodology adopted to carry out this water reuse case study includes:

- Review of technical documents.
- Interviews with institutional heads at RADEEMA (Jaouher Touria and Houda Bilrha from the Water Department and Adil Daoudi and Tarik Al Mansoure from the WWTP and REUSE division related to the Operations Department at RADEEMA).
- Interviews with managers at the Marrakech WWTP and Urban Landscaping Water Reuse project at RADEEMA.

In addition, the author wrote an e-mail to Adil Daoudi from the Operations Department in which he outlined the project's background and requested the validation of information and data provided in the template. He also requested missing data. This triangulation approach combined with the effective participation of RADEEMA in providing the data for this water reuse case has made it possible to complete the template almost fully.

Additional resources used in gathering data for this study include:

AFD-Ministère de l'Intérieur: Assistance technique à la Direction des Réseaux Public Locaux du Ministère de l'Intérieur, pour la mise en œuvre du Programme d'Appui Institutionnel au Secteur de l'Assainissement au Maroc (PAISAM), dans le cadre d'une subvention de la FIV d'un montant de deux millions d'euros en gestion déléguée à l'AFD a été octroyée pour le financement dudit PAISAM.

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National documents were also consulted including the National Sanitation Plan (2009), the National Water Plan (2018) and the National Mutualized Sanitation Plan (2017).

Case Study 2: Morocco

Boukhalef wastewater treatment plant and Tangier green space and golf course water reuse

Brahim Soudi, Thomas Fer and Imane El Hatimi

Acronyms

ABH	River Basin Agency
APDN	Northern Development Agency
PNE	National Water Plan
RADEEMA	Water and Electricity Distribution Authority of Marrakech

History and project justification

The Boukhalef Wastewater Treatment Plant (Boukhalef WWTP) was constructed to increase capacity in wastewater treatment and to provide irrigation water for green spaces in Tangier city. Operational since 2015, the plant was designed in the face of increasing deficits in water reserves at the Ibn Battouta Dam, which serves residents of the cities of Tangier and Assilah with drinking water. Treated wastewater can provide an additional water resource, particularly for irrigation purposes. This subsequently reduces pressure on conventional water resources. According to Amendis, this project will save nearly 3 million m^3/year of water and improve the health and living environment of residents, and bring additional benefits for promoting tourism, for example, through the investment and development of green landscaped areas and golf courses around the city.

The Boukhalef WWTP covers a total area of 4.3 ha and is located in Gzenaya, an industrial zone on the border of the Free Zone of Tangier (Figure 2.1).

Before the construction of the Boukhalef WWTP, wastewater from Tangier city was discharged directly into the Mediterranean Sea after collection. Since 2015, when the plant became operational, domestic wastewater from the Rabat Road area, Boukhalef South, Gezenaya center, and the domestic and industrial effluents of Gezenaya and the Tangier Free Zone is treated there and then reused in irrigation projects.

FIGURE 2.1 Map showing location of the Boukhalef WWTP. WWTP Coordinates: 35.716954, -5.932413. *SOURCE*: Google Earth.

Reuse case description at a glance

The Boukhalef WWTP started operations in 2015 and has a capacity of 10,700 m^3/day. This capacity is anticipated to increase, after current expansion works, to 42,700 m^3/day. The plant uses an activated sludge treatment system and treats the water to a tertiary level (Figure 2.2). The recycled water it produces is used to irrigate golf courses and municipal green spaces.

The project has been carried out in three phases:

The first phase started in 2015 with the commissioning of the Boukhalef WWTP, the laying of an 8 km distribution network and the installation of a 120 liters per second (L/s) pumping station to irrigate an area of 110 ha of green spaces at the Qatari Diar Golf Course.

The second phase, which started in 2019, saw the expansion of the reuse network toward the center of Tangier to irrigate municipal green spaces and the Tangier Golf Royal. In addition, two storage tanks with a total capacity of 6,000 m^3 and a capacity discharge station at 120 L/s were constructed. A second tertiary treatment plant was also established, and 21.5 km of distribution network laid. The target of this phase was the irrigation of 141 ha. To date, 115 ha, including 70 ha for the Royal Golf Tangier, located in the Municipalities of Tangier and Gzenaya, are irrigated with recycled water from the plant.

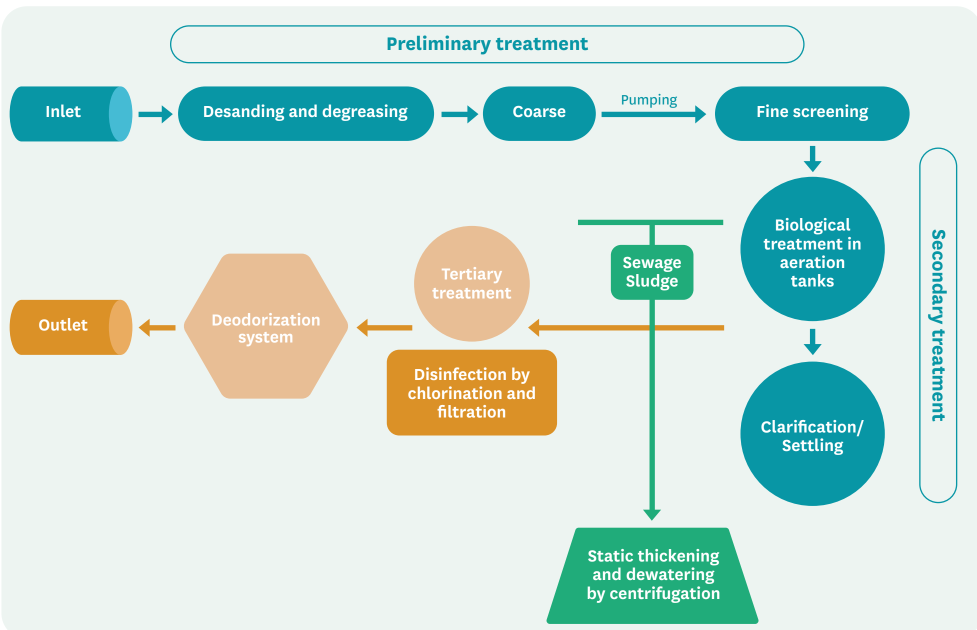

FIGURE 2.2 Boukhalef WWTP and water reuse system: Simplified schematic diagram.
SOURCE: B. Soudi.

The third phase, which is in progress, will increase the capacity of the Boukhalef WWTP to 42,700 m^3/d and expand the irrigation area to 150 additional hectares across the rest of the city. Construction work for this expansion is in the final phase and a study to extend the transport and distribution network is almost complete.

National institutional and policy framework

The current policy framework in Morocco is supportive of this water reuse project, including its replication and scaling as part of a strong promotion of water reuse, which is included in many policies, plans and programs (the National Water Strategy, the National Water Plan, the National Shared Sanitation Plan and the Emergency Drinking Water Supply and Irrigation Program (2020–2027). In addition, national integrated water resource management plans integrate reuse at the scale of river basins.

However, the governance of the project faces some difficulties (Figure 2.3), particularly in

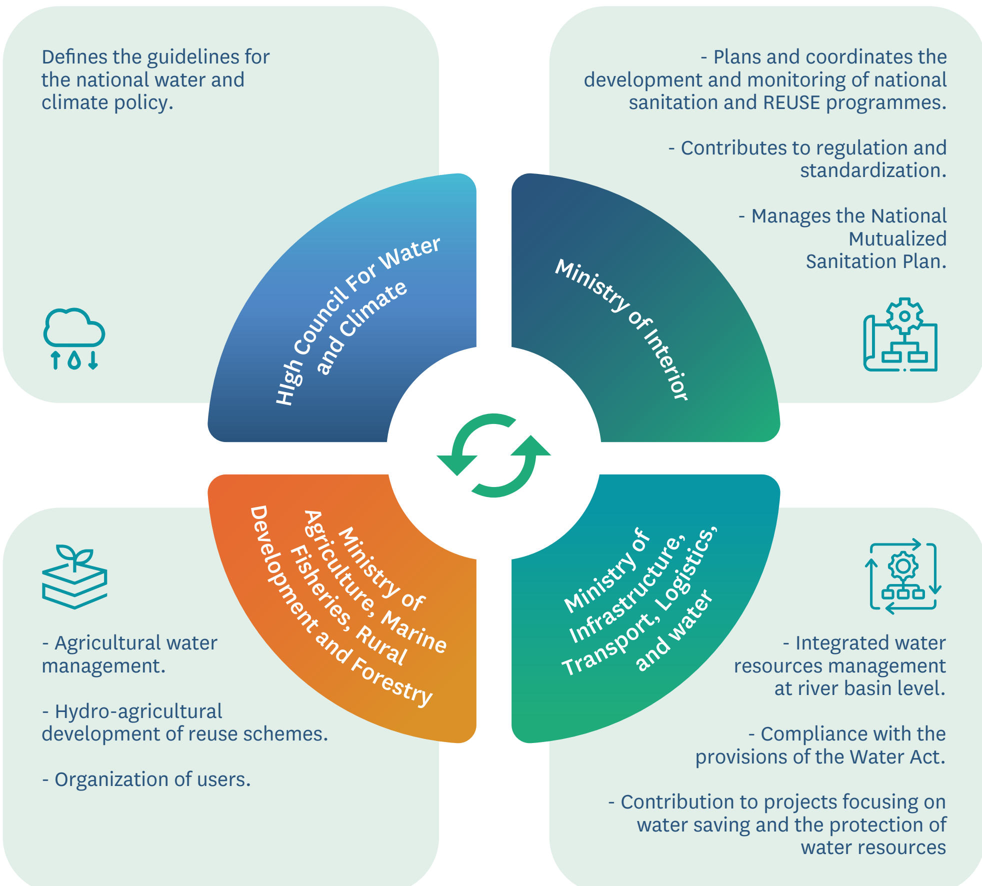

FIGURE 2.3 Key institutional players for wastewater treatment and reuse.
SOURCE: B. Soudi, Institute of Agronomy and Veterinary Medicine.

terms of intersectoral coordination and regulatory gaps. These include the definition of standards for sewage sludge recovery and the risk of non-financial viability of public partnership contracts agreed between the municipality and Amendis, the sanitation operator. From a technical point of view, these contracts do not clarify the sharing of responsibilities, in particular concerning the quality of the recycled water used to irrigate golf courses, which is prone to deterioration.

Other ministerial departments including the Ministry of Health and the Ministry of the Environment, as well as several water commissions, are also connected to this institutional scheme with territorial and regional representative entities including the National Office of Electricity and Drinking Water (ONEE-Water Branch), public service operators such as Amendis and private concessionaires.

Water recovery and reuse are also subject to regulatory compliance (Table 2.1).

TABLE 2.1 Regulatory texts relating to the recovery and management of wastewater in Morocco.

Law, decree or order	Arrangement
Decree n°2-05-1534 du 21 Chaoual 1426 (November 24, 2005) on the terms and conditions for the preparation and revision of the PDAIREs and the National Water Plan (PNE). Official Bulletin No. 5562 of 20/09/2007. Included in the new law 36-15.	The preparation of the draft master plan for the integrated development of water resources (PDAIRE) is entrusted to the River Basin Agency (ABH) of each basin in consultation with the other stakeholders in the field of water. Among the components of the master plan are the plan of its financing and the action plan for monitoring its implementation. The draft of the National Water Plan (PNE) is drawn up by the Minister responsible for water in consultation with the other ministerial departments and institutions that are members of the Higher Council for Water and Climate under the conditions specified in numerous articles of the same Decree.
Decree n°2-05-1533 du 14 Moharram 1427 (13 February 2006) on autonomous sanitation. Official Bulletin No. 5404 of 16/03/2006 (Article 4).	Any installation of an autonomous sanitation system in rural areas is to be declared to the technical services of the municipality.
Decree n°2-97-224 du 21 Joumada II 1418 (October 1997) laying down the conditions for the artificial accumulation of water. Official Bulletin No. 4532 of 06/11/1997.	Articles 2 and 3: Artificial accumulation of raw wastewater shall be permitted only if it is an integral part of a system for treating such water, approved by the water basin agency concerned. The application for authorization is addressed to the corresponding ABH.
Decree n°2-97-875 du 6 Chaoual 1418 (04 February 1998) on the use of wastewater. Official Bulletin No. 4558 of 05/02/1998 (under revision) Articles 1; 2; 10; 11 and 12.	It is forbidden to use wastewater unless it is declared treated in accordance with the standards. It is also forbidden to use wastewater, even if treated, for drinking, preparation, packaging or preservation of products or foodstuffs. The conditions of application and the criteria used to benefit from the financial assistance are regulated and the application is filed with the ABH.
Joint Order n°1276-01 du 10 Chaabane 1423 (17 October 2002) setting standards for the quality of water intended for irrigation. OB No. 5062 of 05/12/2002 (under revision).	Treated wastewater whose reuse is thus authorized must meet the quality standards set by this Order laying down the quality standards for water intended for irrigation.

SOURCE: B. Soudi, Institute of Agronomy and Veterinary Medicine.

Stakeholders involved and management model

The management model for the use of recycled water from the Boukhalef WWTP for golf courses and green spaces operates within a partnership framework in conjunction with other municipalities including Fnideq, Tetouan and M'diq in the north of Morocco.

A formal agreement establishes the partnership and cooperation between the signatory parties (Figure 2.4), by defining their roles and responsibilities, in particular with regard to (i) financing and implementation of projects, (ii) monitoring of achievements and (iii) monitoring the quality of treated wastewater and the operating and monitoring of projects.

The responsibilities of the key players and their functional relationships are outlined below:

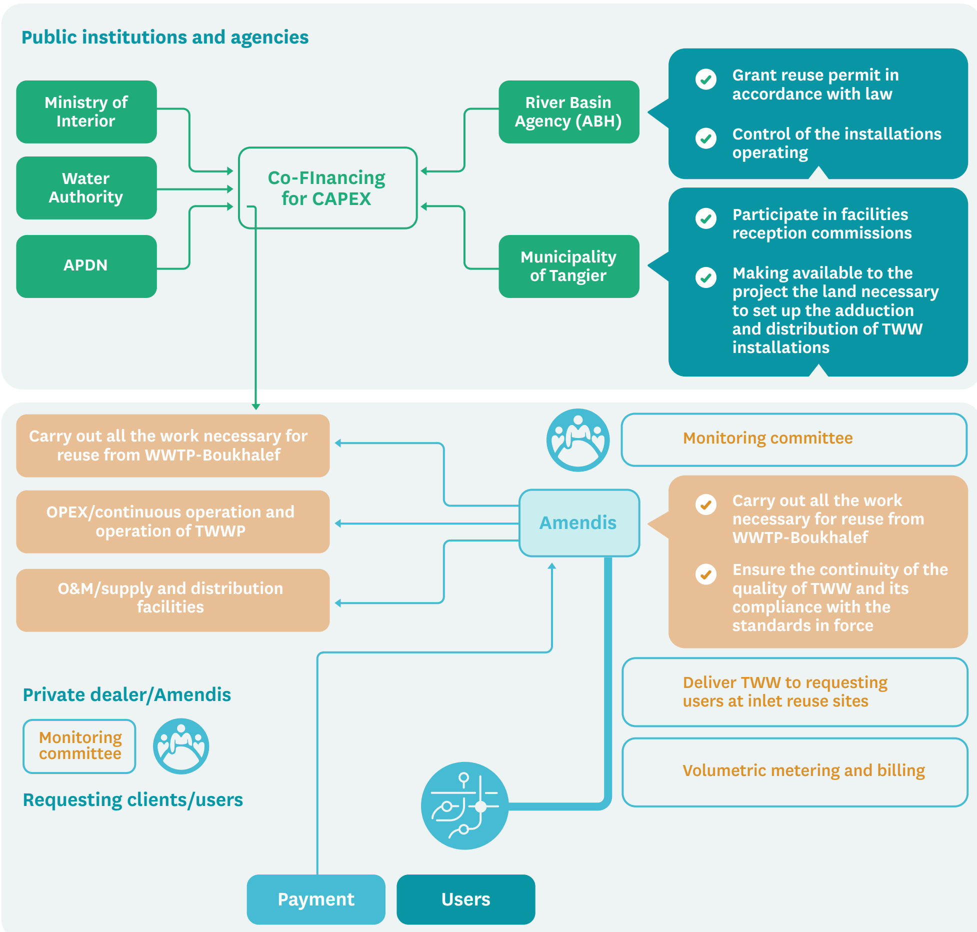

FIGURE 2.4 Management model of Buokhalef wastewater treatment plant and Tangier green spaces and golf courses reuse project.
SOURCE: B. Soudi, Institute of Agronomy and Veterinary Medicine.
NOTES: Northern Promotion and Development Agency (ADPN), Capital Expenditure (CAPEX), Operational Expenditure (OPEX), Operations and Management (O&M), Treated wastewater (TWW).

- The ABH provides financial support and permits for water reuse motivated by the economy and the protection of water resources in accordance with the law.
- The municipality of Tangier provides the land and financial contribution for the construction of the wastewater treatment plant.
- The Ministry of the Interior, the Water Authority and the Northern Development Agency (APDN) invest the capital expenditure (CAPEX).
- Amendis, a private entity, manages necessary works and installations, ensures the consistency of the quality of the treated wastewater intended for reuse, covers the operating expenses (OPEX) and maintenance and delivers recycled water to end-users at USD 0.27/m^3.
- A monitoring committee monitors compliance with the terms of the partnership contract and the overall operation of the treatment and reuse system.

Funding and financial outlook and cost recovery

Boukhalef WWTP's operation and maintenance costs are around USD 0.088 million (MAD 0.88 million)/year, which includes USD 0.033 million for maintenance and USD 0.27 million for electricity. Table 2.2 summarizes data on CAPEX, OPEX and cost recovery.

TABLE 2.2 Funding and financial outlook and cost recovery.

<table>
<tr><td>Segments REUSE value chain</td><td colspan="2">Construction and equipment services (description and dimensions)</td></tr>
<tr><td>Description</td><td colspan="2">Tertiary treatment plant with a capacity of 10,700 m^3/d (2015 until present).
Expansion to 42,700 m^3/day</td></tr>
<tr><td>Who delivers?</td><td colspan="2">Amendis as delegated private concessionaire from the municipality (contracting with specialized companies)</td></tr>
<tr><td rowspan="10">Financing source contribution to the initial investment</td><td colspan="2">The municipality of Tangier provides the construction land</td></tr>
<tr><td>Stakeholders</td><td>Co-finance (USD Millions)</td></tr>
<tr><td>Municipality of Tangier</td><td>1.1</td></tr>
<tr><td>Ministry of Interior</td><td>1.1</td></tr>
<tr><td>Water Authority</td><td>2.53</td></tr>
<tr><td>Basin River Agency (ABH)</td><td>0.22</td></tr>
<tr><td>Agency for the Promotion and Economic and Social Development of the Northern Prefectures of the Kingdom (APDN)</td><td>0.33</td></tr>
<tr><td>Regional Council of Tangier-Tetouan-Al Hoceima Tangier-Tetouan-Al Hoceima</td><td>0.77</td></tr>
<tr><td>Total</td><td>6.05</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td rowspan="2">Cost recovery</td><td colspan="2">Sanitation tax integrated into the Drinking Water and Electricity Bill
OPEX related to tertiary and complementary treatment.</td></tr>
<tr><td colspan="2">Selling price to the golf promoters: USD 0.27/m^3</td></tr>
<tr><td>Entity in charge of OPEX</td><td colspan="2">Amendis</td></tr>
<tr><td>O&M</td><td colspan="2">Amendis</td></tr>
</table>

SOURCE: B. Soudi, Institute of Agronomy and Veterinary Medicine (on the basis of data provided by AMENDIS). *NOTES:* Capital Expenditure (CAPEX), Operations and Management (O&M), Operating Expenditure (OPEX).

Socioeconomic, health and environmental benefits and impacts

Currently, the reuse system has not generated much employment in the long term although Amendis consider it likely this will change. In terms of the design and implementation of the wastewater treatment plant and reuse system, jobs have been created for companies engaged in construction work, but Amendis are not able to provide data on this. In terms of tourism, the city of Tangier is one of the cities most frequented by recreational and seaside tourists in Morocco. Wastewater treatment and reuse of the recycled water makes it possible to improve the attractiveness of the city through the expansion of green spaces and at the golf courses that benefit from the project.

The collection and processing of wastewater has greatly improved the local environment compared to the pre-project situation and reuse is having a very positive impact in terms of reducing groundwater and other water uses, saving 3 million m^3/year.

Gender equality

In a recent push, Amendis has been promoting gender diversity and equality, in particular through its recruitment policies. This strategy has brought results. In 2016, more than 18% of the supervisors employed at the Boukhalef WWTP and in its administration were women. In 2018, that number rose to more than 20%. Amendis is also encouraging more women to enter the technical field (Amendis 2019), particularly as the proportion of women in technical and engineering training schools is higher than that of men and their skills are equal.

Resilience to COVID-19

Overall, the impact of the pandemic on the project was limited. Boukhalef WWTP uses advanced technology and different levels of treatment that makes it possible to eliminate any probability of the virus being present in the treated wastewater. Also, treated wastewater goes through a final stage of tertiary treatment specific to reuse, and ultimately, chlorine disinfection, which ensures the destruction of any living organism before the water enters the network. Quality tests and monitoring are also carried out regularly.

Scalability and replicability potential

The Tangier project is already being scaled up in the northern region of Morocco. As mentioned earlier, it is part of a cluster of projects that are managed under the same partnership agreement. The replication and scaling up of this type of project are driven by the National Water Strategy and the National Water Plan, which set out a roadmap to promoting the reuse of treated wastewater to alleviate pressure on conventional water resources and build resilience to climate change. Portability is ensured by the good documentation of technologies and by the success of public-private partnership contracts between Amendis and the municipality of Tangier. Also, the extension of green spaces and the establishment of new golf courses in the city of Tangier and its surroundings will absorb the expected increases in the volumes of treated wastewater through reuse for irrigation.

SWOT analysis

Table 2.3 summarizes the strengths and weaknesses, opportunities and threats (SWOT) of the Boukhalef WWTP and Tangier green spaces and golf courses reuse project.

TABLE 2.3 Boukhalef WWTP and Tangier green spaces and golf courses reuse project: SWOT analysis.

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ■ Competence and professionalism of Amendis. ■ Financial contributions from partners in the reuse project as a whole. ■ Funding under the National Shared Sanitation Plan. ■ Financial solvency of wastewater reuse. ■ Strong mobilization of actors at the regional level. ■ An innovative project in the Mediterranean region. ■ Strong support of Tangier Municipality for green spaces in the city and tourist locations.	**WEAKNESSES** ■ Unclear responsibility for the quality of treated wastewater within golf courses. ■ The total area of green spaces has risen to 283 ha, which is disproportionate in its distribution at the district level. ■ Despite best efforts, a good number of gardens and green spaces within certain districts remain very poorly maintained. ■ Lack of awareness and respect for green spaces by citizens resulting in a low level of cleanliness. ■ Lack of staff to maintain green landscapes.
EXTERNAL FACTORS ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ■ Objectives to promote reuse in policies, plans and programs. ■ Water scarcity due to climate change makes a great opportunity for the fast deployment of water reuse in North Morocco.	**THREATS** ■ Risk of financial non-viability of the project. ■ The reluctance of golf course developers and users of conventional water because the conventional water is cheap or free.

SOURCE: B. Soudi, Institute of Agronomy and Veterinary Medicine.

Key factors for success along the project and lessons learned

During the design, construction and operation of the project, key factors of success include:

- Implementation efficiency in terms of the quality of the treatment and distribution works, due to the technical and managerial competence of Amendis. Collection, treatment and pollution remediation targets were met during the period 2002–2020.
- Amendis has finalized and scaled up the required level of treatment and has set up the distribution network that transports the treated wastewater to the reuse sites.
- In comparison with agricultural recovery, this reuse model is viable because it involves a logic of remuneration with solvent users, which contributes irrefutably to cost recovery.
- The current expansion of the WWTP system is a relevant indicator of the scalability and sustainability of the project.

Methods and resources

The methodology adopted to carry out this water reuse case study includes:

- Review of technical documents.
- Interviews with institutional heads from the national water authority (Jaouher Touria and Houda Bilrha from the Water Department; Abdelhamid Benabdelfadel from the ABH).
- Interviews with managers at the Boukhalef Wastewater Treatment Plant and Water Reuse project (Thomas Fer, Water & Sanitation Director and Imane El Hatimi, Coordinator of Plural Performance and Digital Transformation, Amendis – the water and electricity operator for northern regions of Morocco).

