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

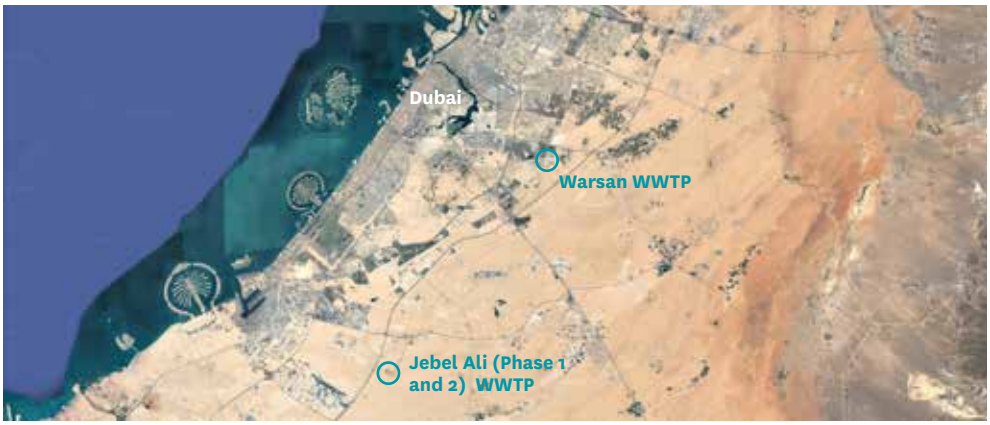

FIGURE 9.1 Jebel Ali WWTP: Location map. *SOURCE*: Google Earth

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.

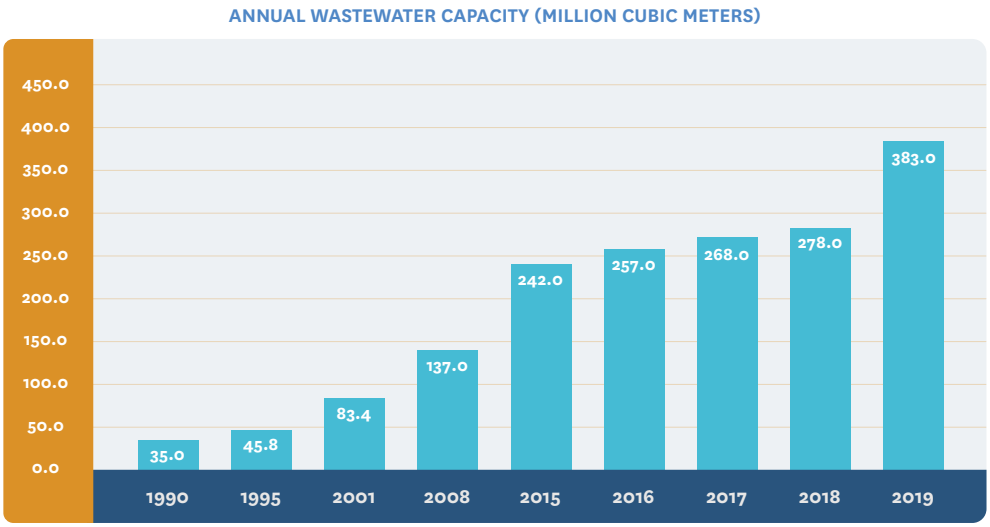

FIGURE 9.3 Jebel Ali WWTP: Annual capacity 1990–2019.

- 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 m^3/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.

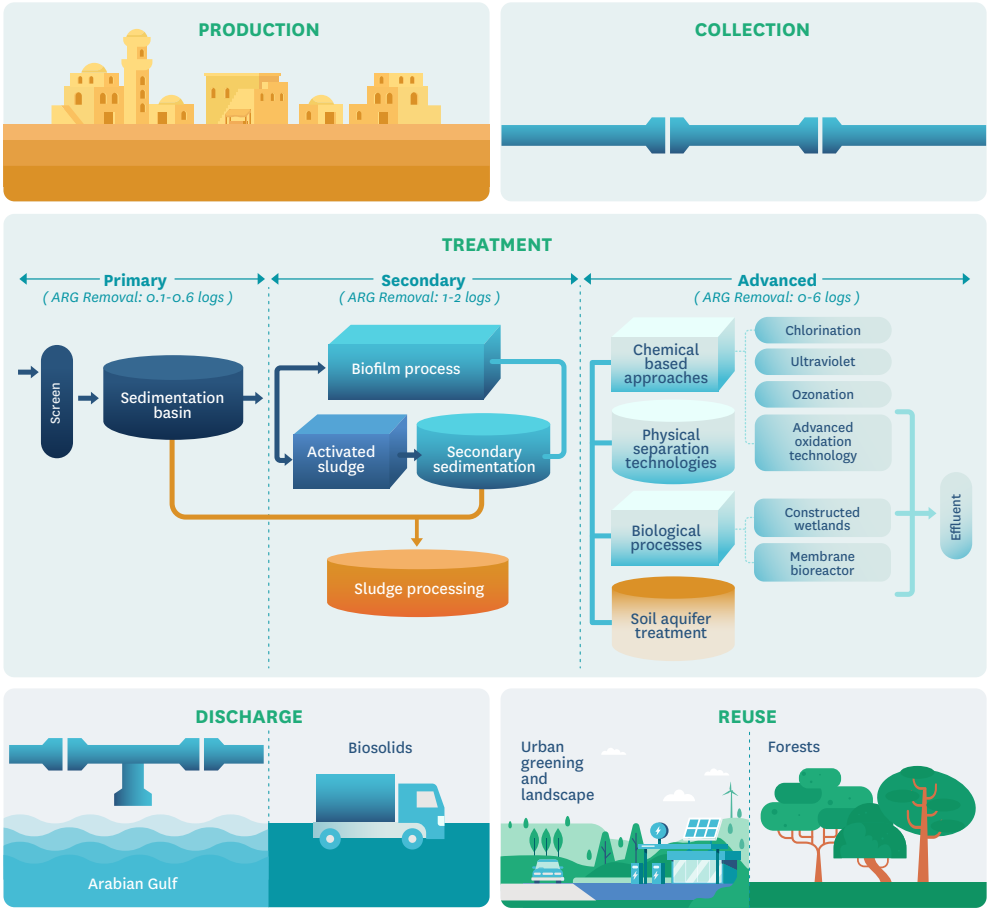

FIGURE 9.4 Jebel Ali WWTP and water reuse: Schematic diagram.

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 m², 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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