In addition, the author wrote an e-mail to Thomas Fer, the project manager at Amendis, outlining the project's background and requesting the validation of information and data provided in the template, and to provide missing data. This triangulation approach combined with the effective participation of Amendis in providing data for this water reuse case has made it possible to complete the template almost fully.

Additional resources used in gathering data for this study include:

AFD-Ministère de l'Intérieur: Assistance technique à la Direction des Réseaux Public Locaux du Ministère de l'Intérieur, pour la mise en œuvre du Programme d'Appui Institutionnel au Secteur de l'Assainissement au Maroc (PAISAM), dans le cadre d'une subvention de la FIV d'un montant de deux millions d'euros en gestion déléguée à l'AFD a été octroyée pour le financement dudit PAISAM.

Amendis. 2019. *AMENDIS MAG* March 2019, Issue 5. Morocco. *Amendis*. https://www.amendis.ma/sites/g/files/dvc3316/files/document/2019/04/MG_Ndeg5_Mars_2019_VF.pdf

Amendis. 2021. Étude d'extension du système de réutilisation des eaux traitées de la STEP Boukhalef pour arroser les espaces verts de la ville de Tanger. Étude d'Avant – Projet – Sommaire.

CESE (Conseil Economique Social et Environnemental). 2014. *Gouvernance par la gestion intégrée des ressources en eau au Maroc: levier fondamental de développement durable*. CESE.

Cherif, E.; Salmoun, F. 2018. Diagnostic of the environmental situation of the west coast of Tangier. *Journal of Materials and Environmental Science* 9*:* 631–640. https://doi.org/10.26872/jmes.2018.9.2.70

Faïssal, N. 2019. Réutilisation des eaux usées à Tanger: La station d'épuration Boukhalef donnée en exemple. *Aujourd'hui le Maroc*. April 25 2019. Available at https://aujourdhui.ma/economie/reutilisation-des-eaux-usees-a-tanger-la-station-depuration-boukhalef-donnee-en-exemple (accessed on June 27, 2022).

Laghzaoui, F.; Ferehoun, S. 2018. Issues and challenges of environmental management of local authorities in Morocco: The case of the city of Tangier. *International Journal of Advanced Engineering and Management Research* 3(6).

Maquet, C. 2020. Wastewater reuse: a solution with a future. *Field Actions Science Reports* Special Issue 22: 64–69. https://journals.openedition.org/factsreports/6341 (includes appendix on *Wastewater for city watering: an innovative partnership between the city of Tangier and Amendis (Veolia). Interview with Driss Riffi Temsamani, Vice-President of Tangier municipality).*

Soudi, B. 2012. Pour BEI_SAFEGE-ONEP. Évaluation Environnementale Stratégique ONEP - Programme Assainissement.

World Bank. 2017. *Gestion de la Rareté de l'Eau en Milieu Urbain au Maroc*. Washington: World Bank. Available at https://documents1.worldbank.org/curated/en/488091516133312338/pdf/summary-report.pdf (accessed on June 27, 2022).

Ziyad, A. 2021. *River basin master plans: planning and water management tools to identify hydraulic projects*. Paper presented at AFRICA 2017: Water storage and hydropower development for Africa, March 14–16, 2017, Marrakech, Morocco.

National documents were also consulted including the National Sanitation Plan (2009), the National Water Plan (2018) and the National Mutualized Sanitation Plan (2017).

Case Study 3: Tunisia

Sfax Sud wastewater treatment plant and El Hajeb public irrigated perimeter

Chokri Saffar and Ibticem Chamtouri

Acronyms

ANPE	National Environmental Protection Agency
CRA	Agricultural Outreach Unit
GDA	Agricultural Development Group*
CRDA	Regional Commission for Agricultural Development*
CTV	Territorial Extension Unit*
DGGREE	Directorate General of Rural Engineering and Water Management*
DHMPE	Directorate of Environmental Health and Environmental Protection
MALE	Ministry of Local Affairs and the Environment
MARHP	Ministry of Agriculture, Water Resources and Fisheries
MSP	Ministry of Public Health
ONAS	Official Sanitation Office*
WWTP	Wastewater Treatment Plant

**Translated from French*

History and project justification

The Sfax Governate is an arid to semi-arid zone on the east coast of Tunisia with an average temperature of 20°C. It has an annual negative water balance of 1,000 mm, which is when demand exceeds supply. This means that irrigation is necessary to help farmers achieve the best crop yields. Given the scarcity of natural water resources including both groundwater and surface water, recycled water from wastewater treatment plants provides a valuable new water source that can be used for irrigation. This approach forms part of the national strategy for agricultural water recycling and has been adopted in the Public Irrigated Perimeter of El Hajeb (hereinafter the El Hajeb Perimeter).

The El Hajeb Perimeter is the first of its kind in Sfax. It was developed in 1988 on state-owned land and covers 240 ha. It is irrigated by recycled water from the Sfax Sud Wastewater Treatment Plant (hereinafter Sfax Sud WWTP). Given the good results achieved in terms of agricultural development and both the ongoing and predicted climatic conditions in the area, the perimeter area was extended several times during the 1990s and 2000s and now covers 444 ha divided between seven farmers (Figures 3.1 and 3.2).

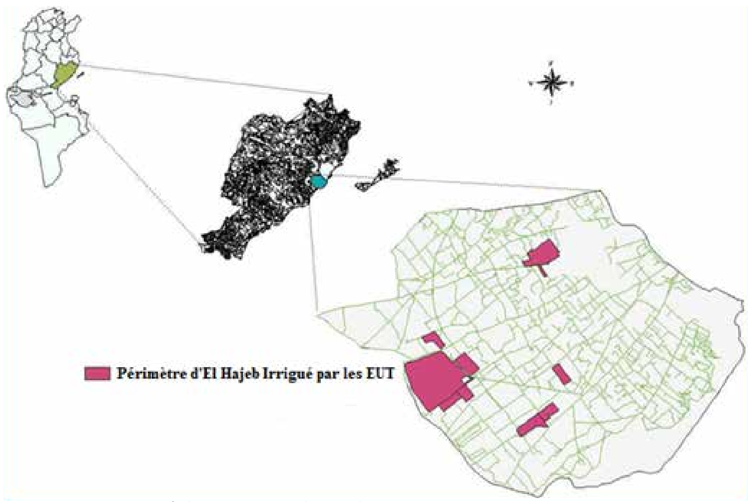

FIGURE 3.1 Location map of the existing El Hajeb Perimeter.

FIGURE 3.2 Map showing location of El Hajeb Perimeter and Sfax Sud WWTP. *SOURCE*: Google Earth.

Water reuse case description at a glance

Sfax Sud WWTP serves a population of around 526,800 people and is located 6 km south of Sfax city. Collected wastewater enters the station from basins in Sfax Centre and Sfax Sud from domestic (47%) and industrial water (21%) sources. Upon arrival, it is treated at a secondary level using a low-load activated sludge treatment system (Figure 3.3), which biologically removes biodegradable organics and nutrients.

Currently, Sfax Sud WWTP is undergoing rehabilitation works under the oversight and management of the National Office of Sanitation (ONAS) at an estimated cost of USD 2.8 million, financed by the African Development Bank. The size of the rehabilitation and expan-

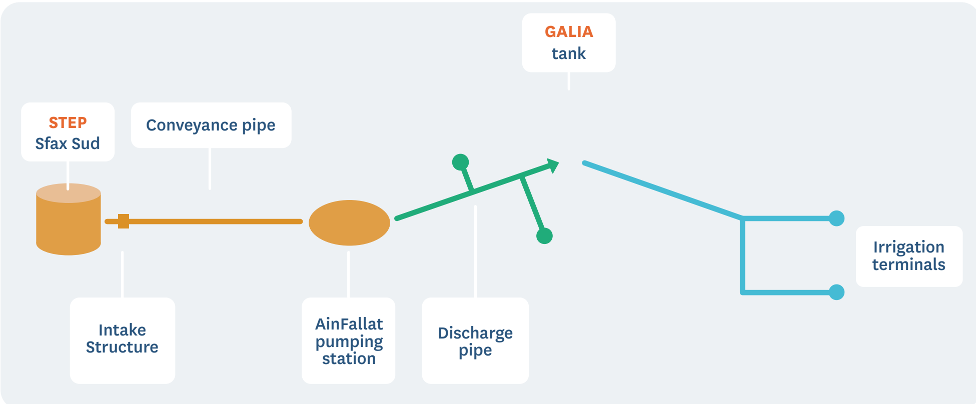

FIGURE 3.3 Sfax Sud wastewater treatment plant and water reuse system: Schematic diagram 1.

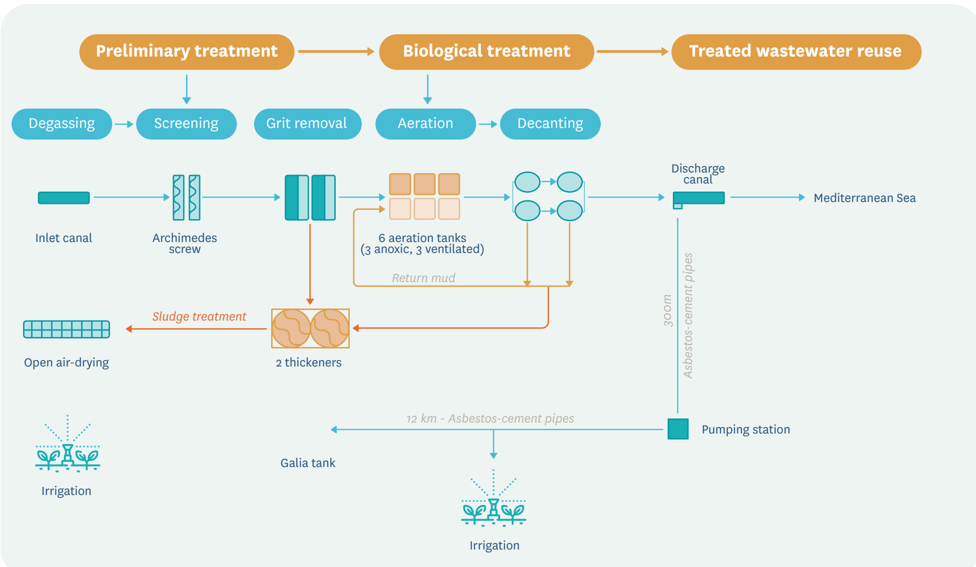

FIGURE 3.4 Sfax Sud wastewater treatment plant and water reuse system: Schematic diagram 2.

sion works are based on a projected average flow of 52,000 m^3/day by 2026. This compares to its current capacity of 49,500 m^3/day. Recycled water reaches the El Hajeb Perimeter from Sfax Sud WWTP (Figures 3.3 and 3.4, above) via:

- An intake structure that diverts part of the recycled water flow leaving Sfax Sud WWTP into a confined concrete inlet pipe that leads to the pumping station's suction tank.
- A pumping station that has a buried suction tank, a pumping room with four electric pumps and hydromechanical and electrical equipment.
- An asbestos-cement delivery pipe that is 12 km long and conveys the recycled water to a tank in a 14 m high tower located at the head of the perimeter.
- A distribution network from the tank consisting of asbestos-cement pipes equipped with irrigation hydrants.

The volume of water that is pumped to the perimeter varies between 1.4 m^3–3.7 m^3/year, giving a reuse rate of between 10–47% (Table 3.1). This figure is variable due to the frequent breakdown of the pumping units and deterioration in the quality of the recycled water. Service to the seven farms within the El Hajed Perimeter is on demand.

National institutional and policy environment

Wastewater discharge into the environment in Tunisia is regulated by Decree No 85-56 (January 2, 1985) with limits and quality standards set by the Ministry of Local Affairs and the Environment and the Ministry of Industry and Small and Medium Enterprises (March 26, 2018). It also requires authorization from the National Sanitation Office (ONAS) subject to its compliance with conditions for the discharge and disposal of non-domestic wastewater in the sewerage networks set out by Decree No. 94-1885 (September 12, 1994).

TABLE 3.1 Irrigable areas and land use of farms served by Sfax Sud WWTPs.

Perimeter or operator	Initial irrigable area (ha)	Current irrigable area (ha)	Land use
1 State domain	240	236	Fodder crops intercropped with olive trees
2 State domain	40	30	
3a Private plot	70	14	
4 Private plot	8	8	
5 Private plot	14	14	
3b Private plot	36	36	Fodder crops on bare land+
6 Private plot	72	72	
7 Private plot	12	12	
8 Private plot	22	22	Forages on bare land and inter-cropped with olive trees
9 (private plot)	70	0	Olive tree
Total area	584	444	

NOTES: + Bare land = land that does not contain trees.

In terms of water reuse for agricultural purposes and required measures to protect the health of consumers and the environment, regulations are set out in Decree No. 89-1047 (July 28, 1989) and modified by Decree No. 89-1047 (July 28, 1989) and Decree No. 93-2447 (December 13, 1993). The required quality of recycled water from wastewater treatment plants for agricultural use is set out in Standard NT106.03 (September 12, 1994). In addition, the list of crops that can be irrigated by recycled water was set out by the Ministry of Agriculture and Water Resources in 1994, which also ruled out its use in market gardening, meaning that it cannot be used on fruits and vegetables that can be eaten raw.

Recycled water from wastewater treatment plants is provided to the Regional Commissions for Agricultural Development (CRDA) free of charge by ONAS. The CRDAs then charge farmers a nominal fee of USD 0.0073/m^3 for water consumption. This pricing system was implemented by a presidential decision in 1998 to promote recycled water use for agricultural purposes.

At the institutional level, four actors play a key role in the field of recycled water reuse for irrigation:

- ONAS who owns and operates the wastewater treatment plants.
- The Ministry of Agriculture, Hydraulic Resources and Fisheries is the managing authority for recycled water reuse through the CRDA that first developed the areas to be irrigated with recycled water from the wastewater treatment plants. Direct contact with farmers is made through agricultural development groups.
- The CRDA as the distributor of recycled water and the Ministry of Health share monitoring of treated wastewater quality.
- The end-user.

Stakeholders involved and management model

The El Hajeb Perimeter was developed by the Regional Commission for Agricultural Development (CRDA) of Sfax under the supervision of the Ministry of Agriculture, Hydraulic Resources and Fishing.

Since the creation of the El Hajeb Perimeter, project beneficiaries have been organized into the El Moustakbal Agricultural Development Group (GDA). The management of the infrastructure and resources made available through the water reuse project is delegated by the CRDA Sfax to the GDA via a management contract that specifies which tasks are carried out by the GDA and which are carried out by the CRDA which includes regional representatives such as the Territorial Extension Unit (CTV), the Agricultural Outreach Unit (CRA) and others who provide technical assistance to farmers (Figure 3.5).

In 2015, in compliance with requirements governing the operation of treated wastewater concerning potential risks to human health, Sfax CRDA signed an agreement, which is renewable annually, with the Sfax Occupational Medical Group (Groupement de Médecine de Travail), to provide medical services for El Hajeb Perimeter managers including periodic medical check-ups and annual medical examinations. It also signed a second agreement with El Hedi Chaker, a public health institution, and the National Engineering School of Sfax for the continuous monitoring of the recycled water quality that is supplied to El Hajeb Perimeter, according to reuse regulations.

The Ministry of Health also carries out periodic bacteriological analyses of the recycled water before it is transferred to the perimeter from Sfax Sud WWTP and of the crops irrigated by the recycled water. If standards are not met, the results are communicated to the CRDA so that it can stop supplying the recycled water until the required quality is restored. The National Office of Sanitation (ONAS) also controls the quality of the treated wastewater at the Sfax Sud WWTP. In the event of problems with quality, ONAS also informs the CRDA so that they can stop serving the perimeter.

However, in both cases, information is often late, or the water is not stopped in time, which means that recycled water that does not comply with standards is sometimes transferred to the perimeter.

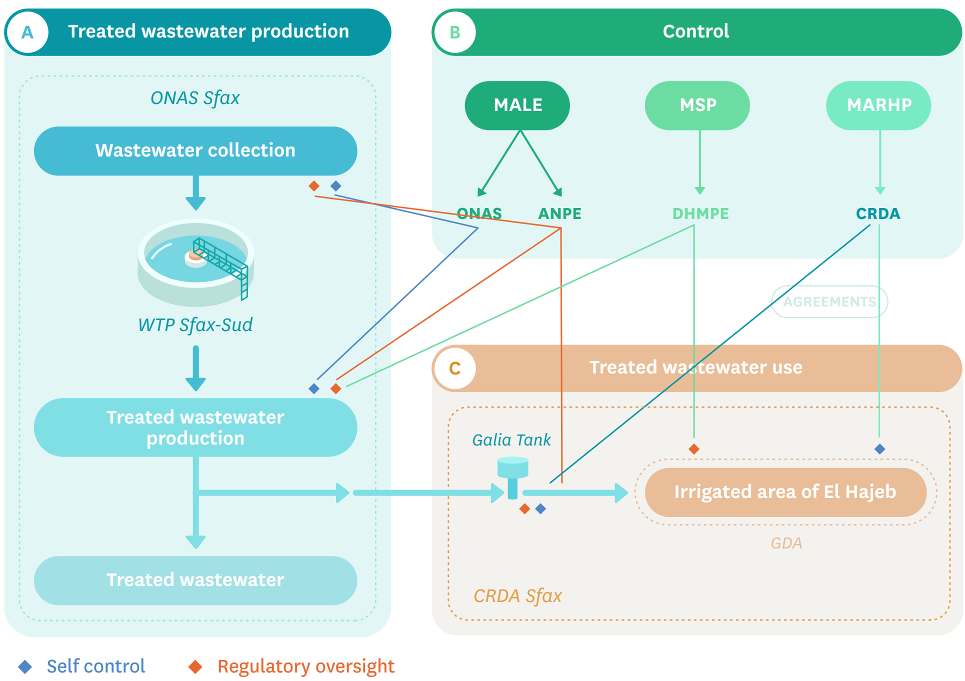

FIGURE 3.5 El Hajeb Perimeter management and stakeholder model.
NOTES: National Environmental Protection Agency (ANPE), Regional Commission for Agricultural Development (CRDA), Directorate of Environmental Health and Environmental Protection (DHMPE), Agricultural Development Group (GDA), Ministry of Local Affairs and the Environment (MALE), Ministry of Agriculture, Water Resources and Fisheries (MARHP), Ministry of Public Health (MSP), National Sanitation Office (ONAS), Wastewater Treatment Plant (WWTP).

Funding and financial outlook and cost recovery

Table 3.2 summarizes the capital expenditure, operating expenditure and cost recovery related to the Sfax Sud Wastewater Treatment Plant and El Jaheb Public Irrigated Perimeter Water Reuse Case.

Socioeconomic, health and environmental benefits and impacts

The transfer of recycled water from the Sfax Sud WWTP to the El Hajeb has meant a significant increase in the agricultural production of the irrigated farms. Current agricultural production includes 533.5 t of olives, 2,045 t of milk, 68.72 t of meat, 4165 t of manure and 150 heifers. This in turn increases farmers' incomes. Olive tree crops generate an income of USD 804/ha, while fodder crops are used to feed cattle. This herd generates a gross annual income of USD 2,574,615 through the sale of milk and meat.

The creation of the El Hajeb Perimeter has made it possible to recover an average of 30% of the treated wastewater discharge from the Sfax Sud WWTP, which would have gone into the

TABLE 3.2 Funding and financial outlook and cost recovery.

	Wastewater collection and transfer	Wastewater treatment	Wastewater conveyance	Wastewater distribution
Construction and equipment services (description and dimensions)	The collection network of wastewater, mainly domestic, of Sfax City and its surroundings, consists of 180 km of wastewater collectors, 140 km of combined collectors and 13 pumping stations.	Sfax Sud WWTP: Equipped to carry out treatment at a secondary level using a low-load activated sludge treatment system.	Intake structure. Asbestos-cement pipeline (AC) DN800 length 260 m. Pumping station equipped with 3 x 100 liters per second (L/s) - HMT: 120 m +1 emergency. Pressure pipe in AC DN500 length 12 km. 14 m high tower tank with a capacity of 250 m^3. A control station with four flow meters. A remote management system between CRDA, Pumping Station and Galia Tank.	Buried pipe distribution network serving seven current operators including: • Two distribution networks at the level of the state domain (236 ha + 30 ha) consisting of AC pipes and irrigation hydrants. • An AC pipeline (DN 500 to 300 – length 6 km) was installed in 2006 to serve a private plot (72 ha) and on which are grafted four unfinished irrigation terminals planned for extensions. • A small PVC distribution network serving a private plot, starting from the control station. These networks each start from the control station and are equipped with a flow meter (four flow meters in total): • An AC DN250 pipeline. • An AC DN150 pipeline. • A plug for a private plot onto the discharge pipe.

Mediterranean Sea. However, the aging of the pipes and the poor condition of the regulation tank are leading to leaks and losses. This water stagnates in the perimeter for long periods, especially in winter, which causes discontent among the population passing through the area because of the bad smells and the proliferation of insects. However, no water-borne diseases have been recorded in the area.

Similarly, the passage of the existing pressure pipe through densely populated areas recently built outside the confines of building regulations prevents intervention measures to be taken on the pipe for repair or maintenance constituting a risk to the health of the resident population.

The rehabilitation works to the infrastructure and extension of the irrigated perimeter will undoubtedly increase the agricultural production of the area, reduce the volume of treated wastewater discharged into the sea and avoid its stagnation in the perimeter caused by breakages and overflow in the Galia tank and bring additional income to the perimeter's operators.

TABLE 3.2 Funding and financial outlook and cost recovery (continued).

	Wastewater collection and transfer	Wastewater treatment	Wastewater conveyance	Wastewater distribution
Stakeholder providing the service	ONAS Sfax	ONAS Sfax	CRDA Sfax	CRDA Sfax
CAPEX in USD	Data not available	Data not available	3.75 million	1.5 million
Recovery CAPEX and % subsidy	State funding		State funding	State funding
Operations and monitoring (O&M) services (description)	Infrastructure maintenance, pumping costs, renewal, salaries	Infrastructure maintenance, pumping costs, renewal, salaries	Infrastructure maintenance, pumping costs, renewal, salaries	Infrastructure maintenance, renewal, salaries
Stakeholder providing the service	ONAS Sfax	ONAS Sfax	CRDA Sfax	CRDA Sfax and GDA
OPEX (USD/m³)	Data not available	0.032	0.080	
OPEX recovery and % subsidy	Nearly 70% of ONAS's financial resources come from sanitation fees, mainly collected through SONEDE's invoicing: USD 0.02-0.05/m³ according to the following principles: (i) beneficiary-payer; (ii) polluter-payer and (iii) solidarity between users. The rest of ONAS's budget comes from state subsidies (25.6%) and other related activities (5.4%). In the face of all its expenses, ONAS provides recycled water from wastewater treatment plants to CRDAs free of charge.		CRDA Sfax sells treated wastewater to the GDA for USD 0.016/m³, which results in a significant subsidy of around USD 0.074/m³ borne by the CRDA. Application of the reduced price is decided by the State and is to encourage the use of recycled water which is sold by the GDA to farmers at a unit price of USD 0.073/m³.	

NOTES: Capital Expenditure (CAPEX), Regional Commission for Agricultural Development (CRDA), Agricultural Development Group (GDA), Total Pump Height (HMT), Official Sanitation Office (ONAS), Operational Expenditure (OPEX), Societé Nationale d'Exploitation et de Distribution des Eaux (SONEDE – National Water Company).

Gender equality

When the perimeter was created, both men and women were able to be potential beneficiaries under the terms of the CRDA, as long as they undertook to comply with legislation requirements. Yet despite this, currently, there are no women operators as although not excluded from the project, no women have applied to join it. Women do work occasionally on the farms as day laborers but there are no statistics on the frequency of this work.

Similarly, during the development of the rehabilitation and extension of the perimeter studies, the environmental and social evaluation of the project and the public consultations carried out by the Sfax CRDA, women played an important role in the meetings, taking part in discussions on different components of the project. Their opinions were also considered in the final design of the project. For example, during the design of the stage of the conveyance system, the proposed location and sizing of the storage tank on the perimeter were improved following a complaint presented by a woman representing a mixed group of 350 people (men and women). The complaint related to strong odors and the proliferation of insects.

Scalability and replicability potential

The El Hajeb Perimeter is located in an extensive agricultural area where both arboriculture, especially of dry-farmed olive trees and cattle rearing (without the use of a grazing area due to the lack of irrigation), and fodder production play an important role in generating income for the local communities. The lack of other sources of water and the arid climate makes it highly possible that the irrigated area will be extended, particularly in response to demand from a large proportion of the farmers in the area who deem it necessary. This model could work well in other areas where the general climatic and operating conditions are the same.

However, in addition to the development and rehabilitation of the irrigation networks of the El Hajeb Perimeter, the CRDA need also to:

- Program the installation of a complementary wastewater treatment system to remedy fluctuations in the quality of Sfax Sud WWTP discharges
- Revise the price of water sold to farmers to cover the operating costs of the installed network. The model followed at present is that of public financing without revenue from the sale of water, given the adoption of the low cost for recycled water sales. For the El Hajeb Perimeter, the supply of recycled water to the perimeter costs Sfax CRDA USD 0.080/m^3 while it sells the water to the GDA at USD 0.006/m^3, which generates a significant subsidy of USD 0.074/m^3, which is borne by the CRDA.

SWOT analysis

Table 3.3 summarizes the strengths, weaknesses, opportunities and threats observed in the Sfax Sud WWTP and El Hajeb case study.

Key factors for success along the project and lessons learned

During the design, construction and operation of the project, key factors of success include:

- Political will to promote the use of recycled water from wastewater treatment plants at the national level.
- The commitment of the ONAS to rehabilitate and increase the capacity of wastewater treatment plants and improve the quality of the recycled water, including rehabilitation of the Sfax Sud WWTP.
- The mitigation of environmental and health impacts of the treated wastewater discharges into the natural environment is one of the main driving forces in favor of recycled water use, as in the case of the El Hajeb Perimeter, which is resulting in a 30% discharge reduction into the Mediterranean Sea near the Sfax salt flats, a nature reserve designated as a RAMSAR site.
- The importance of crops in and around the project area that can grow well under the water reuse irrigation scheme, in this case, an extensive olive orchard and the cultivation of fodder crops, which is done in conjunction with dairy cattle rearing in the plots irrigated by water from the project.

Lessons learned include:

- Supervision and monitoring of farmers is an important factor in the success of public irrigated perimeters.
- The monitoring of treated wastewater shows quality fluctuations due to the existence of illicit polluted discharges in ONAS sewers despite continuous control of the networks. ONAS must commit to ensuring a good quality of treated wastewater and consider installing a complementary water treatment plant at the head of the perimeters irrigated through the water reuse project.

Methods and resources

This water reuse case was prepared in collaboration with:

- The Regional Commission for Agricultural Development (CRDA), Sfax Governorate: The two people contacted were the District Head of the Exploitation of Irrigated Perimeters and the District Head of Rural Engineering.

TABLE 3.3 Sfax Sud WWTP and El Hajeb Perimeter: SWOT analysis.

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ■ Commitment of ONAS in projects concerning the improvement of wastewater treatment and the important potential of water reuse from the Sfax Sud WWTP: currently an average of 42,000 m^3/day and planned to reach 52,000 m3/day by 2026. ■ Fertilizing power of recycled water: less mineral fertilizer inputs. ■ High potential for agricultural land to be irrigated by recycled water and high motivation of farmers in the area for the project. ■ No other source of water for irrigation near the existing perimeter. ■ Development of cattle breeding in the area and the presence of a milk collection center nearby as well as oil mills. ■ More than 30 years of experience with recycled water irrigation in the project area and a high rate of intensification in the existing perimeter (155%).	**WEAKNESSES** ■ Poor treated wastewater quality that does not meet the requirements of the discharge standard (NT106-02) and the standard for reuse in irrigation (NT106-03). ■ Lack of storage tanks at the head of the irrigation network. ■ Restrictive list of authorized crops with few high-value crops. ■ Low pricing set at USD 0.072/m^3. The costs of the reuse of the treated wastewater are largely borne by the CRDA. ■ Increased operating costs due to the degradation of existing facilities (for the Sfax Sud WWTP and the El Hajeb Perimeter). ■ Non-compliance with treated wastewater quality control frequencies and parameters to be analyzed, both at the Sfax CRDA and more recently at ONAS (since the launch of the Sfax Sud WWTP rehabilitation project in 2016). ■ At the operational level, few material and human resources were allocated to the treated wastewater operator, especially given insufficient flows transferred to the perimeter due to the failure of the existing infrastructure. ■ Lack of user awareness of the risks of treated wastewater and lack of resources to raise user awareness
EXTERNAL FACTORS ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ■ A political will to promote recycled water from wastewater treatment plants as a new source of water. ■ Many users are willing to pay more for the quality of recycled water. ■ Less discharge of treated wastewater into the sea reduces potential pollution, especially near the Sfax salt flats (RAMSAR site). ■ The El Hajeb Perimeter has been in operation for about 33 years and constitutes an extensive field of research on the reuse of treated wastewater in irrigation. ■ A desire on the part of the distributing body (Sfax CRDA) to promote the use of recycled water in the El Hajeb Perimeter and extend irrigated areas as a result of a general political will to promote the water reuse. ■ Climate change is reducing conventional water resources, with water stress affecting Tunisia, particularly in the Sfax area including the salinization of groundwater, meaning water reuse is becoming even more critical. ■ Flagship projects such as the Ouardanine Public Irrigation Perimeter for various fruit trees in addition to the El Hajeb Perimeter for fodder crops, dairy cattle breeding and olive trees.	**THREATS** ■ Low rate of progress in the rehabilitation of the Sfax Sud WWTP. ■ Illegal connection of polluting industries to the ONAS network affects the quality of treated wastewater. ■ The producer and the treated wastewater quality controller belong to the same ministry which can create risks of conflicts of interest. It is noted that the treated wastewater produced often does not comply with the NT106-02 discharge standard, yet it sometimes is discharged into the sea or transferred to the perimeter without immediately informing the CRDA. ■ Insufficient coordination amongst producers, distributors, managers and users. ■ A lack of control over the quality of the treated wastewater produced. ■ Difficulties in mobilizing funds for the upkeep and maintenance of existing installations and the realization of new complementary wastewater treatment projects provided by ONAS to address the majority of cases not compliant with the NT106-03 standard.

- The treated wastewater producers: ONAS and the Sfax Sud WWTP.
- The Public Irrigated Perimeter of El Hajeb management body: the Agricultural Development Group (GDA).
- Current perimeter operators.

The approach included:

- Analysis of documentation on the perimeter and the Sfax Sud WWTP 2019 studies on the rehabilitation and extension project of the El Hajeb Perimeter (feasibility study, detailed design study, execution study, and environmental and social impact study) and operating reports.
- Consultation with staff, resource persons and local populations to collect data on the Sfax Sud WWTP and the current state of the El Hajeb Perimeter. This consultation was to verify the collected information to accurately complete the data tables. Some data could not be collected, however, especially at the level of ONAS.
- Field observations, investigations and direct contact with the farmers at the site of the El Hajeb Perimeter were also carried out to determine which crops are grown and current resource and use constraints.
- ONAS (National Sanitation Office) operating reports of Sfax Sud Wastewater Treatment Plant, 2009–2013 and operating reports of the Sfax Sud WWTP (not complete reports), 2016–2017 and 2018.

Additional resources used in gathering data for this study include:

CRDA (Regional Commission for Agricultural Development). 2006. *Feasibility study of the extension project of the El Hajeb Perimeter irrigated by recycled water from Sfax Sud Wastewater Treatment Plant*. Tunisia. CRDA.

CRDA. 2019. *Feasibility study of the rehabilitation and extension project of the El Hajeb Perimeter irrigated by recycled water from Sfax Sud Wastewater Treatment Plant*. Tunisia. CRDA.

CRDA. 2020. *Detailed preliminary design study of the rehabilitation and extension project of the El Hajeb Perimeter irrigated by recycled water from Sfax Sud Wastewater Treatment Plant*. Tunisia. CRDA.

DGGREE (Directorate General of Rural Engineering and Water Management). 2020. *Environmental and social impact study of the rehabilitation and extension project of El Hajeb Perimeter irrigated by recycled water from Sfax Sud Wastewater Treatment Plant*. Tunisia. DGGREE.

MARHP (Ministry of Agriculture, Hydraulic Resources and Fisheries). 2017. *Fee policy evaluation study and review and implementation of new pricing schemes, Dual pricing of treated wastewater at the level of the Public Irrigated Perimeter – Phase 1 diagnosis*. MARHP; DGGREE (Directorate General of Rural Engineering and Water Management); KFW (Kreditanstalt für Wiederaufbau).

MARHP. 2018. *Preliminary study for a national plan Reuse of treated wastewater for Tunisia - Diagnosis of the existing situation*. MARHP; ONAS (National Sanitation Office); the Ministry of Health.

Case Study 4: Tunisia

Ouardanine wastewater treatment plant and public irrigated perimeter

Chokri Saffar and Ibticem Chamtouri

Acronyms

ANPE	National Environmental Protection Agency
CRA	Agricultural Outreach Unit
GDA	Agricultural Development Group*
CRDA	Regional Commission for Agricultural Development*
CTV	Territorial Extension Unit*
DGGREE	Directorate General of Rural Engineering and Water Management*
DHMPE	Directorate of Environmental Health and Environmental Protection
MALE	Ministry of Local Affairs and the Environment
MARHP	Ministry of Agriculture, Water Resources and Fisheries
MSP	Ministry of Public Health
ONAS	Official Sanitation Office*
WWTP	Wastewater Treatment Plant

**Translated from French*

History and project justification

The Ouardanine Public Irrigated Perimeter (Ouardanine Perimeter) is an agricultural area created in the Monastir Governorate in central-eastern Tunisia planted to fruit trees, fodder crops and olives. Initially the perimeter covered an area of more than 50 ha. It was extended in 1997 to 74 ha. Today the land is owned by 42 farmers (Figure 4.1).

The area is considered a pilot site in that it was created in an agricultural area that lacks freshwater, and that also experiences flooding problems from the discharge of treated wastewater from the Ouardanine Wastewater Treatment Plant (Ouardanine WWTP) into the Oued El Guelta *wadi* (valley).

The Ouardanine WWTP was established in 1993 with a design flow of 1,500 m^3/day. The plant uses a medium-load activated sludge treatment system and is currently undergoing rehabilitation works through the National Sanitation Office (ONAS) to expand capacity by almost double. In 2006, a filtration station and a storage tank were installed by the Regional Commission for Agricultural Development (CRDA) Monastir to improve the quality of the discharged recycled water. They are located upstream of the pumping station toward the perimeter.

The Ouardanine Perimeter is an active location for scientific research and studies on irrigated agriculture in the Republic of Tunisia (Tunisia) and the first at the national level to use sludge as organic fertilizer to fertilize the land.

FIGURE 4.1 Location map of the Ouardanine WWTP. *SOURCE*: Google Earth.

Water reuse case description at a glance

The Ouardanine Perimeter is irrigated by recycled water from the Ouardanine WWTP, which is located 2 km north of Ouardanine town in the Monastir Governorate. Wastewater collections come from predominantly domestic sources in the town, although some wastewater comes from industrial sources, for example, car washes and slaughterhouses. The Ouardanine WWTP was built with a design flow of 1,500 m^3/day, which is expected to be increased to 2,900 m^3/day when the current extension project is completed.

Wastewater is treated at a secondary level by a medium-load activated sludge treatment system at the plant and then conveyed to the Oued El Guelta *wadi* upstream of the Ouardanine Perimeter (Figure 4.2) by means of:

- A storage basin with a capacity of 1,000 m^3 that is located near the Ouardanine WWTP's discharge point into the El Guelta *wadi*.
- A filtration plant consisting of two gravel filters, two screen filters and two disc filters.
- A pumping station with a suction tank equipped with three 20 L/s pumps of 40 m in height, one of which is an emergency pump.
- A 2.4 km long DN250 asbestos cement delivery pipe.
- A semi-underground reinforced concrete regulation tank with a capacity of 500 m^3 is located at the head of the perimeter.
- A buried piping distribution network fed by gravity from the regulation tank equipped with 22 irrigation hydrants. The irrigation hydrants are reinforced concrete manholes with tamper-proof closures and equipped with valves and a meter, although it is noted that these meters are generally out of order. The payment of volumes used by each farmer is made on a flat rate basis in relation to the irrigated area. A common fee is applied corresponding to an annual amount of USD 99/ha/year/farmer.
- Plot networks with buried PVC pipes installed by farmers.

The irrigation techniques used are localized for arboriculture while sprinkler irrigation is used for forage crops.

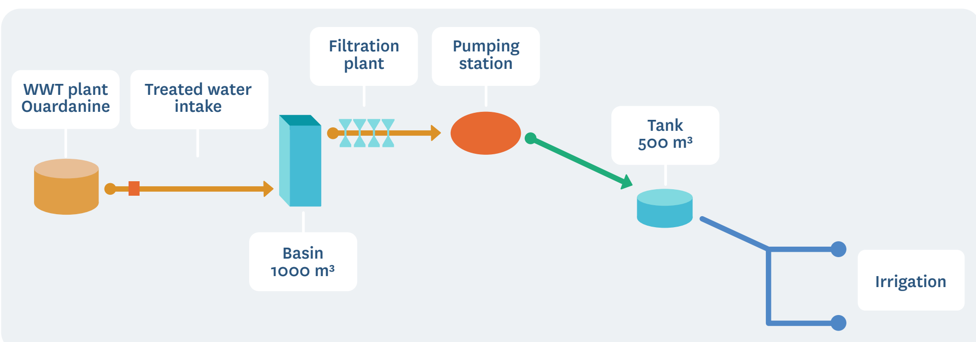

FIGURE 4.2 The Ouardanine WWTP and Public Irrigated Perimeter: Schematic diagram.

National institutional and policy framework

Wastewater discharge into the environment in Tunisia is regulated by Decree No 85-56 (January 2, 1985) with limits and quality standards set by the Ministry of Local Affairs and the Environment and the Ministry of Industry and Small and Medium Enterprises (March 26, 2018). It also requires authorization from the ONAS subject to its compliance with conditions for the discharge and disposal of non-domestic wastewater in the sewerage networks set out by Decree No 94-1885 (September 12, 1994).

In terms of water reuse for agricultural purposes and required measures to protect the health of consumers and the environment, regulations are set out in Decree No. 89-1047 (July 28, 1989) and modified by Decree No. 89-1047 (July 28, 1989) and Decree No. 93-2447 (December 13, 1993). The required quality of recycled water from wastewater treatment plants for agricultural use is set out in Standard NT106.03 (September 12, 1994). In addition, the list of crops that can be irrigated by recycled water was set out by the Ministry of Agriculture and Water Resources in 1994, which also ruled out its use in market gardening, meaning that it cannot be used on fruits and vegetables that can be eaten raw.

Recycled water from wastewater treatment plants is provided to the Regional Commissions for Agricultural Development (CRDA) free of charge by ONAS. The CRDAs then charge farmers a nominal fee of USD 0.0073/m^3 for water consumption. This pricing system was implemented by a presidential decision in 1998 to promote recycled water use for agricultural purposes.

At the institutional level, four actors play a key role in the field of recycled water reuse for irrigation:

- ONAS who owns and operates the wastewater treatment plants.
- The Ministry of Agriculture, Hydraulic Resources and Fisheries is the managing authority for recycled water reuse through the CRDA that first developed the areas to be irrigated with recycled water from the wastewater treatment plants. Direct contact with farmers is made through agricultural development groups.
- The CRDA as the distributor of recycled water and the Ministry of Health share monitoring of treated wastewater quality.
- The end-user.

Stakeholders involved and management model

The public irrigated area of Ouardanine was developed by the Regional Commission for Agricultural Development (CRDA) Monastir. The recycled water from the Ouardanine WWTP that is transferred to the Ouardanine Perimeter is produced and supplied free of charge by ONAS.

Project beneficiaries have been organized into an Agricultural Development Group (GDA). The management of the infrastructure and resources provided through the water reuse project is delegated by the CDRA Monastir via a management contract that specifies which tasks are carried out by the GDA and which are carried out by CRDA Monastir. The main tasks carried out by the GDA are limited to distributing water to the farmers, reading meters, collecting water payments and carrying out minor repairs to the irrigation network within the perimeter. Since the sale price of the recycled water is very low and does not cover the necessary expenses such as energy, maintenance and personnel costs, CRDA Monastir covers the energy costs related to the pumping of water through WWTP invoices, as well as major repairs of the transfer network from the intake structure to the regulation tank. Since January 2021, the GDA has been asked to contribute to energy costs by paying an annual amount of USD 2,150/year.

The CRDA Monastir and its representatives at the regional level including the Territorial Extension Unit (CTV), the Agricultural Outreach Unit (CRA) and others provide technical assistance to farmers and supervise the GDA.

Quality control of the recycled water from the WWTP is carried out by ONAS, the CRDA and the Ministry of Public Health according to the schedule set by current legislation (Figure 4.3).

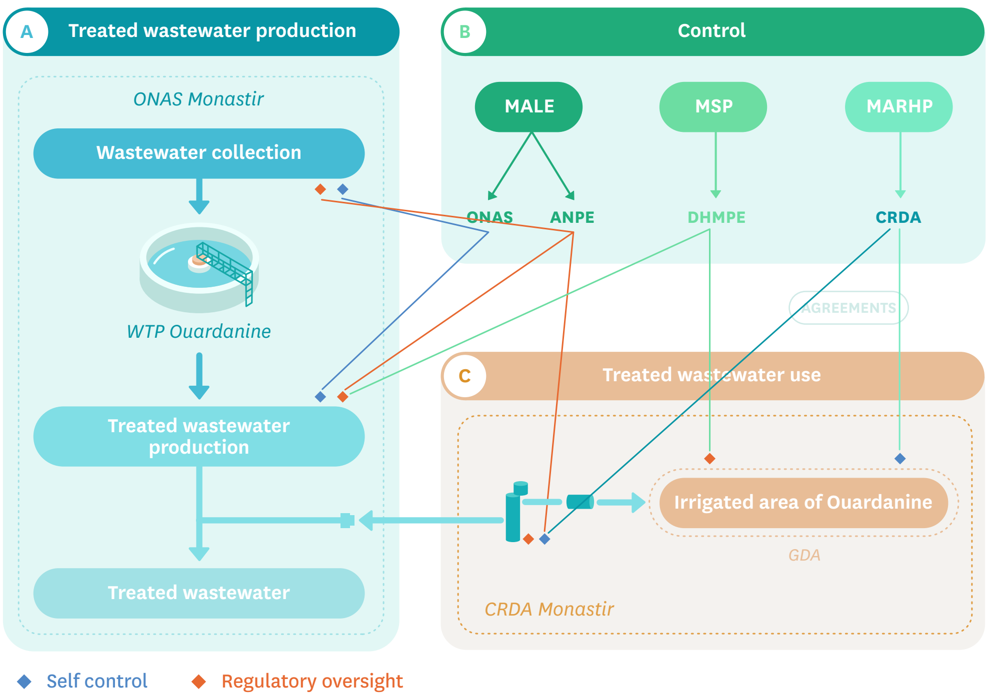

FIGURE 4.3 Ouardanine WWTP and Public Irrigated Perimeter: Stakeholder and management model. *NOTES*: National Environmental Protection Agency (ANPE), Regional Commission for Agricultural Development (CRDA), Directorate of Environmental Health and Environmental Protection (DHMPE), Agricultural Development Group (GDA), Ministry of Local Affairs and the Environment (MALE), Ministry of Agriculture, Water Resources and Fisheries (MARHP), Ministry of Public Health (MSP), National Sanitation Office (ONAS), Wastewater Treatment Plant (WWTP).

Funding and financial outlook and cost recovery

Table 4.1 summarizes the capital expenditure, operating expenditure and cost recovery related to the Ouardanine WWTP and Perimeter.

Socioeconomic, health and environmental benefits and impacts

The creation of the Ouardanine Perimeter has resulted in significant socio-economic, health and environmental benefits.

Economic benefits include an increase in the value of agricultural land. The price of an irrigated hectare increased from USD 1,800 in 1996 to USD 1,364 in 2014. It is currently valued at USD 7,182.

There has also been an increase in the agricultural production of the irrigated farms, which represents triple the average recorded in the whole of the Republic of Tunisia including:

- 25 ha of peach trees with an average production of 30 tons/ha.
- 10 ha of fig trees with an average production of 10 tons/ha.
- 15 ha of pomegranate trees with an average production of 40 tons/ha.
- 24 ha of olive trees intercropped with various fruit trees.

TABLE 4.1 Funding and financial outlook and cost recovery.

	Wastewater collection and transfer	Wastewater treatment	Transfer of treated wastewater	TWW Distribution
Construction and equipment services (description and dimensions)	Wastewater collection network of the city of Ouardanine	Ouardanine WWTP	A storage basin with a capacity of 1,000 m^3 located near the discharge point of the WWTP into the El Guelta *wadi*, fed from the discharge pipe of the WWTP in DN300 asbestos-cement A filtration plant consisting of two gravel filters, two screen filters and two disc filters A pumping station with a suction tank equipped with three 20 L/s pumps of 40 m HMT, one of which is an emergency pump A DN250 asbestos-cement delivery pipe with a length of approximately 2.4 km	A semi-buried reinforced concrete regulation tank of circular shape and capacity of 500 m^3 is located at the head of the perimeter A buried asbestos cement pipe distribution network (2.7 km) of DN150 and 300 mm, served by gravity from the regulation tank 22 irrigation posts

	Wastewater collection and transfer	Wastewater treatment	Transfer of treated wastewater	TWW Distribution
Stakeholder providing the service	ONAS Ouardanine/ Monastir	ONAS Ouardanine/Monastir	CRDA Monastir	CRDA Monastir
Capital Expenditure (CAPEX) (in USD)	No access to this data	No access to this data	Perimeter development in 1994: 0.5 million Storage basin creation in 2006–2007: 100,000 Installation of a filtration plant in 2006–2007: 80,000 Rehabilitation of the pumping station in 2016: 20,000 Construction of 1.7 km of agricultural tracks within the perimeter: 25,000	Rehabilitation of the distribution network in 2012: 20,000
Recovery CAPEX and % subsidy	100% subsidy ONAS provides free recycled water to the CRDA of Monastir		State funding	State funding
Operating & Management (O&M) services (description)	Infrastructure maintenance, pumping costs, renewal, salaries	Infrastructure maintenance, pumping costs, renewal, salaries	Infrastructure maintenance, pumping costs, renewal, salaries	Infrastructure maintenance, renewal, salaries
Stakeholder providing the service	ONAS Ouardanine/ Monastir	ONAS Ouardanine/Monastir	CRDA Monastir	CRDA Monastir and GDA
Operating expenses (OPEX) (in USD/m³)	Data not available		Water costs of CRDA Monastir 0.090	
OPEX recovery and % subsidy	Nearly 70% of ONAS's financial resources come from sanitation fees, mainly collected through SONEDE's billing: USD 0.02 to 0.05/m³ according to the following principles (i) beneficiary-pays; (ii) polluter-pays and (iii) solidarity between users. The rest of ONAS's budget is financed by the State (25.6%) and other related activities (5.4%). Given all its expenses, ONAS provides the recycled water from the WWTP to the CRDAs free of charge.		CRDA Monastir sells the recycled water to the GDA at USD 0.016/m³, which results in a significant subsidy of USD 0.074/m³ borne by the CRDA. In application of the reduced price decided by the State to encourage the use of recycled water, it is sold by the GDA to the farmers at a unit price of USD 0.0073/m³.	

NOTES: Capital Expenditure (CAPEX), Regional Commission for Agricultural Development (CRDA), Agricultural Development Group (GDA), Total Pump Height (HMT), Official Sanitation Office (ONAS), Operational Expenditure (OPEX), Societé Nationale d'Exploitation et de Distribution des Eaux (SONEDE – National Water Company).

Jobs have also been created for young people in the project area as the number of working days has increased from 20 days/ha in 1996 to 155 days/ha just four years after the perimeter was irrigated.

Environmental benefits include minimizing the discharge of recycled water from Ouardanine WWTP into the El Guelta *wadi*. In 2019, between March to September, all of the recycled water was used within the perimeter as a result of a significant lowering of the water table, which is an ongoing challenge. This enabled the return of agricultural activity on 7.2 km of land located near the *wadi* that had been previously damaged because of discharge (Image 4.1). Other benefits include the use of treatment sludge from the plant as an organic fertilizer.

The Ouardanine Perimeter also plays an important role in raising awareness of irrigation by recycled water from wastewater treatment plants at the local as well as national levels. It receives an average of 1,000 visitors each year.

Gender equality

When the perimeter was created, both men and women were able to be potential beneficiaries under the terms of the CRDA, as long as they undertook to comply with legislation requirements.

Currently, out of a total of 42 farmers, there are two female heads of household. This equates to about 5%. In contrast, in terms of women's participation in agricultural work, the numbers are quite substantial. For half of the farmers in the project area, working the land is a family tradition in which women and even children take part. It is also reported that, in addition to household members, the heads of farms also use female labor from neighboring areas when necessary. At least four women per farm are occasionally assigned to the perimeter.

IMAGE 4.1 Stagnation of treated wastewater in the El Guelta wadi at the Ouardanine perimeter (June 2021). *SOURCE*: I. Chamtouri, Hydroplante, Tunis.

Scalability and feasibility potential

The Ouardanine Perimeter is located in an extensive agricultural area where both arboriculture (especially dry-farmed olive trees) and cattle rearing (without a grazing area owing to the absence of irrigation and fodder production) play an important role in generating income for the population. The absence of other sources of conventional water and the aridity of the climate makes the possibility of extending the irrigated area highly probable, particularly given the demands made by a large proportion of the farmers in the area who deem it necessary.

SWOT analysis

Table 4.2 summarizes the analysis of the strengths and weaknesses of using recycled water from wastewater treatment plants and the opportunities and threats that may be observed in the Ouardanine WWTP and Perimeter case study.

TABLE 4.2 The Ouardanine WWTP and Public Irrigated Perimeter: SWOT analysis.

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ■ A significant potential in continuous recycled water availability throughout the year. ■ Fertilizing power of recycled water means less mineral fertilizer use. ■ High potential for agricultural land to be irrigated and high motivation of farmers in the area for the project. ■ No other continuous source of water for irrigation near the existing perimeter. ■ More than 24 years of experience with recycled water for irrigation in the project area and a high rate of intensification in the existing perimeter (140%).	**WEAKNESSES** ■ Restrictive list of authorized crops with few high-value crops. ■ Poor pricing, set at USD 0.072/m^3, which means costs of reusing treated wastewater are largely borne by the CRDA. ■ Frequencies of non-compliance with recycled water quality control and all other parameters to be analyzed, at the CRDA and the ONAS. ■ Poor management of the additional treatment equipment installed at the head of the perimeter including algal growth in the storage tank. This tank is very deep (3 m), which favors the development of septic conditions.
EXTERNAL FACTORS ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ■ A political will to promote water reuse. ■ Many users are willing to pay more for recycled water from wastewater treatment plants to get better quality water. ■ Less discharge into the *wadi* and sometimes all of the recycled water produced is used (from March to September).	**THREATS** ■ Poor flow of the El Guelta *wadi* following discharges of treated wastewater and sludge which generate the development of vegetation formed by reeds and other halophilic plants which slow down water flow. This causes a rise in the static level of the water table which can asphyxiate the fruit trees, salinization of the soil and proliferation of insects, as well as odor nuisance. ■ Difficulties related to the quality of the recycled water.

Key factors for success along the project and lessons learned

During the design, construction and operation of the project, key factors of success include:

- The political will to promote the use of recycled water from wastewater treatment plants at the national level.
- The commitment of the ONAS to rehabilitate and extend WWTPs and improve the quality of treated wastewater.
- The mitigation of the environmental and health impacts of treated wastewater discharges into the natural environment, which is one of the main driving forces for its reuse. In the case of the Ouardanine Perimeter, irrigation using recycled water enables the preservation of agricultural land located near the discharge outlet of the plant at the Oued El Guelta.
- The strong and important fertilizing power of recycled water from the WWTPs is significantly increasing agricultural production. The Ouardanine Perimeter is one of the successful water reuse sites in Tunisia, particularly in terms of the development of irrigated arboriculture (Image 4.2).

Lessons learned include:

- The supervision and monitoring of farmers is an important factor in the success of public irrigated perimeters.
- The quality of the water produced by the WWTPs and supplied for irrigation must comply with at least the NT106-02 discharge standard to ensure efficient operation of the public

IMAGE 4.2 Fig tree plot irrigated by TWW–Quardanine irrigated perimeter. Photo: I. Chamtouri.

irrigated perimeters. The installation of a complementary treatment plant at the head of the perimeters, as in this case, is becoming a necessity given the fluctuations in the quality of treated wastewater throughout the operation of the WWTPs and illicit polluted discharges into the ONAS sewers despite continuous control of the networks.

Methods and resources

This water reuse case was prepared in collaboration with:

- The treated wastewater distributor: The Regional Commission for Agricultural Development (CRDA) Monastir.
- The treated wastewater producer: The National Sanitation Office of Ouardanine (ONAS), Ouardanine WWTP.
- The Ouardanine Public Irrigated Perimeter management body: the Agricultural Development Group (GDA).
- Current perimeter operators.

The approach included:

- Analysis of documentation concerning the Ouardanine Public Irrigated Perimeter and the Ouardanine WWTP.
- Consultation with staff at local structures, resource persons and local populations to collect required data on the plant and the current state of the existing perimeter. Note that some data could not be obtained, especially concerning ONAS.
- Field observations and investigations, which were carried out on June 17, 2021, at the Ouardanine Public Irrigated Perimeter. The investigations included direct communication with farmers to determine crops grown and current operating constraints.

Additional resources used in gathering data for this study include:

CDRA (Regional Commission for Agricultural Development). 2020a. *Irrigated Perimeter, Follow up sheet*. Ouardanine. CRDA.

CRDA. 2020b. *Physico-chemical and bacteriological analysis sheets for treated wastewater collected from the Ouardanine Public Irrigated Perimeter storage basin (2019 and 2020)*. Monastir. CRDA.

MARHP (Ministry of Agriculture, Hydraulic Resources and Fisheries). 2017. Fee *policy evaluation study and review and implementation of new pricing schemes, Dual pricing of treated wastewater at the level of the Public Irrigated Perimeter – Phase 1 diagnosis*. Tunisia. MARHP; DGGREE (Directorate General of Rural Engineering and Water Management); KFW (Kreditanstalt für Wiederaufbau).

ONAS (National Sanitation Office). 2003. *Feasibility study for the development of treated wastewater reuse in the Ouardanine region*. Republic of Tunisia. ONAS.

ONAS. 2018a. *Preliminary study for a national plan: Reuse of treated wastewater for Tunisia - Diagnosis of the existing situation*. Tunisia. MARHP (Ministry of Agriculture, Hydraulic Resources and Fisheries); ONAS; the Ministry of Health.

ONAS. 2018b. *Ouardanine wastewater treatment plant activity report*. Ouardanine. ONAS.

Case Study 5: Palestine

Jericho wastewater treatment plant and West Bank date palm irrigation

Nidal Mahmoud

Acronyms

JICA	Japanese International Cooperation Agency
JM	Jericho Municipality
MOA	Ministry of Agriculture
PFU	Palestinian Farmers' Union
PWA	Palestinian Water Authority
WWTP	Wastewater Treatment Plant

History and project justification

Although it has reasonable long-term average rainfall – 450 mm to 600 mm annually – Palestine experiences serious constraints to accessing water resources. This is due in part to a high dependence on aquifers and hot, dry summers that result in water loss, for example, through increased evaporation. Water access is also challenging due to political unrest in the West Bank[1] area, which impacts on flows to harvesting structures such as dams (PWA 2017). These two factors combined mean that the West Bank has a water deficit – the difference between supply and demand – of 36 MCM/year. This gap is expected to grow significantly if no other sources are developed, and no further demand management is implemented (PWA 2017).

The Jericho Wastewater Treatment Plant (Jericho WWTP) started operations in June 2014 with the dual purpose of treating wastewater generated in the area and providing recycled water as a new source of irrigation water for date palm cultivation (Images 5.1 and 5.2) in the West Bank, to reduce the burden on water availability compared to demand (JICA 2014).

[1]Note: Boundaries and names shown and the designations used on any maps or text within this case study are used as geographical references and do not imply official endorsement or acceptance by the International Water Management Institute (IWMI).

IMAGE 5.1 Date palm (*Phoenix dactylifera* L.) farms in the Jericho district. Photos: the author.

IMAGE 5.2 Jericho WWTP and surrounding date palm farms. Photo: I Abu Seiba

Before its construction, households in the area depended on thousands of cesspits with waste materials discharged into open *wadis* (valleys) and resulting in continuous deterioration of human living and environmental conditions.

Reuse case description at a glance

Jericho WWTP is an extended aeration-activated sludge plant. It started operations in 2014 with a planned daily average capacity of 6,600 m^3/day by 2020, and will reach a maximum of 9,600 m^3/day by 2025, equivalent to 80,000 people. The project included the installation of more than 30 km of new sewers (with a diameter of 200–700 mm) to collect wastewater generated in Jericho City and its surrounding areas (Table 5.1 and Figures 5.1 and 5.2).

TABLE 5.1 Jericho WWTP: Data sheet.

Area (hectares)	10.3
Mean temperature (°C)	15–40
Annual average precipitation (mm)	50–400
Overall mean sea level (m)	-250
Population to be served by the project (capita)	23,600
Number of workers	10
Civil structures	Waste Receiving Tank for Vacuum Trucks Grit Chamber (two channels) Reactor (two tanks) Final Clarifier (two tanks) Sludge Thickener (two tanks) Disinfection Tank Irrigation Tank Sludge-Drying Bed (six beds) In-plant Landscaping In-plant Piping Architectural Structures (Reinforced Concrete/Concrete Block) Administration Building Substation Building Workshop Building, Blower and Electric Room Return-Sludge Pump House Chlorine House Thickened-Sludge Pump House
Type of treatment process	Extended Aeration Activated Sludge Process
Aeration type	Diffusers

SOURCE: JICA 2011.

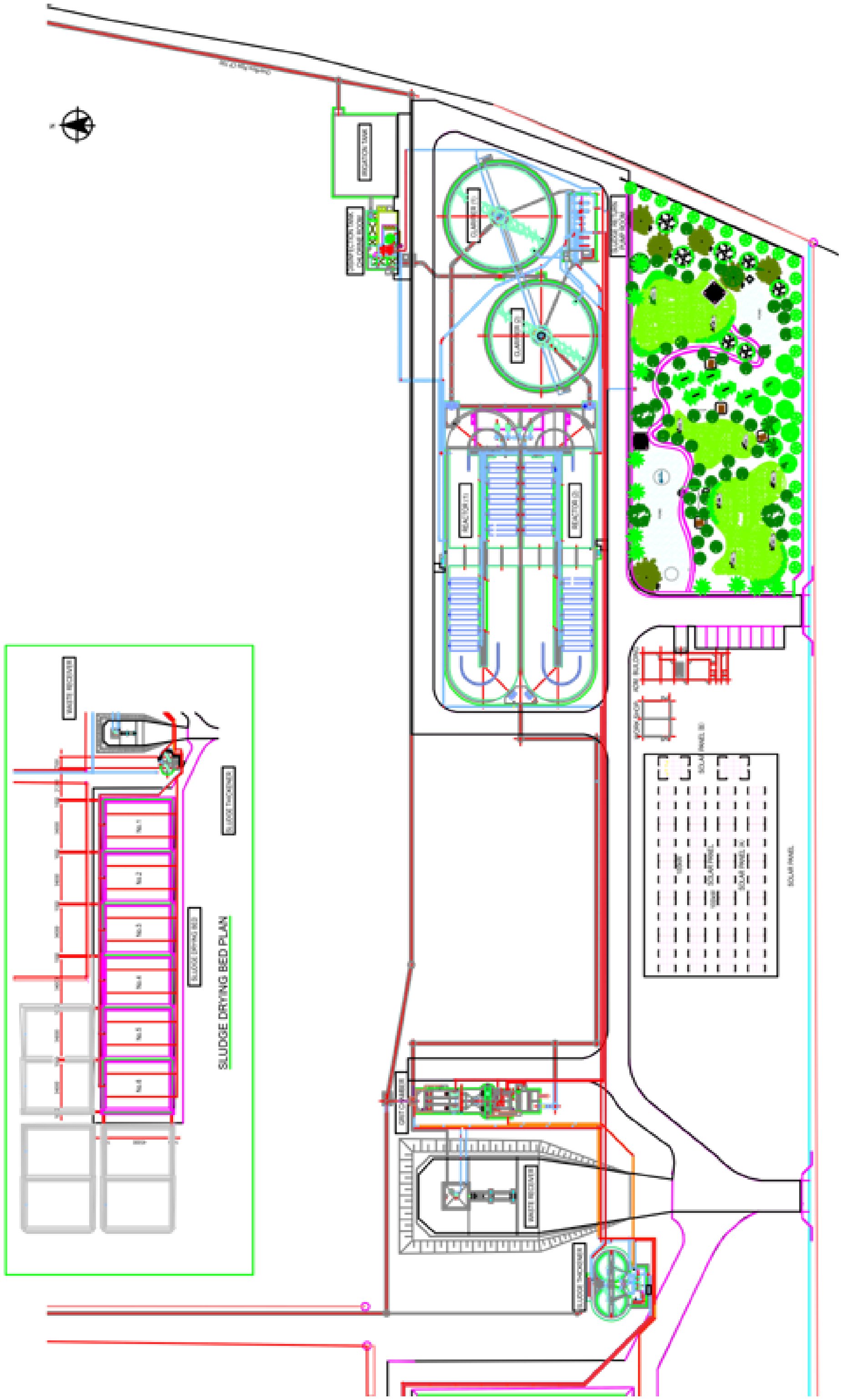

FIGURE 5.1 Jericho WWTP: Schematic diagram. *SOURCE:* Jericho Municipality.

FIGURE 5.2 Jericho location and borders overlaid on a map showing Jericho WWTP and water reuse area.
SOURCE: Google Earth (31°50'23.16" N 35°29'57.60" E).

In terms of water reuse capacities, the Jericho WWTP has an effluent storage tank – the irrigation tank – that is equipped with several pumps that take the treated effluent to the date palm tree farms that use it for irrigation (Image 5.3) using surface drip irrigation. These pumps, installed by the farmers, convey the treated effluent directly into the farms' irrigation networks. The amount pumped to each farm is measured by a flow meter with the volume of reused water averaging is 1,247 m^3/day, which is enough to irrigate 30 ha.

National institutional and policy environment

One of the most important agricultural strategic objectives for Palestine is to conserve and rehabilitate its natural resources essential to supporting production systems. To this end,

IMAGE 5.3 Effluent storage and irrigation tank and the effluent pumps and the flow meters at Jericho WWTP. Photos: I Abu Seiba.

the Ministry of Agriculture is looking to increase the availability of both conventional and unconventional water resources for both crop producers and livestock breeders (MOA 2016), including a substantial increase in the use of recycled water from wastewater treatment plants (PWA 2014; MOA and PWA 2014). The government officially recognizes this water as an agricultural water resource (Palestinian Agricultural Law No 2/2003) and its use is included in the Palestinian National Climate Change Adaptation Plan (Smithers 2016). Its use also supports one of the main objectives of the National Agriculture Sector Strategy (2017–2022), which requires that natural and agricultural resources are sustainably managed and better adapted to climate change (MOA 2016).

In 2003, the Palestinian Standards Institute issued a Treated Wastewater Standard (PSI 742-2003). This sets out the important parameters and requirements concerning its use as irrigation water and for discharge to the *wadis*. It also issued Obligatory Technical Regulations (PSI TR 34, 2012) that divide the quality of recycled water specialized for irrigation into four categories: high quality (A), good quality (B), moderate quality (C) and low quality (D). The regulations also set out obligatory requirements and technical instructions for controlling, permitting, conveying and reusing recycled water from wastewater treatment plants for irrigation. The most recent standard of treated effluent use for irrigation issued by the Palestinian Standards Institute was the Treated Wastewater – Treated Wastewater Effluent for Agricultural Purposes (Restricted) (PSI 742-2015) in 2015 (PSI 2015).

Stakeholders involved and management model

Several stakeholders at different levels are involved in the Jericho WWTP and water reuse project (Figure 5.3).

At the national level, the Palestinian Water Authority (PWA) is the main actor at the water policy-making level. PWA owns Jericho WWTP and is the national body responsible for policy, planning and monitoring of water-related service delivery including monitoring effluent quality. They are also responsible for future upgrades of the plant.

Day-to-day operations at the Jericho WWTP are managed by staff. Staff also carry out analysis on effluent quality, report results back to the PWA and manage the process of supplying recycled water to the farmers including the related contractual and financial administration responsibilities.

Matters relating to irrigated water come under the authority of the Ministry of Agriculture (MOA), which issues licenses to permit farmers to use recycled water from WWTPs. It also monitors the quality of water used for irrigation and the standards of the marketed crops that are produced through its use. In conjunction with the PWA, they also grant licenses to the water users' association, which is a coordinated group for the farmers who are the main end-users. Currently, the farmers make individual agreements in terms of purchasing recycled water from the Jericho WWTP, but it is expected that the water users' association will soon become active and manage the use of all irrigation water sources including recycled water (Figure 5.3).

In terms of relationships between the various stakeholders, coherence is low and not fully functional at a practical level, particularly when it comes to follow-up activities, such as checking the recycled water quality, reporting and sharing data, and managing the distribution of recycled water to farmers.

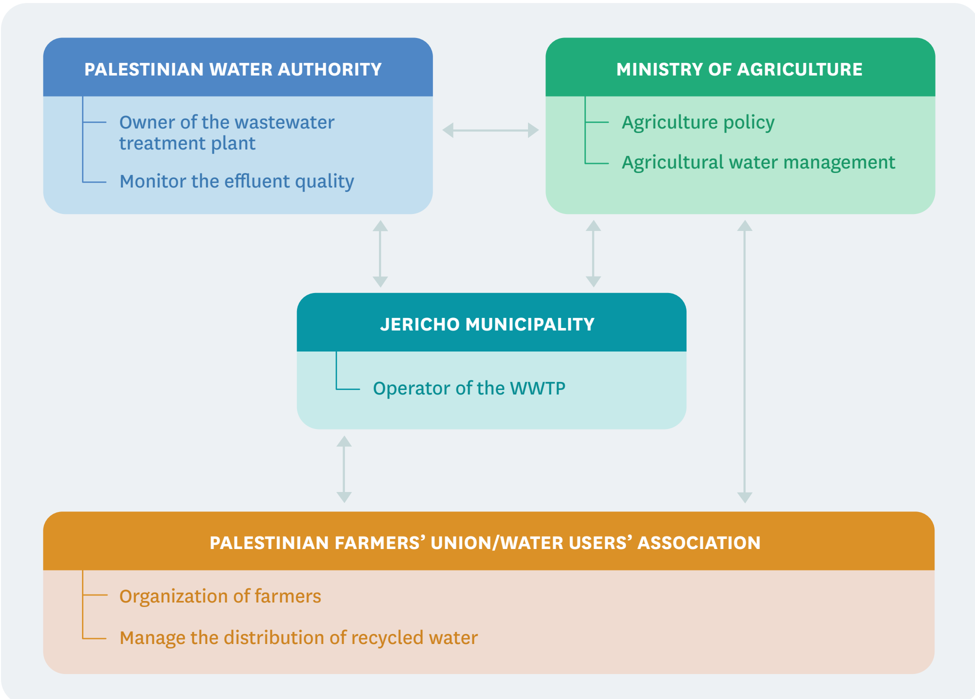

FIGURE 5.3 Jericho WWTP and West Bank Date Palm Irrigation Project: Stakeholders and management model.

Funding and financial outlook and cost recovery

The Japanese International Cooperation Agency (JICA) sponsored the Jericho WWTP and West Bank Date Palm Irrigation Project as a Grant Aid Project by the Japanese Government at a total cost of USD 32 million. Around 30% of Jericho WWTP's operational costs are recovered by selling treated effluent for reuse (Figure 5.4, Table 5.2). This benefits farmers who receive a reduced tariff for wastewater services.

In Jericho, there is a high demand for irrigation water, which still has limited supplies. Now this is resulting in more than 80% of recycled water produced at the plant being reused. A questionnaire revealed that the cost of recycled water (USD 0.20/m^3 including the 0.16 USD paid to the Jericho WWTP and the pumping cost of around USD 0.02/m^3) is cheaper than the cost of groundwater (USD 0.3-0.7/m³). On some days, the percentage of reused effluent quantity is higher than 100% due to the accumulation of water from previous days. The percentages of cost recovery increase with time as treatment operational unit costs decrease due to flow increases. Jericho WWTP is expected to make more profit with time.

Socioeconomic, health and environmental benefits and impacts

Date palm cultivation is a fundamental part of the development of the agricultural economy in Jericho, yet its potential has been limited by the low availability of water resources for irrigation. The Jericho WWTP provides an attractive new non-conventional water resource that is already almost fully utilized for supplementary irrigation on date palm farms, representing 8–25% of the total irrigation water used for date palm cultivation in Jericho. The areas of the farms partially irrigated with recycled water from wastewater treatment plants range from 10 to 300 ha, with the average area exceeding 85 ha. Each hectare is typically planted with 140 palm trees.

Most of the farmers (80%) mix the recycled water with groundwater. This reduces the salinity of the groundwater. 20% of these farmers have also reduced the volume of chemical fertilizers they add to their soils due to the increased nutrients in the recycled water – all farmers in the area use both chemical and organic fertilizers. The farmers have not observed any

FIGURE 5.4 Percentage of treatment operational cost due to effluent selling for reuse.

negative impacts on the soil since irrigation through the reuse project started and likewise, all of them affirmed that they had never witnessed any disease outbreaks in humans, animals or the irrigated date palms.

In terms of employment, each farm has 2–30 full-time workers and represents the main source of livelihood for both owners and employees so are hugely important. The marketed

TABLE 5.2 Capital expenditure, operating costs and cost recovery.

Wastewater collection and transport	WW treatment	Transport of treated wastewater	Additional wastewater treatment for reuse	Distribution of reclaimed water to end-users
Construction and equipment services (description and dimensions)	Wastewater treatment plant, land leasing, fence, access road, and power cable, engineering services, equipment, bank commission.	Treated effluent is stored in an irrigation tank (1,000 m³) that is located at the site of Jericho WWTP. Farmers directly pump the effluent onto their farms. Capital cost and recovery are mixed with the wastewater treatment costs.	Chlorination unit – capital cost and recovery are mixed with the wastewater treatment costs.	Small pumps and main pipes – the cost of units is paid by the farmers. There are 10 systems, each with a cost of around USD 300.
Stakeholder that delivers the service	JM PWA	JM PWA	JM PWA	PFU
CAPEX (in USD)	23 million	Cost and recovery are mixed with the wastewater treatment	Cost and recovery are mixed with the wastewater treatment	3,000
CAPEX recovery (in USD and % of subsidy	0 (100%)	0	0	0
Operations & Management Services (description)	Electricity, diesel, chlorine and staff costs		Chlorine	Pumping of treated wastewater to the farms
Stakeholder that delivers the service	JM	JM	JM	PFU
OPEX in USD/year	268,755+	0	3,232	Note: pumping cost is pre-paid by the farmers at USD 39,850
OPEX recovery in USD/year and % of subsidy	211,143++ (Average) water charges/tariffs to households (and other urban users) for wastewater services (USD/m³ used)			80,000+++ (0% subsidy) 498,130 m³ reclaimed water sold/year x 0.16/m³

NOTES: Capital expenditure (CAPEX), Jericho Municipality (JM), Israeli New Shekel (NIS), Operational expenditure (OPEX), Palestinian Farmers' Union (PFU), Palestine Water Authority (PWA). + Based on May 2021 data. ++Domestic water calculated for 2021 based on wastewater amount entering WWTP multiplied by 1.165 (annual increase speculated based on 2019 and 2020 data), divided by 0.427 (percentage of water converted to wastewater based on previous studies in Jericho); 0.16 USD is equivalent to NIS 0.5 that is charged for each 1 m3 of water supply as a wastewater fee. +++Reused wastewater calculated for 2021 based on the data available for 2020 multiplied by 1.27 as speculated from the increase based on the previous year (2019).

effluent is beneficial for the farmers and the general public as it brings back revenues that cover almost 30% of operational costs.

Gender equality

All of the farmers involved in the project, including farmer-owners and workers, are male. Work on remote date palm farms is considered to be extremely laborious and socially unacceptable for women. There are opportunities for women in segregating and packing the dates, a period which lasts for five months and where female workers represent 75–100% of the workforce. However, as the farms are family businesses, while owned by men, women are involved in managing the business.

At the Jericho WWTP, all the staff members are male, even though there are no institutional barriers to women working there. Low participation of women in the workforce is a national issue in Palestine, reaching only 18% of total women of work age (PCBS 2020). Additionally, a recent study showed the percentage distribution of 20–29-year-olds with an intermediate diploma or bachelor's degree who had qualified in engineering was 4% of the females compared to 11% of the males (PCBS 2019).

Resilience to COVID-19

While the COVID-19 pandemic did not have a clear impact on the Jericho WWTP's performance, the profits of the farmers and three date factories were negatively impacted. The factories had extra health safety expenditures that increased operational costs by at least 3% while some workers at the factories infected by COVID-19 were placed in quarantine on full salary. Of particular consequence were the mobility restrictions including on international travel, which negatively impacted date sales and increased shipping costs. Moreover, local and international demand decreased simply because of reduced social gatherings and events, which resulted in a reduction in the sale price of around 30% and a market that was largely localized. However, despite the negative economic effects of the pandemic, the date palm agro-industry has managed to withstand the crisis, even with reduced profits during this period.

Scalability and replicability potential

The demand for treated effluent produced at the Jericho WWTP is such that the recycled water is used to its maximum limit for date palm irrigation, in an area with limited availability of other water resources. In fact, there is a waiting list of farmers who want to join the scheme as soon as capacity increases. Those that are already receiving the recycled water are highly satisfied. They have not experienced any negative impacts on either the quantity or the quality of the dates, or the general environment. On the contrary, farmers are seeing positive impacts.

The Jericho WWTP is not yet operating at full capacity, which is predicted to reach four times current production. This means the scalability potential of reclaimed water use in the date palm farms in Jericho is very high. Likewise, because of the great success of Jericho the wastewater treatment and reuse scheme, from socio-economic and environmental perspectives, the high replicability of the project is foreseen not only in Palestine but also in other countries in the region with similar conditions.

SWOT analysis

Table 5.3 presents the strengths, weaknesses, opportunities and threats of treated wastewater and its use as a recycled water source for date palm irrigation in Jericho.

TABLE 5.3 Jericho WWTP and West Bank date palm irrigation: SWOT analysis.

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ■ Minimum water quantity can be guaranteed ■ Benefits of side product ■ Low energy requirements ■ Advanced system of water purification ■ Associated social, environmental and economic benefits	**WEAKNESSES** ■ High price of treated effluent ■ Not enough storage is available for surplus water during some seasons
EXTERNAL FACTORS ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ■ Water conservation policy ■ Demand for reclaimed water is higher than plant potential ■ High acceptance of treated wastewater as a water source ■ Public awareness of the water scarcity problem and the potential of the new source ■ Increasing drought period ■ Increased use of bio-solids (sludge) is possible ■ Emphasis on alternative sources of water ■ Easy social marketing of the benefits of the product	**THREATS** ■ Improper operations and management arrangements can endanger functioning ■ Possible health risks to operators, neighbors, farmers and consumers ■ If the team does not fully appreciate the potential benefits of monitoring and reflection, it will not be implemented adequately ■ No full recovery of CAPEX and OPEX ■ Low coherence of stakeholders

Key factors for success along the project and lessons learned

During the design, construction and operation of the project, key factors of success in the Jericho WWTP and West Bank date palm irrigation project include:

- The Jericho WWTP successfully provided the agreed quantities of wastewater to farmers, satisfying their needs and creating a client base, as well are reusing all of its wastewater.
- Wastewater reuse creates income for Jericho WWTP and as such contributes to the financial sustainability of this important environmental infrastructure and reduces the tariff charges to the serviced population.
- Recycled water from the Jericho WWTP is an additional source of water that has enhanced the potential of date palm agribusinesses in the Jericho district.
- No negative impacts were reported on date palms, humans and animals from the use of recycled water from Jericho WWTP. The soil also appears to be unaffected although this is based only on visual observations comparing it to other parts of the farms where treated effluent is not used.

Lessons learned include:

- Stakeholders require more knowledge on treated effluent and better coordination, which can be achieved through workshops and meetings that are better organized and more frequent.
- Farmers have indicated the need for training on the use of treated effluent for more productive and safer use of the resource.

Methods

Reports were collected about the status of water in the West Bank and wastewater treatment and reuse and reviewed. These included monthly reports on the Jericho WWTP for the period January 2019 to May 2021, which contained data about influent, effluent and reuse quantities, and the treatment cost and power consumption recorded by the plant operators.

A structured questionnaire was designed to collect data from each of the seven farmers in the irrigation area. It was designed after consultation with key people concerned with water reuse at the Ministry of Agriculture and the Jericho WWTP. The farmers, who own and manage large date palm tree farms, are using recycled water from Jericho WWTP to irrigate their farms. Interviews were carried out with each farmer, five of which were carried out in person. Other interviewees included the chief operator of Jericho WWTP and the Director of the Wastewater Reuse Department of the Ministry of Agriculture (MOA).

The questionnaire included 58 structured questions, in addition to open questions, grouped in the following main categories:

- General information about the farmers and the irrigated farms
- Knowledge level of the farmers
- Practices of recycled water reuse from wastewater treatment plants
- Monitoring reuse process on farms
- Prices and quantity of water
- Incentives and obstacles
- Impacts of using recycled water from wastewater treatment plants

The collected data were analyzed and processed using Microsoft Excel.

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Case Study 6: Jordan

Tala Bay wastewater treatment plant and water reuse by hotels and resorts

Loay Froukh

Acronyms

ADC	Aqaba Development Corporation
ASEZ	Aqaba Special Economic Zone
ASEZA	Aqaba Special Economic Zone Authority
AWC	Aqaba Water Company
JPTD	Jordan Projects for Tourism Development
USAID	United States Agency for International Development
WAJ	Water Authority of Jordan
WWTP	Wastewater Treatment Plant

History and project justification

Aqaba is a city in southern Jordan on the Red Sea, close to the Saudi Arabian border and Egypt. It is popular with tourists who come to enjoy its many attractions including its marine life and coral reefs, warm weather in the winter season and proximity to the famous historical city of Petra.

Tala Bay Hotels and Resorts complex (hereinafter Tala Bay Resort) was the first resort and lifestyle complex to be developed in Jordan (Figure 6.1). On the shores of the Red Sea, 14 km south of Aqaba, it occupies an area of 2.7 million m^2 (JPTD 2022). It extends along 7 km of shoreline and its hillside position gives visitors panoramic views of the marina and Mount Sinai.

Tala Bay Resort's development was carried out as part of the Aqaba Special Economic Zone (ASEZ) – a low tax, duty-free, multi-sector development zone inaugurated in 2001 (ASEZA 2001; ADC 2022; AWC 2022). Its management and development come under the responsibility of the Aqaba Special Economic Zone Authority (ASEZA) (ASEZA 2001; ADC 2022). Being part of ASEZ has made Aqaba attractive to investors including Jordan Projects for Tourism Development (JPTD), one of the investors in the Tala Bay Resort.

The resort was constructed on Aqaba's southern beach, which has no wastewater collection system. As is the case with all developed projects in areas with no wastewater collection system in place, the developers needed to construct a WWTP. This requirement also provides an opportunity to supply recycled water from the plant for use around the complex to irrigate the landscaped spaces, for example, green areas and gardens. Tala Bay Wastewater Treatment Plant (Tala Bay WWTP) started operations in 2005 to serve this need.

FIGURE 6.1 Map of Tala Bay, Jordan showing location of WWTP.
SOURCE: Google Earth.

Reuse case description at a glance

The Tala Bay WWTP started operations in 2005 serving the Tala Bay Resort. Initially, it had a capacity of 300 m³/day, which increased to 1,000 m³/day when Aquatreat Water and Wastewater Engineering Company constructed a new Tala Bay WWTP (WAJ 2020). The plant is located on the offshore side of the resort, where the water is pumped through lifting stations to the main trunk line, which has a diameter of 250 mm and is 8 km long. There are four lifting stations inside the resort compound and another four lifting stations outside the compound (Figure 6.2).

The plant uses a modified activated sludge treatment system and collected wastewater goes through three stages of treatment: primary (grit removal and sedimentation tanks), secondary (biological activated sludge and nitrogen removal) and tertiary (polishing ponds followed by chlorination disinfection) (Figure 6.3). The sludge is then dried and transported for disposal.

Recycled water from the Tala Bay WWTP is then returned to the resort where it is stored in an on-site tank with a capacity of 8,000 m³. The water is pumped from the storage tank to be reused in different ways around the resort, for example, to the sprinkler systems to irrigate the green areas in the resort or to the drip network to irrigate the trees. Some of the recycled water is pumped to nearby hotels such as the Mövenpick Resort and Spa. Currently, 500–1,000 m³/day of the recycled water is used for irrigation, with the rate varying depending on occupancy in the hotels and resorts.

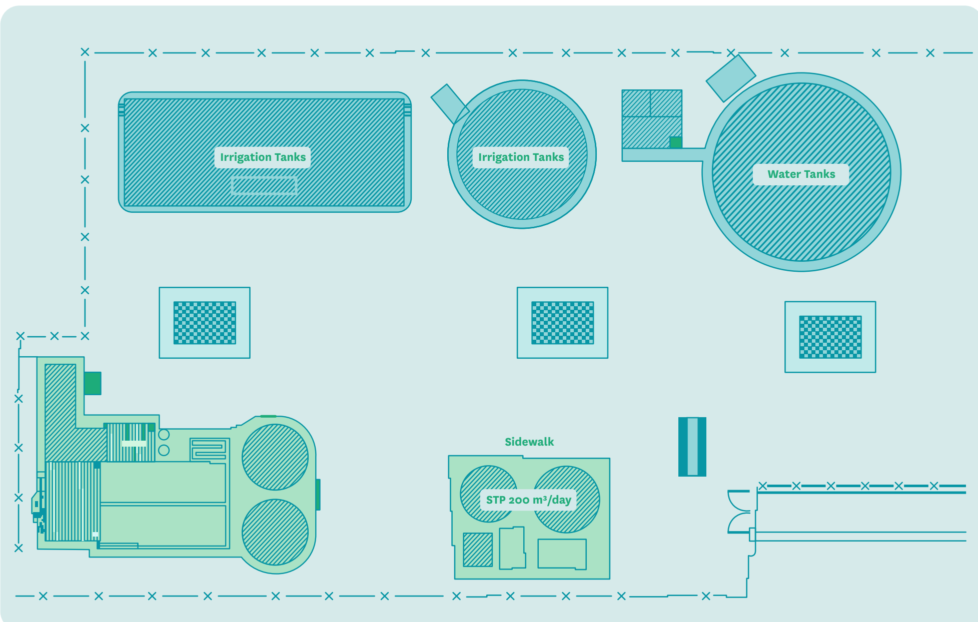

FIGURE 6.2 Tala Bay WWTP: Site map.
SOURCE: Jordan Projects for Tourism Development (JPTD).

One of the main challenges facing the use of recycled water for irrigating the landscaped areas is increased levels of salinity in the water, which is affecting the drip irrigation system. This increase is mainly due to hotel water uses including laundry and restaurants (JPTD 2022).

National institutional and policy environment

Jordan's National Water Strategy promotes decentralized wastewater treatment plants for industry and tourism and is very clear on the need to recycle water for various reuse purposes. The Tala Bay WWTP was constructed with both wastewater treatment and water reuse in mind, thereby contributing to the national strategy (WAJ 2020).

Tala Bay WWTP is privately owned by JPTD (ADC 2022). This means that responsibility for its operations and maintenance (O&M) as well as water reuse within the hotel area lies solely with JPTD and not the Aqaba Water Company, which is responsible for water and sanitation services in the Aqaba Governorate and water reuse from wastewater treatment plants that serve Aqaba city. As the recycled water from the Tala Bay WWTP is mostly used to irrigate the landscaped areas in the resort area with some transferred to nearby private hotels like the Mövenpick Resort and Spa, it does not come under the Aqaba Water Company's overview. However, JPTD is required to follow ASEZA's environmental regulations on wastewater treatment and reuse that have been adopted by the Ministry of Environment, as well as the national water quality standards for landscaping, which have also been adopted by the Ministry of Water and Irrigation (ASEZA 2001; ADC 2022; AWC 2022).

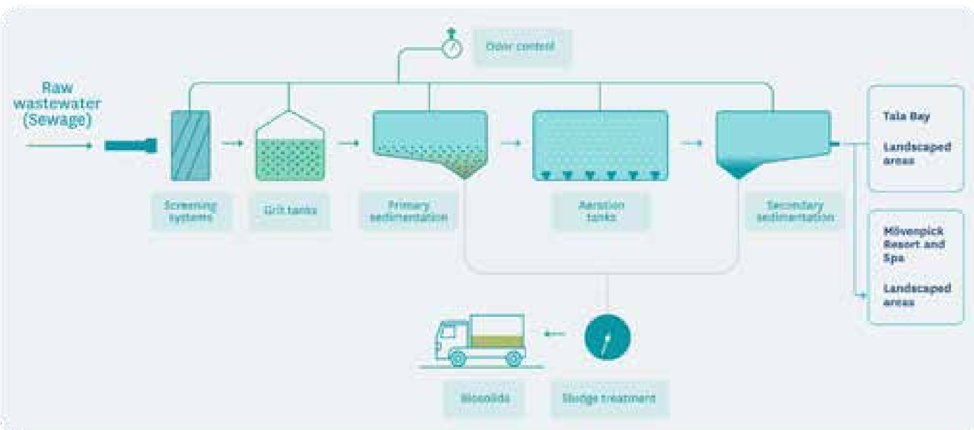

FIGURE 6.3 Tala Bay WWTP: Schematic diagram of treatment and reuse system.

Stakeholders involved and management model

ASEZA is responsible for managing the development of Aqaba including through the development of master plans and investment opportunities and is one of the key stakeholders involved with the management of the Tala Bay WWTP (ASEZA 2001). The plant was constructed by JPTD as a private investor as part of the development of the Tala Bay Resort. Approval for its construction was obtained from ASEZA, which implies fulfillment of its environmental regulations.

The Ministry of Environment and Health plays a minor role confined to the specific case of contamination to the surrounding land or sea caused by Tala Bay WWTP. Bin Hayyan Laboratories, a private laboratory, is responsible for testing effluent samples to ensure they meet the defined parameters set by ASEZA (ADC 2022).

Other stakeholders include commercial entities which provide chemicals, tools and equipment for Tala Bay WWTP's O&M.

Funding and financial outlook and cost recovery

Tala Bay WWTP is owned by JPTD, a private company that covers the costs of its construction, operations and maintenance.

Operation and maintenance costs in the company's annual budget (such as staff salaries, electricity, fuel, spare parts and chemicals) are around USD 350,000 (JOD 200,000)/year. The percentage of cost recovery ranges from 10% to 20% and is generated from the sale of water. As part of its business operations, JPTD sells part of its recycled water to nearby hotels, mainly the Mövenpick Resort and Spa, for use in landscaped areas. The price of sold water ranges between USD 0.7 and USD 1.4 /m^3 (JOD 0.5 and JOD 0.9) (ADC 2022). Higher prices are charged for industrial and commercial purposes and lower prices are charged for irrigation (Table 6.1).

Socioeconomic, health and environmental benefits and impacts

The water reuse project brings significant economic savings for the Tala Bay Hotels and Resorts complex. Fresh water is expensive for commercial and industrial entities, costing an average of USD 2.5-4/m^3 with a saving of between USD 400/day and USD 2,500/day through the use of recycled water to irrigate their trees and green landscaped areas. Excess water is also sold to other nearby hotels, mainly the nearby Mövenpick Resort and Spa, providing a further source of income.

In addition, water reuse is improving the environment by expanding the green areas around the hotels and the Tala Bay WWTP continues to function properly with no pollution problems reported, benefiting both human and environmental health.

The Tala Bay WWTP has a design capacity of just 1,000 m^3/day, which means that its socio-economic impact is quite small. It has four staff members who are usually local residents of Aqaba.

Gender equality

A study led by the Women Studies Unit of the Ministry of Water and Irrigation in Jordan (USAID 2018; UN Women and REACH 2018) assessed the status of more than 1,200 women working in the water supply and sanitation sector across the country. It revealed that only 11% of employees in the water sector are women and recommended that improved facilities such as nurseries and additional training could help increase this number, particularly in operations where the percentage is much less. There is also a perception of the water sector as being a

TABLE 6.1 Tala Bay WWTP: Funding and financial outlook and cost recovery.

	Wastewater collection and transport	Wastewater treatment	Transport of recycled water	Additional wastewater treatment for reuse	Distribution of reclaimed water to end-users
Construction and equipment services (description and dimensions)	10 km of sewers and eight lifting stations	Activated sludge system	Water pumped 8 to 10 km to the Tala Bay Resort and nearby hotels	None	All reuse is used for irrigation of trees and green areas in the Tala Bay Resort and nearby hotels
Stakeholder that delivers the service	JPTD	JPTD	JPTD	None	JPTD
CAPEX (in USD)	JPTD provided all funds for plant construction				
CAPEX recovery and percentage of subsidy					
O&M services (description)	Jet system, Closed-circuit television (CCTV), manhole covers, replacement of damaged or corroded sewers	Replacement of damaged parts, removal of grit, oil screenings and sludge	Fixing leakage	None	PTD
Stakeholder that delivers the service	JPTD	JPTD	JPTD		JPTD
OPEX (in USD/year)	USD 494,350 (JOD 350,000)				
OPEX recovery and percentage of subsidy	10–20% JPTD covers all remaining costs. There is no subsidy			None	

SOURCE: Jordan Projects for Tourism Development (JPTD). *NOTES*: Capital Expenditure (CAPEX), Jordan Projects for Tourism Development (JPTD), Operations and Maintenance (O&M), Operating expenditure (OPEX).

masculine area of work, particularly when it comes to the long hours and physical fieldwork and some cultural barriers. For example, women are not encouraged to travel alone, which could be required. Yet currently there are no women working in the operation and maintenance of Tala Bay WWTP or any work related to it.

Resilience to COVID-19

In 2020, the working hours and movements of staff and farmers were restricted due to the COVID-19 pandemic, including a period of full lock down from February to April. During that period, only key staff members were allowed to work. This was followed by a period when staff capacity was reduced to 50%. However, the Tala Bay WWTP was able to remain functioning and farmers continued to work and irrigate their farms as usual but with less labor.

Scalability and replicability potential

Private investments in the tourism and industry sector in Jordan need to include the construction of wastewater treatment plants to service their projects as part of their investment plans. Inside cities, development projects can usually connect to existing sewerage networks so that wastewater collection and treatment are covered in water bills. For areas that do not have a sewerage network like Aqaba city's southern beach, the hotels have to construct their own treatment plant.

The construction of a wastewater treatment plant for a stand-alone project, in this case, Tala Bay Resorts, is not based on a financial and economic analysis but is rather considered as any other facility belonging to a hotel and resort complex. The complex needs to be able to collect and dispose of its sewage, which means that any associated costs need to be considered as part of the project cost. However, the reuse of the recycled water produced by the plant represents an added value as it saves the cost of purchasing fresh water for landscaping, which costs USD 2.5–4/m^3 for hotels in Aqaba. In this context, the Tala Bay WWTP provides a good model that could be replicated and scaled in other hotels and resorts.

SWOT analysis

The strengths, weaknesses, opportunities and threats (SWOT) analysis of the Tala Bay WWTP plant and water reuse project is given in Table 6.2. The main outcomes of the project analysis include savings in the use of fresh water and a reduction in water costs and environmental impacts.

Key factors for achieving success along the project life cycle and lessons learned

During the design, construction and operation of the project, key factors for achieving success include the following:

- A functioning hotel and resort with green spaces that attracts many visitors.
- Using recycled water for landscaping saves the use of fresh water.
- The availability of a new source of water that can be used for landscaping purposes by the project and other nearby buildings or hotels.
- Investment projects like big hotels and resorts can be constructed in areas without wastewater collection systems already in place.

Lessons learned include:

- Local community acceptance of investment projects requires potential work opportunities for the local communities.
- Coordination with various governmental organizations was essential for the success of this project.

TABLE 6.2 Tala Bay WWTP and water reuse: SWOT analysis.

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES

INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS**
	■ Significant savings in the cost and use of fresh water
	■ Partial operations and maintenance cost recovery through sales of recycled water to other hotels
	■ Visible environmental benefits:
	  ■ Increasing green areas
	  ■ Improving public health
		WEAKNESSES
		■ An increase in oil percentage in wastewater affects plant efficiency
		■ Although local expertise in running the plant is available, there is limited expertise in advanced process techniques

EXTERNAL FACTORS ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ■ A new source of water for landscaping purposes in the hotel vicinity and other nearby hotels ■ Reduced demand for municipal water for landscaping uses	**THREATS** ■ In case of plant failure, the untreated water will be discharged to the sea ■ Odor problem if the plant's treatment efficiency drops

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Methods and resources

Data about the Tala Bay WWTP and its water reuse were requested directly from the plant manager who was sent a template to complete. The plant manager returned it after three weeks with the requested information.

The consultant reviewed the data and compiled it as needed into the project template. Where data were missing, the consultant made an informed judgment based on personal experience and by comparing information from other similar plants.

Another source of information was the Jordan Projects for Tourism Development website (https://talabay.net/), which provides information about the history of the construction of Tala Bay Hotels and Resorts and the Water Authority of Jordan's Annual Report 2020.

Case Study 7: Jordan

Wadi Musa wastewater treatment plant and the Sadd al Ahmar alfalfa irrigation area

Loay Froukh

Acronyms

ADC	Aqaba Development Corporation
ASEZ	Aqaba Special Economic Zone
ASEZA	Aqaba Special Economic Zone Authority
AWC	Aqaba Water Company
MWI	Ministry of Water and Irrigation
JPTD	Jordan Projects for Tourism Development
USAID	United States Agency for International Development
WAJ	Water Authority of Jordan
WWTP	Wastewater Treatment Plant

History and project justification

Jordan's *National Water Strategy* underlines the important role of water recycling in meeting Jordan's water needs including the need to use treated wastewater as an additional source of water that can be used for irrigation purposes. The Water Authority of Jordan (WAJ) estimates that by 2025 treated wastewater will form 16% of its annual water budget.

The Wadi Musa Wastewater Treatment Plant (Wadi Musa WWTP) is central to this strategy. It is in the southern part of Jordan, close to the historic city of Petra, and is owned by the Aqaba Governorate. It started operations in 2001 to serve 20,000 inhabitants with its main purpose being to treat collected wastewater from hotels in Petra and nearby residential areas. The plant services four communities which are adjacent to the Petra Archaeological Park – Wadi Musa, Taiba, Umm Sayhoun and Beidha (AWC 2021; WAJ 2021).

Wadi Musa WWTP's design capacity is 3,400 m^3/day while the current amount of wastewater treated is 2,796 m^3/day. Recycled water is used for irrigation by agricultural communities in Sadd al Ahmar area as part of the reuse project. These communities depend mainly on livestock and fodder cultivation and have historically relied on groundwater and discharged treated wastewater as a water source. The idea to create a water reuse project to benefit these communities was developed and later implemented by WAJ with the support of USAID funds (AWC 2021; WAJ 2021). It is the first community-based project established in Jordan.

The reuse area is located 10 km north of Petra and is adjacent to the Wadi Musa WWTP where up to 100 ha are irrigated using reclaimed water (Figure 7.1). This is benefiting 80 farmers and

FIGURE 7.1 Wadi Musa WWTP location map. *SOURCE*: Google Earth.

their families whose land is mainly cultivated with fodder crops, mostly alfalfa. The farmers practicing reclaimed water irrigation belong to the Sadd al Ahmar Farmers' Association as part of the project.

Reuse case description at a glance

Wastewater is collected from hotels in Petra city and nearby areas via a wastewater collection network that serves a population of 20,000. Once collected, the wastewater is transferred to the Wadi Musa WWTP (AWC 2021).

Collected water undergoes three stages of mechanical treatment at the plant: primary (grit removal and sedimentation tanks), secondary (biological activated sludge and nitrogen removal) and tertiary (polishing ponds followed by chlorination disinfection) (Figure 7.2) (Image 7.1). Over time, the plant efficiency has dropped with farmers who use its recycled

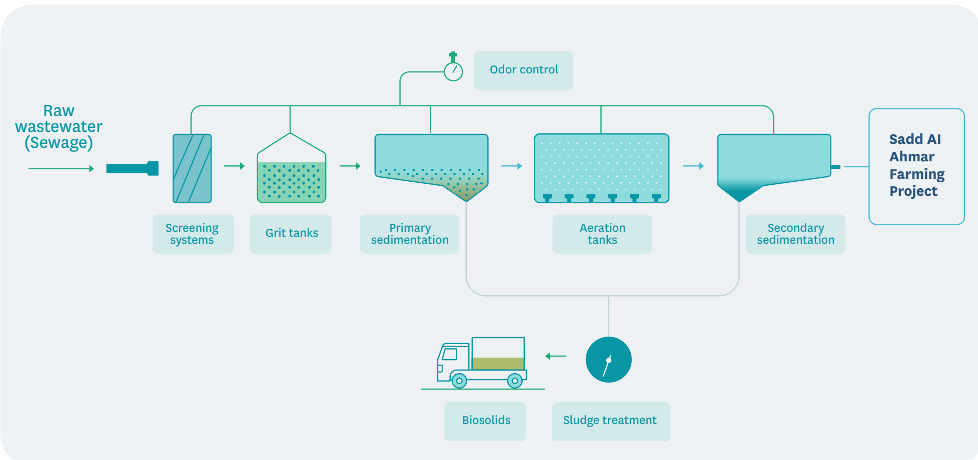

FIGURE 7.2 Wadi Musa WWTP: Schematic diagram for the treatment process and reuse discharge areas.

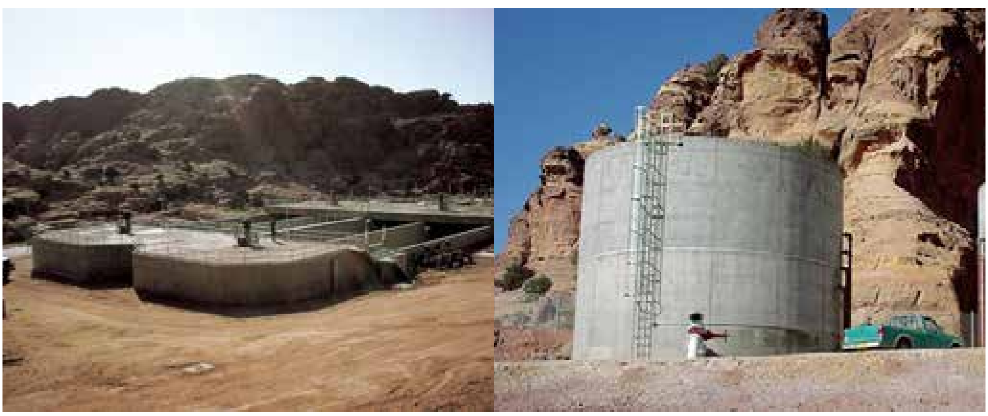

IMAGE 7.1 Aeration tanks (left) and storage tanks (right) at Wadi Musa WWTP.

water for irrigation complaining of a decrease in water quality, particularly its increased salinity, which affects drip irrigation systems.

Wadi Musa WWTP produces 2,796 m^3/day of treated wastewater. This water is transferred to 80 farms around Sadd al Ahmar, an area of 100 ha, to be reused to irrigate fodder crops, mainly alfalfa. The water is given to the farmers at no charge as part of the community-based project's aims to encourage new businesses. The farmers use a drip irrigation system to save water (ACW 2021; WAJ 2021).

This new water source is helping the local community in the Sadd al Ahmar area to work in farming and is creating jobs for the local community including women who are employed for crop harvesting. It is important to note, however, that full gender-disaggregated data is not yet available.

National institutional and policy environment

The Ministry of Water and Irrigation (MWI), which is currently undergoing restructuring, has set guidelines in its *National Water Strategy* that move Jordan toward establishing an institutional capability to monitor, regulate and enforce wastewater regulations including:

- Expanding wastewater collection and treatment capacity to cover all of Jordan as set out in the *2013 National Wastewater Master Plan*.
- Expanding the decentralized wastewater systems.
- Involving the private sector in the operation and maintenance of the wastewater treatment plants.
- Ensuring that treated effluent complies with recently established national standards (JS893- 1995).
- Increasing the use of recycled water for irrigation including for selected crops that suit the irrigation water quality.
- Minimizing environmental risks including specific risks to groundwater aquifers in the development of water reuse systems.
- Setting standards for the construction and management of septic tanks where it is not feasible to have sewerage collection systems and treatment facilities.

In addition, it is a legal requirement that:

- Any building served by a wastewater collection network must connect to the collection system if available.
- An industrial entity cannot connect to the domestic collection system unless its effluent quality is accepted.

The WAJ is responsible for the implementation of Jordan's national wastewater policy and strategy and is currently working as a regulator for the wastewater sector. Operations are carried out by governmental companies (Yarmouk, Miyahuna and Aqaba Water Companies). Within the WAJ, the Planning and Management Department coordinates and monitors wastewater treatment plants. The Aqaba Water Company (AWC) manages the Wadi Musa WWTP (AWC 2021; WAJ 2021).

Stakeholders involved and management model

In Jordan, the MWI is responsible for strategy and donor cooperation including overall planning in the water and sanitation sectors. The WAJ is responsible for the service providers, while the AWC is responsible for water and sanitation services in the southern governorates.

The Wadi Musa WWTP plant is operated by the AWC, which operates and maintains the plant and the sewerage network serving the Petra and Wadi Musa areas (WAJ 2021). It cooperates with all relevant stakeholders in the area to improve water and sanitation services. For example, there is a cooperation agreement with the Royal Scientific Society for testing services for pumps, pipes and other tools and equipment, and similarly, one with the Jordan Standards and Metrology Organization on adopting water quality standards. Both the Ministry of Environment and the Ministry of Health have a monitoring role to protect the environment and human health (Figure 7.3).

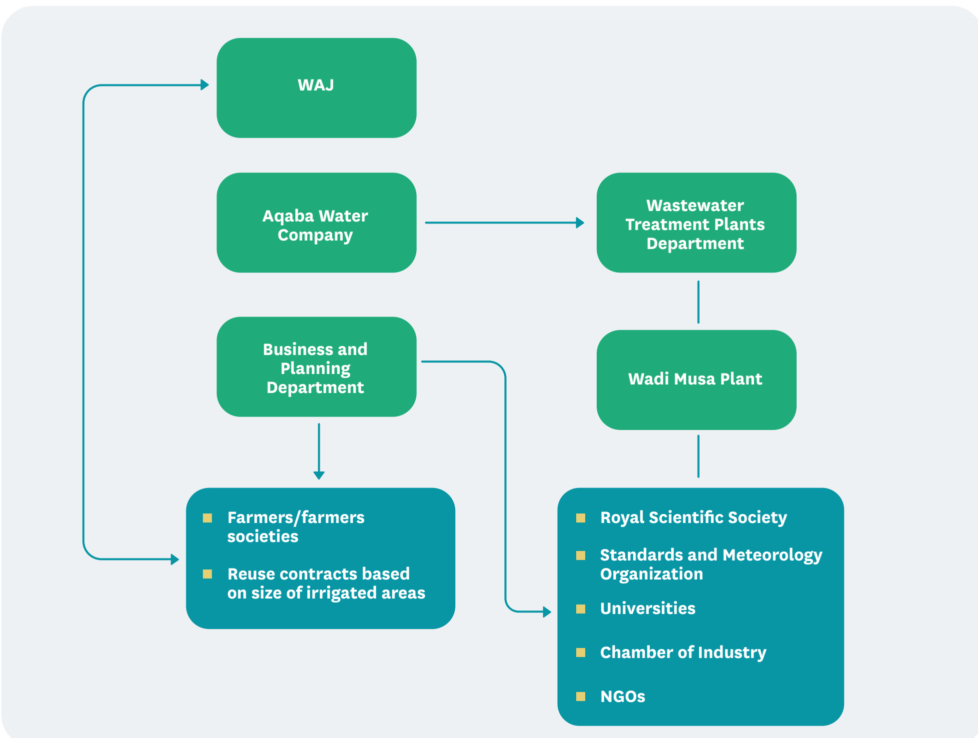

FIGURE 7.3 Stakeholder and management model: Schematic diagram.

The AWC manages the Wadi Musa WWTP as well as the transmission line and booster stations along the line to the Sadd al Ahmar area. The recycled water's distribution to the farms is managed by the Sadd al Ahmar Farmers' Organization, which also manages the marketing and sales of the alfalfa crops at local markets.

The Ministry of Agriculture supports the farmers with training programs on using the drip irrigation system and about the nutrients contained in the recycled water. The high nutrient content of the recycled water means that they no longer need to use fertilizers on their alfalfa crops (as revealed during meetings with Sadd al Ahmar representatives).

Funding and financial outlook and cost recovery

The construction of the Wadi Musa WWTP, reuse transmission line, booster stations, storage tanks and irrigation network were funded by USAID. The operation and maintenance (O&M) costs for the plant and transmission line are covered by the AWC and includes staff salaries, electricity, fuel, spare parts and chemicals (Table 7.1).

The capital expenditure (CAPEX) of the wastewater infrastructure including the sewerage network and the treatment plants is mainly covered by donors' grants with a 10–20% government contribution. The estimated percentage of cost recovery for operation and maintenance cost ranges from 50-70% collected from two sources. The first source is subscription fees while the second source is water consumption bills where a cost percentage that varies from 0.04-1.1 % is added to domestic water consumption costs for sanitation services. The government estimated subsidy ranges from 30-50%.

Socioeconomic, health and environmental impacts and benefits

It is clear that the sewerage network and wastewater treatment are helping to protect human health and the environment in Petra city and Wadi Musa, minimizing the number of septic tanks still in use to just a small area not connected to the sewerage network. Another major health and environmental benefit is the reduction of risk of microbial contamination to groundwater, soil and crops from the septic tanks or raw wastewater discharge in the *wadis* – valleys, rivers and channels that are dry outside the rainy season.

In terms of socioeconomic impact, this new water source is bringing opportunity to 100 farms that are now using it to cultivate alfalfa crops for fodder, creating jobs for 200 to 300 people, including opportunities for women. The families working in the farming activities have been able to generate income from the farms, which is helping them to settle in their areas instead of moving to the big cities for work. In addition, the location of the Wadi Musa WWTP near the reuse project has created jobs for the local community in the operation and maintenance of the plant and the transmission lines.

As the recycled water is rich in nutrients, there are also savings from fertilizer costs. Yields are also increasing by 10 to 15%. Charging fees are also minimal at less than USD 0.2/m^3.

Gender equality

A study led by the Women Studies Unit of the Ministry of Water and Irrigation in Jordan (USAID 2018) assessed the status of more than 1,200 women working in the water supply and sanitation services across the country. The study revealed that only 11% of employees in the water sector are women and recommended that improved facilities such as nurseries and additional training could help increase this number, particularly in operations where the percentage is much less. There is also a perception of the water sector as a masculine area of work, particularly when it comes to the long hours and physical fieldwork. At the Wadi Musa

TABLE 7.1 Wadi Musa WWTP: Funding and financial outlook and cost recovery.

	Wastewater collection and transport	Wastewater treatment	Transport of recycled water	Additional wastewater treatment for reuse	Distribution of reclaimed water to end-users
Construction and equipment services (description and dimensions)	90 km of 200-500 mm diameter sewers and four pump stations	Extended Aeration	Water pumped 10 km to farming project	None	Water pump for 10 km transmission to storage tanks on the farms
Stakeholder that delivers the service	Aqaba Water Company	Aqaba Water Company	Aqaba Water Company	None	Sadd al Ahmar Organization
CAPEX (in USD)	26,000,000	19,100,381.61	*2,000,000	None	*350/1,000 m²
CAPEX recovery and % of subsidy	Most wastewater infrastructure is funded by donors with a government contribution of 10–20%				Farm drip irrigation systems funded by farmers
O&M services (description)	Jet System, Closed-circuit Television (CCTV), manhole covers, replacement of damaged or corroded sewers	Replacement of damaged parts, removal of grit, oil screenings and sludge	Fix booster stations/ transmission lines leakage	None	Fix drip irrigation blockages and distribution lines leakage
Stakeholder that delivers the service	Water Authority of Jordan	Aqaba Water Company	Aqaba Water Company	Aqaba Water Company	Sadd al Ahmar Association
OPEX (in USD/ year)	65,000	500,000 /year	None	None	*35/1,000 m2
OPEX recovery and % of subsidy	*50-70% *Subsidy 30 to 50%				

SOURCE: AWC 2021, WAJ 2021. Notes: Capital Expenditure (CAPEX). Operations and Maintenance (O&M), Operating Expenditure (OPEX). *= Estimated figures.

WWTP, all the operation and management work is done by men. One major reason for this is that the location of the plant is far from Petra city, combined with the type of work, the long hours and the night shifts.

The potential for increased employment opportunities for women through water reuse cases is promising. A UN study showed that women's participation in the agricultural sector remains a critical source of employment for the country's poorest citizens and a major source of food security (UN Women and REACH 2018). The percentage of women working in farming activities as part of the Sadd Al Ahmar reuse project ranges from 10 to 15% (UN Women and REACH 2018).

Resilience to COVID-19

In 2020, the working hours and movements of staff and farmers were restricted due to the COVID-19 pandemic, including a period of full lockdown from February to April. During that period only key staff members were allowed to work. This was followed by a period where staff capacity was reduced to 50%. However, the Wadi Musa WWTP was able to stay functioning and farmers stayed working and irrigating their farms as usual but with less labor.

Scalability and replicability potential

Every newly constructed WWTP in Jordan has an associated water reuse plan. Most plants discharge their treated wastewater to the *wadi*, which goes on to be stored in dams. From the dams, the recycled water is mixed with stormwater, and transferred to the Jordan Valley for irrigation purposes. A few plants like Wadi Musa WWTP have a specific reuse project for their water, where in this case, 100% of recycled water is transferred to the reuse project.

The Wadi Musa WWTP and Sadd al Ahmar reuse model can be considered a success. Having a new source of water has enabled farmers to cultivate their land and generate income for their livelihoods. It is helping the local community stay in their area and build their own farming business. This is an approach that can be replicated in other areas. However, this model relied on full governmental support and donor support to fund the infrastructure for the wastewater treatment plant and the reuse transmission and distribution network. Other elements contributing to this success is the minimal charging fees for the reuse of water (less than USD 0.2/m^3) and the establishment of the Sadd al Ahmar Farmers' Association, which helped the farmers with technical assistance on how to start and maintain their projects and how to market their farm products.

SWOT analysis

The strengths, weaknesses, opportunities and threats (SWOT) analysis for the Wadi Musa WWTP and Sadd al Ahmar alfalfa irrigation area is shown below (Table 7.2). The main analysis outcomes are that the reuse water project has helped to create jobs for the local community, saving groundwater for drinking uses and protecting the environment.

Key factors for the success along the project and lessons learned

During the design, construction and operation of the project, key factors of success include:

- Governmental support at all levels including funding of main lines and distribution networks.
- No charging fees.
- The close location of the farms to the treatment plant requires a 10 km transmission line.
- The topography of the area is almost flat so minimal pumping is required.
- Suitable crops such as alfalfa grow in the area producing good yields.
- A drop in fertilizer use and cost due to water type that is rich in nutrients.

TABLE 7.2 Wadi Musa WWTP and Sadd al Ahmar reuse case: SWOT analysis.

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ■ Availability of a new source of water (3,000 m^3/day) ■ Farming opportunities for the local community. ■ Jobs and a source of income for the local community (200 to 300 people have benefited from the Sadd al Ahmar reuse project so far ■ Visible environmental benefits by increasing the green area ■ Saved groundwater for drinking purposes ■ Less use of fertilizers	**WEAKNESSES** ■ Dependency on governmental funding ■ Farmers pay minimal charges for treated wastewater ■ Limited crops are suitable ■ Surplus water in winter with no use
EXTERNAL FACTORS ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ■ Investment opportunities in agriculture and industry ■ High potential for energy recovery and organic fertilizer production ■ Rural development (land and infrastructure) ■ New settlements	**THREATS** ■ Project sustainability ■ Environmental/health risks due to poor main-tenance ■ Odor problems ■ Drop in land value due to the existence of the wastewater treatment plant ■ Blockages in the drip network due to salinity increase

Lessons learned include:

- The local community is cooperative with such projects once there is governmental support.
- Farmer awareness about efficient irrigation will decrease used water amounts and reduce operation and maintenance costs.
- Facilitation of governmental procedures will encourage farmers to benefit from governmental support.

Methods and resources

Wadi Musa WWTP is managed and operated by the AWC. To access data about the plant, an official request needs to be sent through the WAJ who forwards it to the AWC. Once the requested information is prepared by AWC, it must be processed and screened through the WAJ's Rights to Information Section in Amman before it is released. Direct communication with staff at the plant is not allowed.

For this purpose, a letter requesting the required data for plant characterization was sent to the Secretary-General of the WAJ in May 2021 using the required template. Other sources of information used in this water reuse case study include published WAJ reports, the AWC website and other related websites, and information from previous studies.

It took two weeks for the data request to be processed, approved and delivered. The consultant reviewed the data and compiled it as needed into the template. Where data were missing, the consultant made an informed judgment based on experience, and by comparing information about Wadi Musi WWTP with other similar plants.

Other sources of information used to gather data for this case study included the WAJ's website, meetings with Sadd al Ahmar representatives and various WAJ publications.

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Case Study 8: United Arab Emirates

Al Wathbah-2 wastewater treatment plant and Abu Dhabi irrigation scheme

Mohamed Dawoud

Acronyms

AADC	Al Ain Distribution Company
ADDC	Abu Dhabi Distribution Company
ADSSC	Abu Dhabi Sewerage Services Company
DOE	Department of Energy
RSB	Regulation and Supervision Bureau
SCAD	Statistical Center – Abu Dhabi
UAE	United Arab Emirates
WWTP	Wastewater Treatment Plant

History and project justification

In the Emirate of Abu Dhabi, continued population growth, combined with rapid economic development, has increased wastewater production. This has created an urgent need for sustainable wastewater management to be included in the government's integrated water resource management plans.

In 2021, the estimated population of the Abu Dhabi metropolitan area was 1,512,000, which represents an increase of almost 2% from 2020 (Figure 1). Until 2021, the whole area was served by the Al Mafraq Wastewater Treatment Plant (Al Mafraq WWTP), which had a capacity of 66,902,867 m^3/year (ADSSC 2020). The plant was old, overloaded and not able to cope with the increased wastewater coming from the city and the newly developed surrounding settlements.

In 2011, two new treatment plants and facilities were constructed to boost wastewater treatment services in Abu Dhabi city and the surrounding areas and to eventually replace the Al Mafraq WWTP. Al Wathbah-1 and Al Wathbah-2 Wastewater Treatment Plants (hereinafter Al Wathbah-1 and Al Wathbah-2 WWTPs) were designed to fill gaps in existing treatment facilities caused by the increased volume of wastewater and to produce recycled water to use as irrigation water for farms, parks, green areas and similar around Abu Dhabi as part of sustainable water resource management activities. Each plant has a design capacity of 109,500,000 m^3/year increasing potential capacity from 124,100,000 m^3/year to 219,000,000 m^3/day. In addition, the Al Mafraq WWTP continued to operate, albeit with limited capacity, up to 2021.

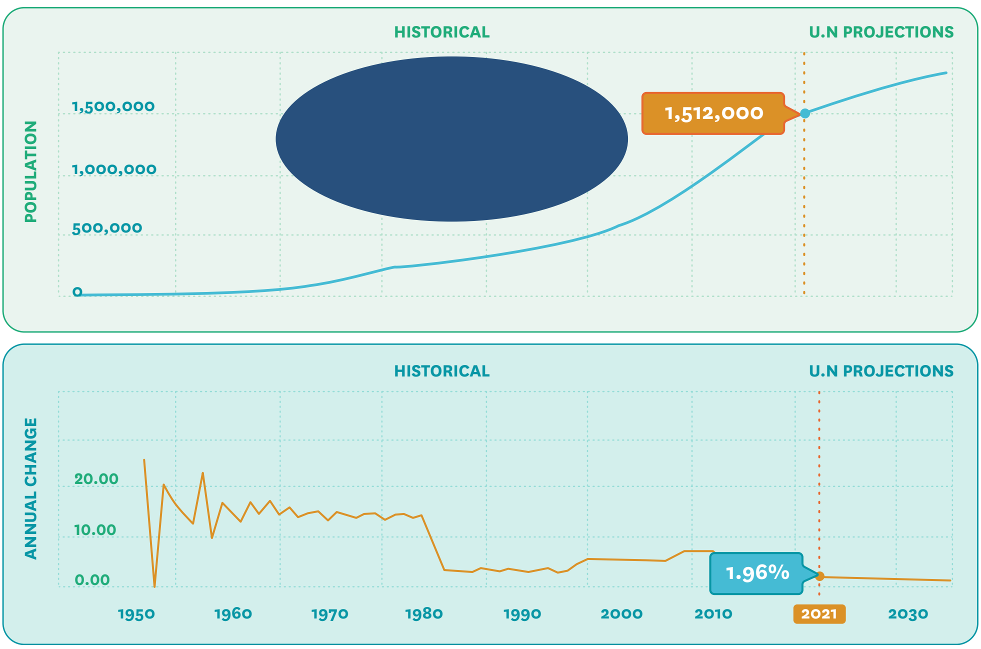

FIGURE 8.1 Metro area population of the Emirate of Abu Dhabi (1950–2030). *SOURCE*: SCAD 2021.

Al Wathbah-2 WWTP (Figure 8.2, Image 8.1) treats a significant part of the wastewater coming from Abu Dhabi City. It has a treatment capacity of 300,000 m^3/day and is designed to serve a population of 1,500,000. Production at the plant increased from 65,000,000 m^3/year in 2012 to more than 82,600,000 m^3/year in 2020 (Figure 8.3).

Challenges facing Al Wathbah-2 WWTP include but are not limited to:

- **Wastewater discharge to the environment:** after the completion of the project, only 45% of the treated water was being recycled and reused. The remaining 55% was discharged to the Al Musaffah Channel on the Arabian Gulf, causing negative economic and environmental impacts. This water can be reused as irrigation water.
- **Treated wastewater quality**: the catchment area for Al Wathbah-2 is below sea level. This has led to seepage of seawater into the collection network and results in high levels of salinity (between 3,000–4,000 ppm), which is reflected in the salinity levels of water produced at the plant. Water with high salinity levels has reduced reuse potential.

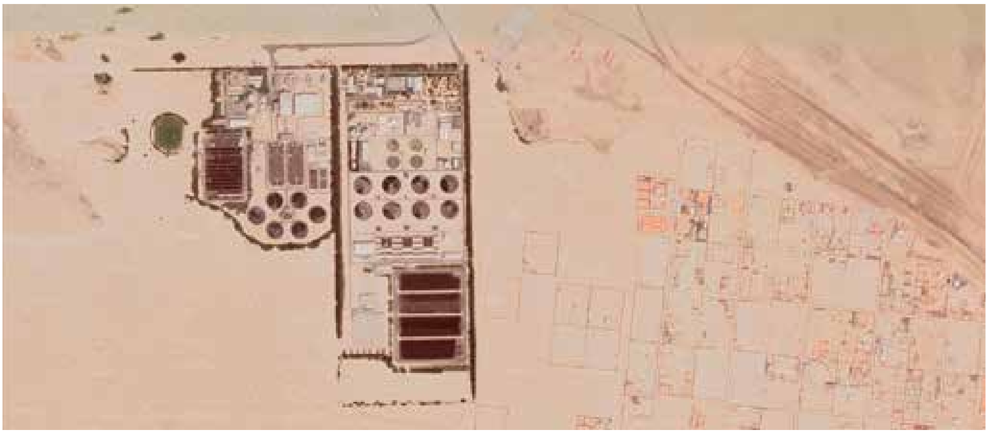

FIGURE 8.2 Al Wathbah-2 WWTP: location map and layout.
SOURCE: Google Earth.

IMAGE 8.1 Al Wathbah-2 WWTP.
SOURCE: ADSSC.

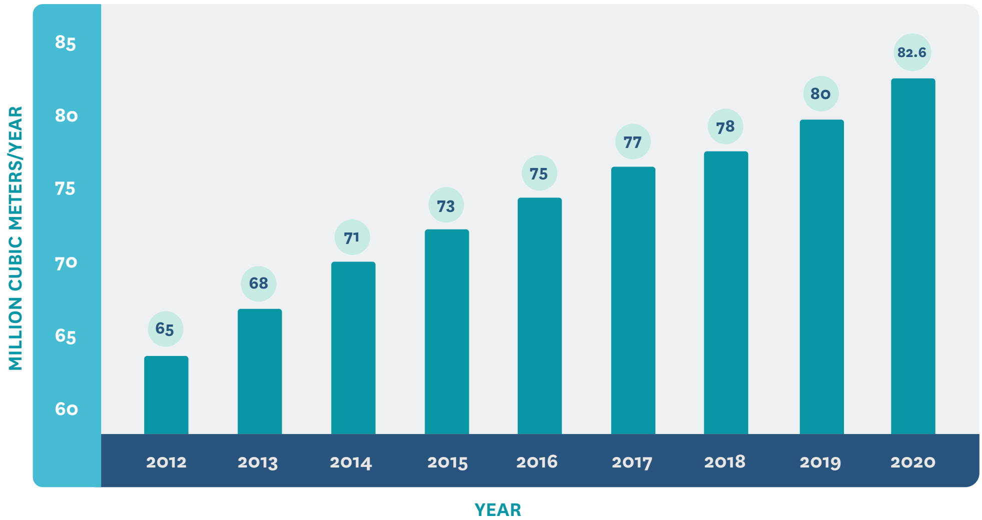

FIGURE 8.3 Al Wathbah-2 WWTP: Production 2012–2020.

Reuse case description at a glance

Water reuse for irrigation, especially for food production, is central to the Emirate of Abu Dhabi's strategy to increase food security and food self-sufficiency. It is also central to its integrated water resource management plans, which include an ambitious target to reach zero discharge of recycled water into the environment by 2020.

To this end, in 2016, the Abu Dhabi government approved two mega projects to reuse 55% of treated water, which was being discharged into the environment. These projects, which include the completion of the required transmission and distribution networks and pumping stations for the recycled water to reach end-users, started in 2020 with an expected completion date of August 2022 and an investment cost of almost USD 0.3 billion. The works had originally been scheduled to be completed by 2020 but were delayed due to the COVID-19 pandemic.

In addition to the 105,000 m^3/day of recycled water from Al Wathbah-2 WWTP currently used for irrigating landscaped areas and green spaces around local amenities, there is significant potential for its use in agricultural irrigation that could contribute to both food and environmental strategies. In 2014, 185 farms were supplied with 27,000 m^3/day of recycled water from the plant. By August 2022, it was anticipated that an additional 390,000 m^3/day of recycled water from Al Wathbah-1 and -2 WWTPs will be used to irrigate 4,200 farms, with half of this recycled water coming from Al Wathbah-2 WWTP (Dawoud 2017) (Figure 8.4).

In environmental terms, a preliminary assessment by the Department of Energy (DOE) found that aquifer recharge using recycled water from the plant could also be used as a means to enhance the quality of brackish groundwater and that excess irrigation wastewater during non-peak seasons could be recharged to the aquifer system to be used later. A big advantage of aquifer recharge using recycled water from wastewater treatment plants is that it breaks the pipe-to-pipe connection of direct reuse. This reuse project will make a significant contribution toward replacing the use of desalinated water by 125,000 m³/day and the costs of maintaining and operating more than 1,000 groundwater wells.

National institutional and policy environment

Wastewater collection, treatment, discharge and reuse in the Emirate of Abu Dhabi have all historically sat under the responsibility of the Regulation and Supervision Bureau (RSB), which is part of the Abu Dhabi Executive Office. However, this changed in 2018 when a new governmental structure was established which included a new Department of Energy (DOE). The DOE was created to drive the Emirate's energy and water transition efforts toward creating a sector that promotes economic development, demographic growth, social development and environmental sustainability (in accordance with Law No. 11 of 2018).

In 2010, the RSB issued the Emirate of Abu Dhabi Trade Effluent Control Regulations Framework (Figures 8.5 and 8.6), to protect public health and regulate various aspects of wastewater treatment, management and monitoring.

Stakeholders involved and management model

Abu Dhabi Sewerage Services Company (ADSSC) manages and operates both the Al Wathbah

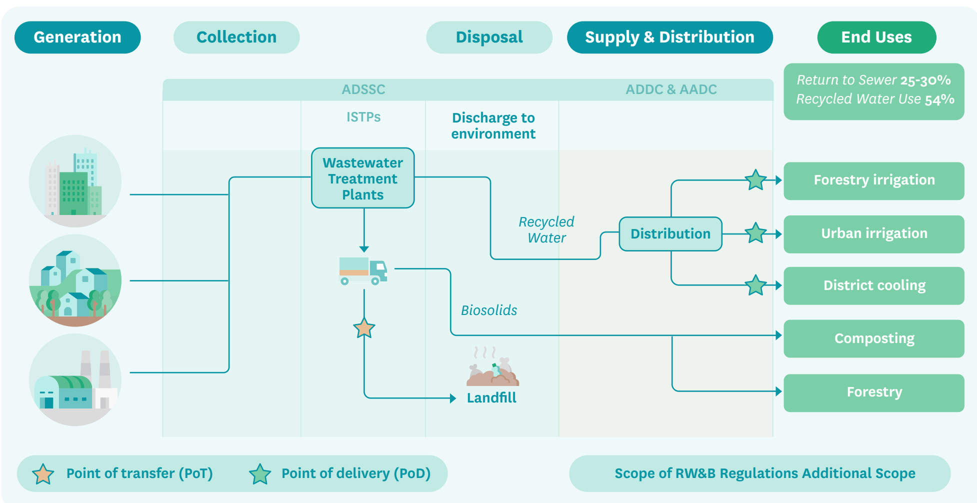

FIGURE 8.4 Al Wathbah-2 WWTP and reuse project: Schematic diagram and management model.
SOURCE: DOE 2019.
NOTES: Al Ain Distribution Company (AADC), Abu Dhabi Distribution Company (AADC), Abu Dhabi Sewerage Services Company (ADSSC), Independent Sewage Treatment Plant (ISTP), Recycled Water and Biosolids (RW&B).

WWTPs and is responsible for different parts of the chain including collection and treatment. The Abu Dhabi Distribution Company (ADDC) and the Al Ain Distribution Company (AADC) have recently been given the responsibility for the transmission and distribution of recycled

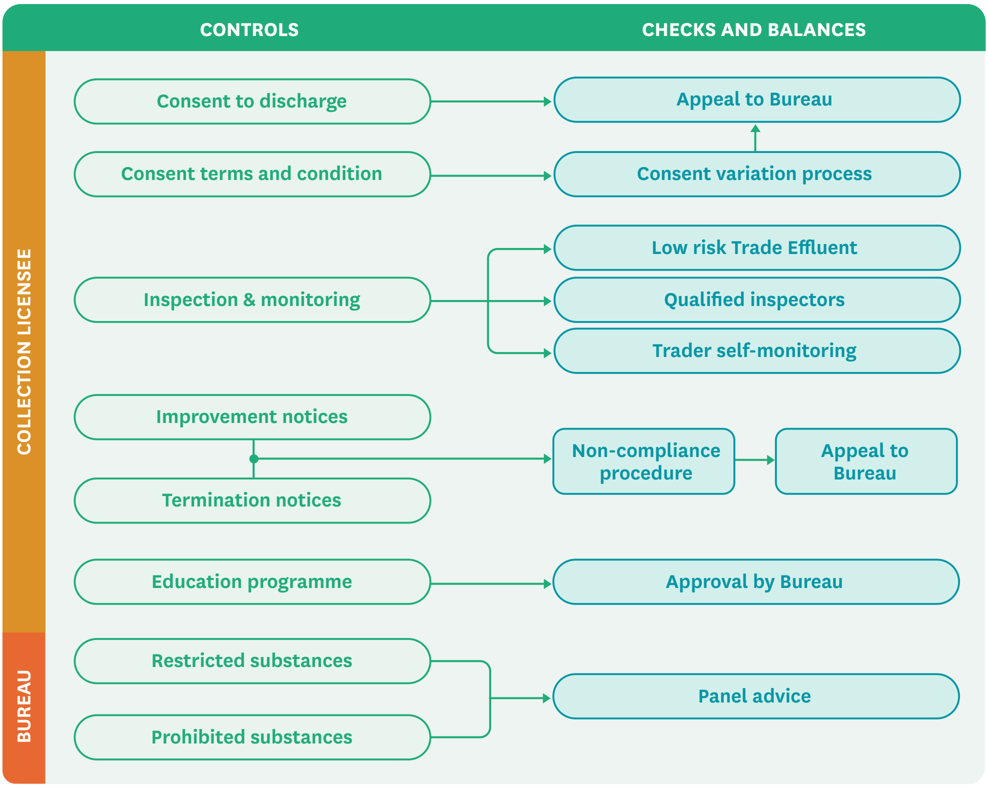

FIGURE 8.5 Emirate of Abu Dhabi Trade Effluent Control Regulations 2010 Framework.
SOURCE: QCC 2010.

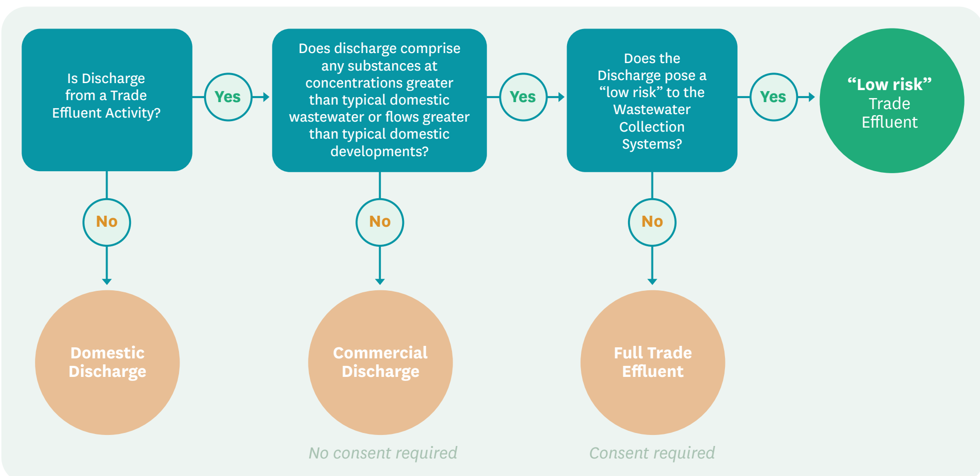

FIGURE 8.6 Trade effluent discharge characterization chart in the Emirate of Abu Dhabi.
SOURCE: QCC 2010.

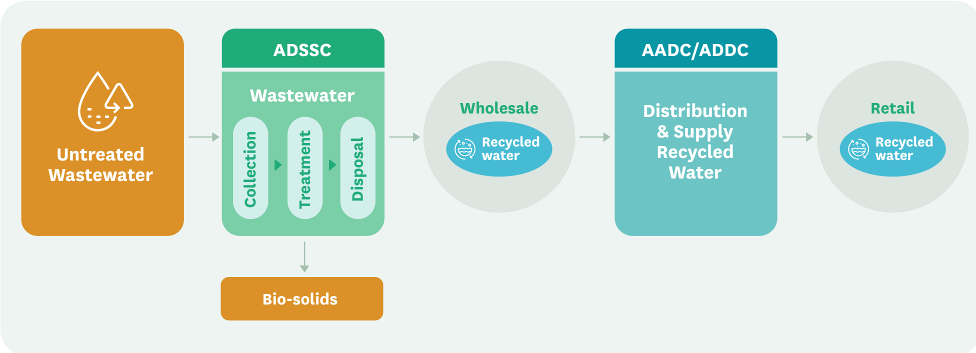

FIGURE 8.7 Structure of the recycled wastewater collection, treatment and reuse for Al Wathbah-2. *SOURCE*: DEO 2019. *NOTES*: Al Ain Distribution Company (AADC), Abu Dhabi Distribution Company (ADDC), Abu Dhabi Sewerage Services Company (ADSSC).

water for non-potable use, the majority of which is for irrigation, while the Department of Energy is responsible for monitoring and regulation. In terms of recycled water business assets in Abu Dhabi, which had a distribution network of 1,050 km and 494 interface points in January 2018, management was separated across different entities (Figure 8.7).

Funding and financial outlook and cost recovery

Al Wathbah-2 WWTP was constructed in 2012 with a capacity of 109,500,000 m^3/year. It is a Build-Own-Operate-Transfer (BOOT) project – a project delivery mechanism in which the government grants a private sector party the right to finance, design, construct, own and operate a project for a set number of years. Al Wathbah-1 and Al Wathbah-2 WWTPs are BOOT projects, owned by the Abu Dhabi government and represented by Abu Dhabi Sewerage Services Company (ADSSC).

Al Wathbah-2 WWTP was designed and constructed by Al Wathbah Veolia Besix Wastewater for USD 280 million (AED 1.029 billion). It has an annual operation cost of USD 35 million (AED 128.6 million). Currently, there is a recycled water tariff with all capital (CAPEX) and operating (OPEX) expenditures paid by a government subsidy. Recycled water is given to the municipalities and end-users at no cost.

Currently, Al Wathbah-2's costs are not covered, but a wholesale tariff for recycled water, which will be enforced from January 2023, is intended to cover ADSSC's costs related to the production of recycled water. The tariff is a result of a proposal by ADSSC to allocate its costs between activities related to wastewater and recycled water and implement a mechanism to recover costs through a wholesale tariff. The Department of Energy (DOE) approved the proposal to have a recycled water tariff of USD 0.46/m^3 (AED 1.7).

TABLE 8.1 Funding and financial outlook and cost recovery.

	Wastewater collection and transport	Wastewater treatment	Transport of recycled water	Additional treatment for reuse	Distribution of recycled water to end-users
Construction and equipment services (description and dimensions)	Collection network including Strategic Tunnel Enhancement Program	Inlet Pumping Station Submersible pumps lift the sewage approximately 23 m into the headwork from where the sewage gravitates through the plants Preliminary Treatment: Fine screens remove all particles with a size larger than 6 mm. In the next step, sand, grit, stones and broken glass settle down in the tanks. Lastly, surface skimmers remove oil and grease from the sewage Secondary Treatment: Removes majority of BOD5 and ammonia from the wastewater through two processes Tertiary Treatment: Ensures that the effluent complies with regulatory standards for irrigation purposes. Dual media filters (pumice stone and sand) are used for the filtration process. Then, the water is disinfected by injecting sodium hypochlorite produced on site. Finally, the recycled water is pumped to a reservoir with a capacity of 50,000 m^3 from where it is distributed to consumers to be used as water for irrigation purposes	Two main transmission pipelines with a diameter of 1,200 mm – One along Al Ain Road with a daily capacity of 250,000 m^3 (75 km) and one along Dubai Road with a capacity of 140,000 m^3 (length 45 km) Three pumping stations and ground reservoirs	No additional treatment for reuse	Distribution network for 4,200 farms
Stakeholder that delivers the service	ADSSC	ADSSC	ADDC	NA	ADAFSA
CAPEX (in USD)	5,700 million	550 million	300 million	NA	50 million
CAPEX recovery and % of subsidy	100% subsidy by the government	100% subsidy by the government	100% subsidy by the government	NA	100% subsidy by the government
Operation and maintenance services (description)	25 years duration of the operation contract	25 years duration of the operation contract	Operation and maintenance contract by ADDC	NA	Operation and maintenance by ADAFSA
Stakeholder that delivers the service	ADSSC	ADSSC	ADDC	NA	ADAFSA
OPEX (in USD/year)	530 million	55 million	30 million	NA	5 million
OPEX recovery and % of subsidy	100% subsidy by the government	100% subsidy by the government	100% subsidy by the government	NA	The newly approved tariffs will be USD 0.46 (1.7 AED)/m^3 starting January 1, 2023.

NOTES: Abu Dhabi Agriculture and Food Security (ADAFSA), Abu Dhabi Distribution Company (ADDC), Abu Dhabi Sewerage Services Company (ADSSC), Biological Oxygen Demand (BOD), Capital Expenditure (CAPEX), Operating Expenditure (OPEX).

The CAPEX and OPEX costs for the reuse infrastructures to irrigate 4,200 farms are fully covered by the municipalities account which pays the Abu Dhabi Distribution Company (ADDC).

Full details are set out in Table 8.1.

Socioeconomic, health and environmental benefits and impacts

The Emirate of Abu Dhabi is witnessing one of the fastest-growing populations and economies in the world, with a projected population of almost 7 million by 2030. The government needed to take action to ensure its wastewater infrastructure needs are met now and in the future.

Although the old Al Mafraq WWTP had been continuously upgraded over its history, including an upgrade in capacity to 260,625 m^3/day in 1997 and new systems for odor control and biosolids management, it became overloaded, leading to raw wastewater discharge into the environment and inefficient treatment of the collected volumes of wastewater. The construction of Al Wathbah-2 WWTP was part of planned activities carried out in the Emirate of Abu Dhabi between 2010 and 2013 to serve the wastewater needs of 3 million inhabitants.

Al Wathbah-2 WWTP is already providing socio-economic, health and environmental benefits including reduced discharge of raw sewage water to the environment, fewer odors and improved biosolids management. Raw sewage discharge has negative health and environmental impacts. The quality of the treated wastewater has improved increasing its reuse potential as irrigation water for both green and landscaped areas and for agricultural areas to replace the present use of desalinated water. This is saving USD 2.77 (AED 10.2)/m^3 of desalinated water and reduces energy consumption, which is also minimizing carbon emissions from the desalination plants. It is also more cost-efficient. Recycled water costs USD 0.051 (AED 1.9)/m^3 compared with expensive desalinated water.

Using recycled water from Al Wathbah-2 WWTP is also helping to improve and enhance deteriorated groundwater quality and increase reserves for future uses. By April 2022, it is expected that 4,200 farms will be irrigated with reused water, which will replace about 250,000 m^3/day of brackish groundwater farms. In addition, the total dry mass of biosolids produced at the plant will be recycled for producing compost. In 2020 this amounted to 13,859 t.

Gender equality

In March 2015, Her Highness Sheikha Fatima bint Mubarak, Chairwoman of the General Women's Union, Supreme Chairwoman of the Family Development Foundation and President of the Supreme Council for Motherhood and Childhood, launched the National Strategy for

Empowerment of Emirati Women in the UAE (2015–2021). The strategy provides a framework for all federal and local government entities, the private sector, as well as social organizations, to set plans that will provide a decent living for women and make them creative in all sustainable and developmental fields. The strategy is the framework for setting up work plans, which would contribute to positioning the UAE among the advanced countries in the area of women's empowerment including in the water industry.

Wastewater development offers huge potential for women's employment even if currently they are under-represented. Only 0.6% of the women workforce are currently employed in the water supply, sewerage and waste management sector although the number of women working in the wastewater sector, including at Al Wathbah-2 WWTP, has increased by 30% since 2015.

The Abu Dhabi government is also dedicated to increasing the number of women in water reuse-related enterprises. Almost a quarter of the farms that will be supplied by treated wastewater from Al Wathbah-1 and Al Wathbah-2 WWTPs are owned by women with the potential to increase their livelihoods and food security. During focus group studies carried out by the government, women showed a high acceptance level in terms of using recycled water from wastewater treatment plants for agricultural purposes.

Resilience to COVID-19

Treated wastewater samples from Al Wathbah-2 WWTP were collected in May and June 2021 and tested for COVID-19 (SARS-CoV-2) viral loads to track the prevalence of the virus and as an early-warning tool for predicting outbreaks in the future. Composite samples collected over 24 hours were made safe and then tested using a variety of different methods. None of the samples tested from Al Wathbah-2 WWTP were positive during the entire sampling period, indicating that the treatment technologies used at the plants are efficient and that the treated water was safe to reuse.

Scalability and replicability potential

The smart management of wastewater treatment plants in the Emirate of Abu Dhabi Emirate including Al Wathbah-2 and the sustainable management of treated wastewater combined are expected to form a cornerstone to achieving Abu Dhabi's sustainability goals. The Abu Dhabi experience is scalable and can be applied throughout the region and beyond. Examples of water reuse achievements that could be replicated include:

- Technology and Service Solutions: To control and manage the big assets and infrastructures, ADSSC has inaugurated a remote control and monitoring system for its wastewater treatment plants including Al Wathbah-2. The system enables means a comprehensive database can be maintained that enables supervisors to analyze data and submit reports to make informed decisions. Data from the system also helps develop and plan maintenance programs.

- Reuse and Achieving Zero Discharge to Environment: Abu Dhabi Government will reach zero discharge of wastewater to the environment by April 2022 by utilizing 390,000 m^3/day in irrigation. All produced treated wastewater, including from Al Wathbah-2 WWTP, will be fully utilized to irrigate 4,200 farms in addition to present use, and future production increases will be used for groundwater aquifer recharge to enhance the groundwater quality and reserve in areas near the existing farms to be used later for irrigation.
- Advanced Treatment Plants: In 2015, ADSSC in collaboration with the Environment Agency constructed the first advanced treatment plant with a capacity of 27,000 m^3/day to irrigate 230 farms that use Al Wathbah-2 tertiary treated water.
- Food Security: The use of recycled water from Al Wathbah-2 WWTP will help the government improve its food self-sufficiency ratio. The ratio is currently 14% with a government target to reach 25% by 2030.

SWOT analysis

An analysis of the strengths, weaknesses, opportunities and threats (SWOT) of the Al Wathbah-2 WWTP and Abu Dhabi water reuse project is shown in Table 8.2 including an overview of serious setbacks it could face during its overall life cycle owing to institutional, economical, technical and social pressures and constraints.

Key factors for success along the project and lessons learned

Key factors for success along the project include:

- Understanding the role that tertiary treated water from the Al Wathbah-2 WWTP can play in an arid region with very limited renewable freshwater resources, as part of integrated water resource management plans and sustainability measures. In addition to being an additional water source, it can also relieve pressure on deteriorated groundwater aquifers and costly desalinated water, reduce energy use and associated carbon dioxide emissions from desalination plants and minimize the environmental impacts of desalination.
- The supply and installation of environmentally friendly bio trickling filters in the wastewater pumping stations have provided an environmentally friendly upgrade to the existing chemical scrubbers for the removal of odorous gas compounds in the recycled water.
- Using recycled water for irrigation in wetlands such as Al Wathbah Wetlands has environmental and ecological positive impacts.

Lessons learned include:

- Reuse of tertiary treated wastewater in irrigation can save using costly desalinated water and safe groundwater.
- Emerging and state-of-the-art technologies can help to reduce both CAPEX and OPEX.
- There are many treatment options for the direct reuse of reclaimed water in developing countries.
- Direct reuse of recycled water from wastewater treatment plants in the Emirate of Abu Dhabi is the most technical and economically feasible solution when compared to other options such as aquifer recharge of district cooling.

TABLE 8.2 Al Wathbah-2 WWTP and Abu Dhabi water reuse project: SWOT analysis.

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ■ Enabling legislative framework ■ Training on operation and management. ■ Construction of collection tunnels to minimize the seepage of seawater into the collection network ■ Wastewater tariffs will be enforced by 1 January 2023 as part of cost recovery	**WEAKNESSES** ■ Discharge of stormwater to the wastewater collection network ■ Only 45% of produced water from the Al Wathbah-2 WWTP is reused ■ Discharge of 55% of recycled water produced is discharged into shallow and closed Al Musaffah marine channels causing negative environmental impacts ■ Lack of wastewater transmission and distribution infrastructures. ■ Seepage of seawater to the collection network is increasing the salinity of raw wastewater to 3,000-4,000 ppm that is not removed by Al Wathbah-2 during the treatment process ■ Discharge of 13,859 tons of biosolids to the environment ■ Wastewater tariffs could be a threat to reuse
EXTERNAL FACTORS ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ■ Raising awareness of the environmental aspects of wastewater treatment plants ■ Construction of transmission and distribution infrastructures to reach 100% utilization of produced treated wastewater ■ Increasing and empowering women's employment in operational roles at the Al Wathbah-2 WWTP, which are currently low ■ Development of legislation related to recycled water use in farming ■ Recycling of 13,859 tons of biosolids for producing compost ■ Establishing agricultural measures to monitor agricultural land that uses recycled water for irrigational purposes ■ Stakeholder involvement and engagement in water reuse for irrigation ■ Enhance cost recovery for reuse in farming	**THREATS** ■ CAPEX needed to implement and maintain proper treatment or mitigation measures to solve the salinity level of treated wastewater from Al Wathbah-2

Methods and resources

To collect and review all the required data on the Al Wathbah-2 WWTP Plant, a data collection form designed by Mohamed Dawoud was sent to the Abu Dhabi Sewerage Services Company (ADSSC). In addition, two interviews were conducted including one with the Abu Dhabi Municipality team and one with the Al Wathbah-2 WWTP operation team.

Other methods used during data collection and analysis included the design of data and output forms regarding the status of Al Wathbah-2 WWTP including capacity, production, reused quantities and quality in alignment with Department of Energy guidelines.

Data were collected and analyzed from different sources as follows:

- UAE Annual Statistical Report 2021 Federal Competitiveness and Statistics Centre (FCSC 2021)
- Data collection sheets and Annual Report, Abu Dhabi Sewerage Services Company (ADSSC)
- Official meetings with the Abu Dhabi Municipality and ADSSC
- Abu Dhabi Annual Statistical Report 2020 (SCAD 2021)
- Interviews with stakeholders involved in the operation of Al Wathbah-2 WWTP, the reuse of recycled water from the plant and wastewater regulation in the Emirate of Abu Dhabi.

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Case Study 9: United Arab Emirates

Jebel Ali wastewater treatment plant and Dubai water reuse

Mohamed Dawoud

Acronyms

EPSS	Environment Protection and Safety Section
UAE	United Arab Emirates
WWTP	Wastewater Treatment Plant

History and project justification

In the Emirate of Dubai, a combination of rapid economic development and population growth has increased wastewater production, increasing the need and urgency for sustainable wastewater management to form part of integrated water resource management plans. The challenges facing wastewater management in the Emirate include but are not limited to:

- The need to develop capacity in science and technology to advance wastewater collection, treatment, reuse and regulations
- Investment in costly wastewater collection, treatment and distribution networks and infrastructure
- Biosolids treatment, reuse and disposal
- Water discharge to environment and reuse.

Jebel Ali Wastewater Treatment Plant (Jebel Ali WWTP) is the United Arab Emirates (UAE) largest state-of-the-art plant, located close to the city of Dubai (Figures 9.1 and 9.2). After the completion of Phase 2 in 2019, it now had an annual capacity of 383 MCM (Table 9.1). Water treated at the plant can be reused for non-potable applications across the Emirate of

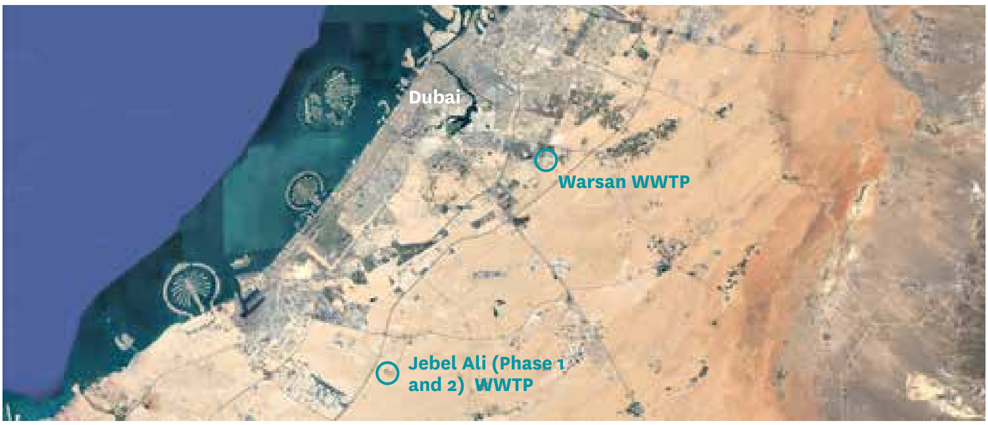

FIGURE 9.1 Jebel Ali WWTP: Location map. *SOURCE*: Google Earth

FIGURE 9.2 Jebel Ali WWTP: Layout map. *SOURCE*: Google Earth

Dubai, with tertiary treated water mainly used for agricultural purposes. When combined with existing facilities, Jebel Ali WWTP will be providing sewage treatment for more than half of Dubai's 3.5 million population, with further expansion possible (Al Awadhi 2014).

Phase One of the Jebel Ali WWTP was constructed in 1980 and upgraded in 1991. This doubled its annual capacity from 45.8 MCM in 1995 to 83.4 MCM in 2001. Capacity increased again in 2008 following the completion of Phase 2 to 137 MCM for USD 354 million (AED 1.3 billion) bringing the combined treatment capacity to 383 MCM (Table 9.1, Figures 9.3 and 9.4). The role of the plant is critical to the water conservation plans of the Dubai Municipality as it allows the city to reduce its use of expensive fresh water by reusing 232 MCM of recycled water to irrigate 6,250 ha of urban green and landscape areas. The plant also handles 21,900 t of solid waste, which can be used as fertilizers or to produce biofuels (Abdel-Dayem 2011).

In the Emirate of Dubai, the wastewater infrastructure network comprises:

- 10 main sewer pumping stations
- 107 subsidiary sewer pumping stations
- 49 stormwater stations
- 87 irrigation pumping stations
- 276 irrigation controllers
- 5,000 km of sewer/storm/irrigation networks

TABLE 9.1 Jebel Ali WWTP Phase 1 and 2 capacity.

No	Phase	Present capacity 2019 (MCM)
1	Jebel Ali WWTP (Phase One) was constructed in 1980 and upgraded in 1991 and 2001	110
2	Jebel Ali WWTP (Phase Two) constructed in 2008	273

SOURCE: Al Awadhi 2014.

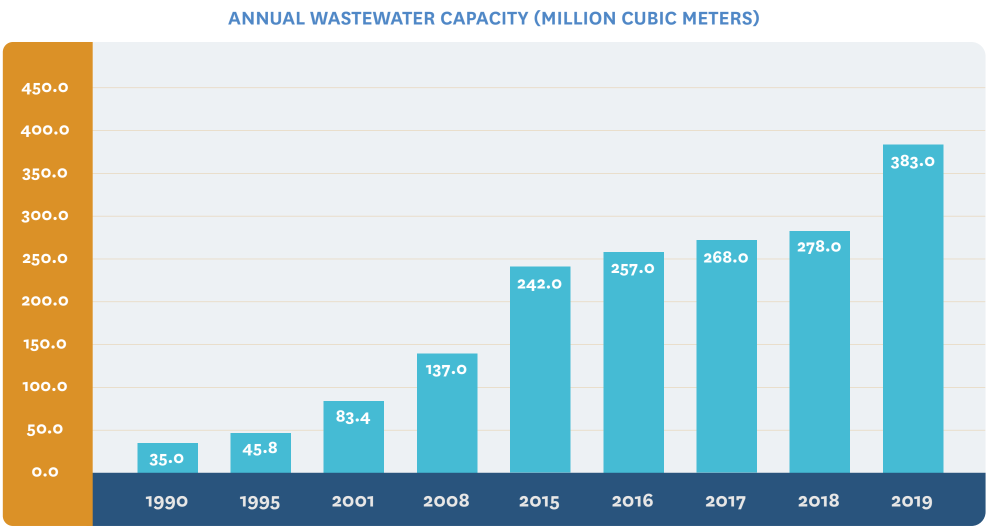

FIGURE 9.3 Jebel Ali WWTP: Annual capacity 1990–2019.

- Two sewerage treatment plants (Jebel Ali and Warsan)
- More than 1,000 employees.

Reuse case description at a glance

In 2008, the Jebel Ali WWTP produced 137 MCM of recycled water through its waste treatment processes. Out of this, 91 MCM were used for irrigation while the remainder was discharged to the environment. In 2019, capacity was increased to 383 MCM with 232 MCM used to irrigate 6,250 ha of land. Currently, the WWTPs in Dubai (Jebel Ali Phase 1 and 2 and Warsan) provide around 700,000 m³/day of treated effluent, which is used as irrigation around the city for landscaped areas, urban greening projects and afforested areas. This water reuse has played a major role in transforming what was an arid region into a beautiful, green, thriving tourist haven for USD 100,000/day. If the same quantity of fresh water has been used for irrigation, it would have cost more than USD 2 million/day of public money. This amounts to a saving of USD 1.9 million/day, which over a year adds up to USD 690 million.

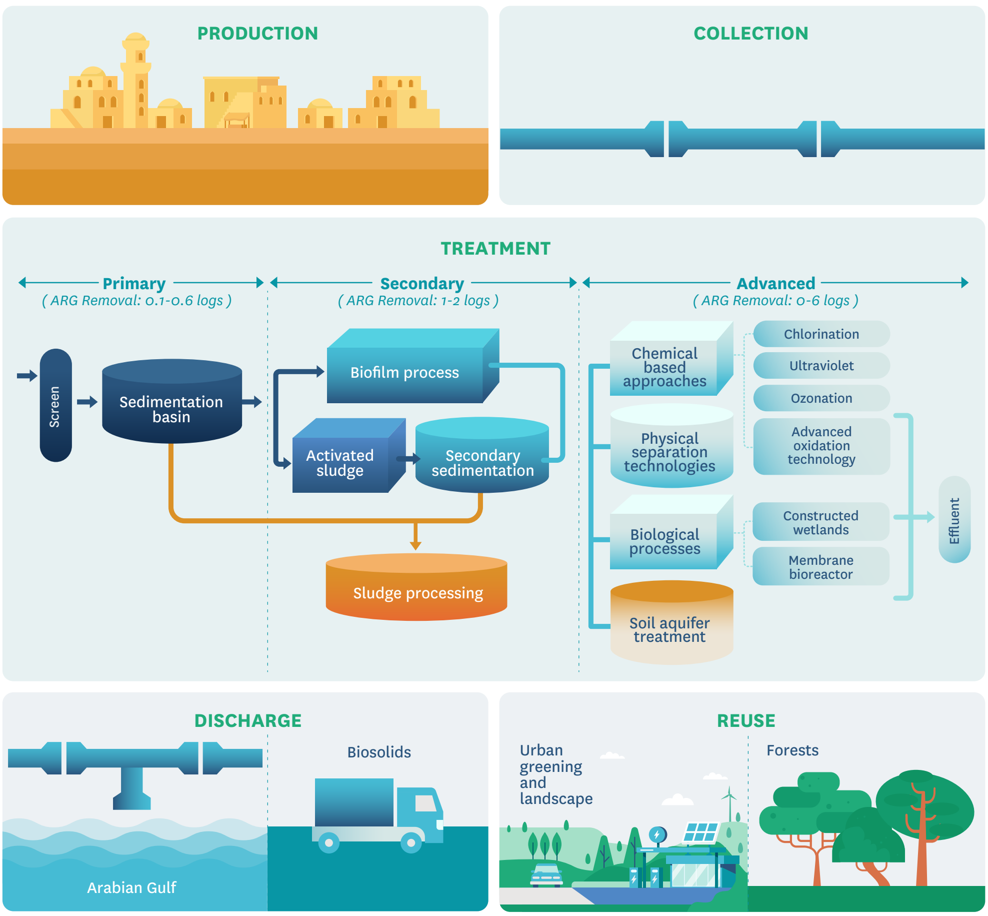

FIGURE 9.4 Jebel Ali WWTP and water reuse: Schematic diagram.

Recently a plan was put forward to recharge the groundwater aquifer system with recycled water from Jebel Ali WWTP. The Dubai Municipality carried out a feasibility study in 2020 and is currently starting a pilot project to assess its technical and economic viability. Based on pilot project results, surplus irrigation water could be used to replenish the aquifer increasing the groundwater reserve and the quality of the groundwater quality. While water reuse for irrigation purposes relieves demand on costly desalinated water resources and brackish saline groundwater resources, there are concerns about impacts on human health as well as groundwater and soil pollution and salinity due to the presence of organic pollutants and heavy metals in the recycled water (Dawoud 2017).

National institutional and policy environment

Wastewater collection, treatment and discharge are regulated by the Environment Protection and Safety Section (EPSS) of the Department of the Environment at the Dubai Municipality. In 2003, the EPSS issued environmental standards which regulated allowable limits of pollutants for land, water and air. In 2011, the Dubai Municipality issued environmental regulations on the use of recycled water from wastewater treatment plants for irrigation, including regulations on the use of thermal treated sludge for agricultural purposes, which were issued by the Environmental Control Section.

The regulations are designed and enforced to protect public health and state that:

- Wastewater treatment plants must meet standard limits for treated wastewater issued by the Dubai Municipality.
- Treated wastewater should be contained within the limits of the Dubai Municipality starting from the inlet point to the outlet point of the irrigation network from both governmental and private treatment facility stations.
- Periodical monitoring of green spaces irrigated by treated wastewater shall be conducted by the Environmental Control Section in cooperation with the Dubai Central Laboratory every six months. This will be done by collecting and analyzing samples of irrigated grasses in various periods after the completion of irrigation.
- Stakeholders need to ensure that the public is not exposed to irrigation water either in the form of spray water or through green spaces irrigated by recycled water from the WWTP to protect them from bacterial and fungal pollutants, especially pathogens and parasitic worm eggs that can be transmitted to humans.
- Irrigation processes should be compatible with the water-holding capacity for the soil, type of plants and depth of roots to reduce water consumption and avoid soil pollution and soil saltiness, and protect groundwater from any leaks from excess usage of irrigation water.
- Stakeholders should implement necessary medical tests periodically for staff in charge of irrigation processes as part of health and safety measures.
- Dubai Municipality Acceptable limits should be followed in accordance with 2008 legislation on restricted and unrestricted irrigation.

Stakeholders involved and management model

The Dubai Municipality manages the Jebel Ali WWTP and is responsible for different parts of the chain including the collection, transmission, treatment and distribution of wastewater for irrigation. The following come under the responsibility of different departments:

- Planning phase (Engineering and Planning Department)
- Construction and operation (Infrastructure Services Department)
- Monitoring and regulation (Health, Safety and Environment Department).

TABLE 9.2 Funding and financial outlook and cost recovery.

	Wastewater collection and transport	Wastewater treatment	Transport of recycled water	Additional treatment for reuse	Distribution of recycled water to end-users
Construction and equipment services (description and dimensions)	The wastewater system in Dubai has long sewage network lines of different diameters which are 3,000 km long, with 56 sub-pumping stations, corresponding to 10 main pumping stations and two sewage treatment plants in Jebel Ali and Warsan The stations/treatment plants are monitored and controlled by SCADA Dubai is planning also to construct a new deep tunnel sewerage system costing USD 3.4 billion (AED 12.5 billion) in the next five years (2021–2025)	The Jebel Ali Sewage Pumping Station in Dubai has an area of 300 m^2, with walls between 2.2 m and 7.3 m high and 25 cm thick slabs. Preliminary Treatment: Fine screens remove all particles with a size larger than 6 mm. In the next step, sand, grit, stones and broken glass settle down in the tanks. Lastly, surface skimmers remove oil and grease from the sewage. Secondary Treatment: Removes the majority of BOD5 and ammonia from the wastewater through two processes. Tertiary Treatment: Ensures that the effluent complies with regulatory standards for irrigation purposes. Dual media filters (pumice stone and sand) are used for the filtration process. Then the water is disinfected by injecting sodium hypochlorite produced on site.	Main transmission network with a length of 120 km and 15 main pumping stations	No additional treatment for reuse	87 irrigation pumping stations, 276 irrigation controllers and 570 km of irrigation networks
Stakeholder that delivers the service	Dubai Municipality	Dubai Municipality	Dubai Municipality	NA	Dubai Municipality
CAPEX (in USD)	3,425 million	775 million	182 million	NA	43 million

Funding and financial outlook and cost recovery

Jebel Ali WWTP is designed to serve up to 1.35 million people. To do this, it is equipped with the most advanced tools in the field of sewage treatment and its final cost is estimated to be USD 775 million. The plant will not need any expansion until 2025.

In return for the sewerage services provided by the Dubai Municipality, occupants of Real Property Units (residency units) are charged tariffs depending on whether they are connected to a public or private sewerage network, and who supervises the network. These tariffs have been applicable and enforced since February 2015 and are detailed below (Table 9.2).

TABLE 9.2 Funding and financial outlook and cost recovery (continued).

	Wastewater collection and transport	Wastewater treatment	Transport of recycled water	Additional treatment for reuse	Distribution of recycled water to end-users
CAPEX recovery and % of subsidy	100% subsidy by the government	100% subsidy by the government	100% subsidy by the government	NA	100% subsidy by the government
Operations and maintenance services (description)	Operations and maintenance contract by Dubai Municipality	Operations and maintenance contract by Dubai Municipality	Operation and maintenance contract by Dubai Municipality	NA	Operation and maintenance by Dubai Municipality
Stakeholder that delivers the service	Dubai Municipality	Dubai Municipality	Dubai Municipality	NA	Dubai Municipality
OPEX (in USD/year)	340 million	76 million	21 million	NA	5 million
OPEX recovery and % of subsidy	AED 0.01[+] for each gallon of water used in a Real Property Unit[++] connected to the public sewerage network. AED 0.01 for each gallon of water used in a Real Property Unit connected to a private sewerage network operated and supervised by DM. AED 0.005 for each gallon of water used in a Real Property Unit connected to a private sewerage network operated and supervised by an entity other than DM.				

NOTES: Biological Oxygen Demand (BOD), Capital Expenditure (CAPEX), Dubai Municipality (DM), Operating Expenditure (OPEX). +USD conversion figures too small to list (AED 0.01 = USD 0.0027). ++ Real Property Unit = a Residential Unit.

Socioeconomic, health and environmental impacts and benefits

Collecting, treating and reusing wastewater for irrigation in landscaping, afforested areas and landscaping can bring socioeconomic, health and environmental impacts such as:

- Increasing green landscaped areas where there is a lack of access to other alternative water resources.
- Minimizing the use of desalinated water for irrigation, which reduces energy consumption and associated carbon emissions from the desalination process and reduces costs – desalinated water costs USD 3.2 (AED 10.2)/m^3 compared to USD 0.51 (AED 1.9)/m^3.
- Reducing negative health and environmental impacts by reducing wastewater discharge.
- Reusing the treated wastewater from Jebel Ali WWTP will help to improve and enhance the deteriorated groundwater quality and reserves for future uses.

The wastewater treatment plants are also designed in line with the Government of Dubai's Energy Conservation and Sustainability Strategy. Where possible they use rationalized energy-consuming processes and components such as gravity rather than pumping to convey water, adopting bio trickling filters to remove ammonia instead of aeration and using biological scrubbers to remove odors. Technological innovations such as variable speed drives for selected pumping needs and advanced process automation systems also help reduce energy use. Other benefits to the environment include contributions to the sanitation of Dubai Saltwater Creek and thereby to the Public Health and Environment of the Dubai City at large.

Gender equality

In March 2015, Her Highness Sheikha Fatima bint Mubarak, Chairwoman of the General Women's Union, Supreme Chairwoman of the Family Development Foundation and President of the Supreme Council for Motherhood and Childhood, launched the National Strategy for Empowerment of Emirati Women in the UAE (2015–2021). The strategy provides a framework for all federal and local government entities, the private sector, as well as social organizations, to set plans that will provide a decent living for women and make them creative in all sustainable and developmental fields. The strategy is the framework for setting up work plans, which would contribute to positioning the UAE among the advanced countries in the area of women empowerment including in the water industry.

Taking gender equality into account, the Dubai Municipality's experience in establishing the Jebel Ali WWTP and reuse scheme has shown that interventions that include the views, input and participation of both men and women generally work better. The Dubai Municipality organized training workshops and seminars focusing on three aspects: water quality, health and hygiene from a policy perspective; embedding gender equality in decision-making on wastewater; and building enabling environments and empowerment for managing wastewater and reuse.

Resilience to COVID-19

From May to December 2021, more than 2,900 raw municipal wastewater samples from 49 separate areas in Dubai were collected and analyzed for COVID-19 (SARS-CoV-2). Almost 30% showed the presence of SARS-CoV-2 genes. At the same time, the viral loads of treated wastewater samples were also tested as a method of tracking the prevalence of the virus and as an early-warning tool for predicting outbreaks in the future. None of the samples tested from Jebel Ali WWTP were positive during the entire sampling period, indicating that the treatment technologies used are efficient and confirming the safety of its treated wastewater for reuse.

Scalability and replicability potential

Efficient management of the Jebel Ali WWTP together with the sustainable management of its produced wastewater is anticipated to become a cornerstone in terms of achieving progress toward Dubai's sustainability goals.

The Dubai experience is scalable in the region and elsewhere in terms of:

- **Technology and Service Solutions:** The wastewater system in Dubai has long sewage network lines of different diameters which are 3,000 km long, with 56 sub-pumping stations, corresponding to 10 main pumping stations and two sewage treatment plants in Jebel Ali and Warsan. To control and manage this huge infrastructure and the assets it contains, the Dubai Municipality inaugurated a remote-control system at the Jebel Ali WWTP. This remote monitoring and control system means a comprehensive database can be maintained that enables supervisors to analyze data and submit reports and supports them to make informed decisions. Data from the system also helps develop and plan maintenance programs.
- **Reuse and Achieving Zero Discharge to Environment:** The Dubai Municipality is the first in the region to reach zero discharge of wastewater to the environment. All produced waste is fully utilized for irrigation and future production increases will be used for groundwater aquifer recharge to enhance the groundwater quality and reserve.

SWOT analysis

An analysis of the strengths, weaknesses, opportunities and threats (SWOT) of the Jebel Ali WWTP and Dubai water reuse project is shown below (Table 9.3).

Key factors for success along the project and lessons learned

During the design, construction and operation of the project, key factors of success include:

- The role that tertiary treated wastewater from Jebel Ali WWTP can play in an arid region with very limited renewable freshwater resources as part of integrated water resource management plans and sustainability measures. In addition to being an additional water source, it can also relieve pressure on deteriorated groundwater aquifers and costly desalinated water, reduce energy use and associated carbon dioxide emissions from desalination plants and minimize desalination environmental impacts.
- Using treated wastewater for groundwater aquifer recharge is also important in arid regions and can help enhance both groundwater quality and reserves. Stored water can be recovered later for different purposes such as irrigation and district cooling.
- The efficient operation system of wastewater plants and infrastructure in Jebel Ali is critical to meeting the growing demand for recycled water delivery. The systems developed have enhanced Dubai's sewer infrastructure to meet the requirements of sustainable development.
- The supply and installation of bio trickling filters in the wastewater pumping stations have provided an environmentally friendly upgrade to the existing chemical scrubbers for the removal of odorous gas compounds in the recycled water.

TABLE 9.3 Jebel Ali WWTP and Dubai Water Reuse Case: SWOT analysis.

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ■ Enabling legislative framework and reuse tariffs ■ Training on operation and management ■ Automated operation and monitoring ■ Jebel Ali WWTP allows Dubai City to reduce the use of costly desalinated seawater by 700,000,000 L/day through reuse applications such as irrigation ■ Increased efficiency achieved in drying biosolids for reuse through using three paddle dryer lines	**WEAKNESSES** ■ Seepage of seawater into the collection network which increases the salinity of raw wastewater to 3,000–4,000 ppm ■ Discharge of biosolids
EXTERNAL FACTORS ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ■ Raising awareness of the environmental aspects of wastewater treatment plants ■ Empowering women through increased employment at the WWTP ■ Development of legislation related to recycled water reuse in farming ■ Establishing agricultural measures to monitor agricultural land that uses recycled water for irrigational purposes ■ Stakeholder involvement and engagement in recycled water use for irrigation ■ Enhanced cost recovery for recycled water uses in farming	**THREATS** ■ CAPEX is needed to implement and maintain proper treatment or mitigation measures to solve the salinity level of treated wastewater

Methods and resources

To collect and review all the required data on the Jebel Ali Wastewater Treatment Plant (Jebel Ali WWTP), a data collection form designed by Mohamed Dawoud was sent to the Dubai Municipality with an official request for completion as per protocol. In addition, two interviews were conducted: one with the Dubai Municipality Team and one with the Jebel Ali WWTP operation team.

Other activities to collect and review data included the design of data and output forms regarding the status of Jebel Ali Wastewater Treatment Plant including capacity, production, reused quantities and quality, in alignment with the Framework for the Development of Environment Statistics (UNSD 2013a, 2013b).

Data were collected and analyzed from different sources as follows:

- UAE Annual Statistical Report 2021 Federal Competitiveness and Statistics Centre (FCSC 2021)
- Data collection sheets from the Dubai Municipality
- Official meetings with the Dubai Municipality and the Dubai Electricity and Water Authority
- The Dubai Annual Statistical Report 2020, Dubai Statistics Centre
- Interviews with stakeholders involved in the operation of Jebel Ali WWTP, the reuse of recycled water from the plant and wastewater regulation in the Emirate of Dubai
- Letters to the Head of Infrastructure Sector at the Dubai Municipality.

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