Case Study 1: Morocco

Marrakech wastewater treatment plant and urban landscaping

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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

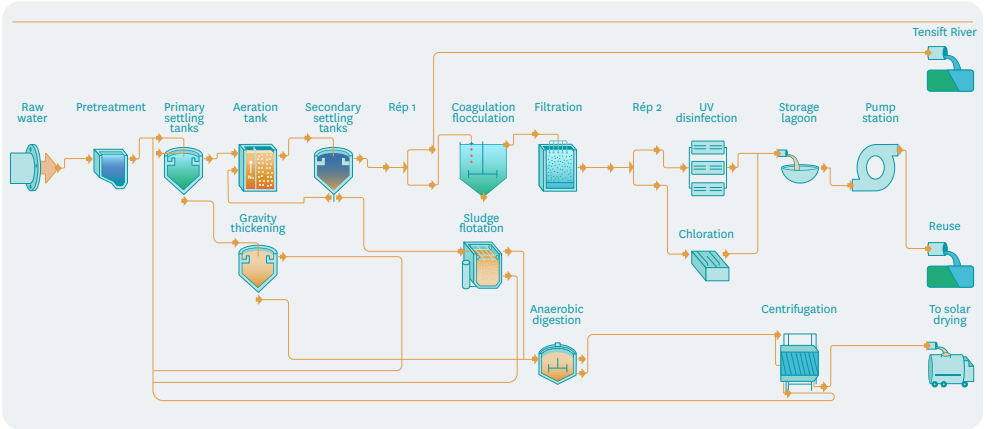

FIGURE 1.2 The Marrakech WWTP and water reuse project: Schematic diagram.
SOURCE: B. Soudi, Institute of Agronomy and Veterinary Medicine.

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

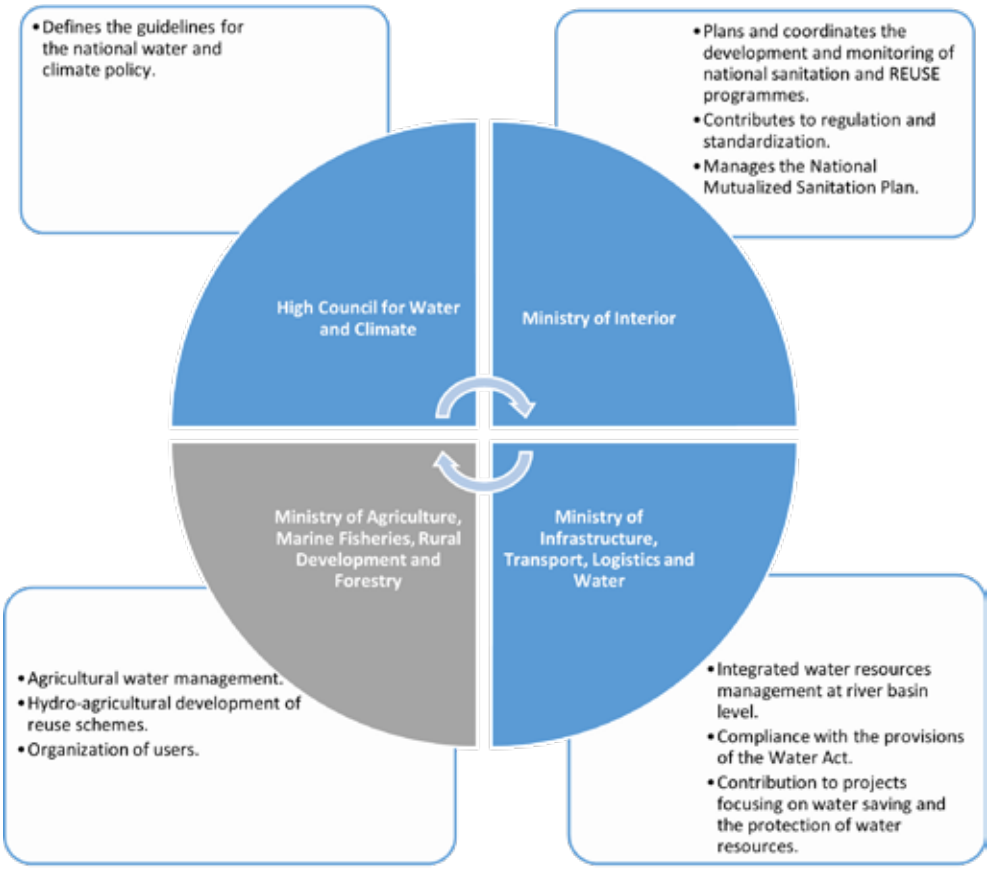

FIGURE 1.3 Key institutional players for wastewater treatment and reuse.
SOURCE: B. Soudi, Institute of Agronomy and Veterinary Medicine.

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

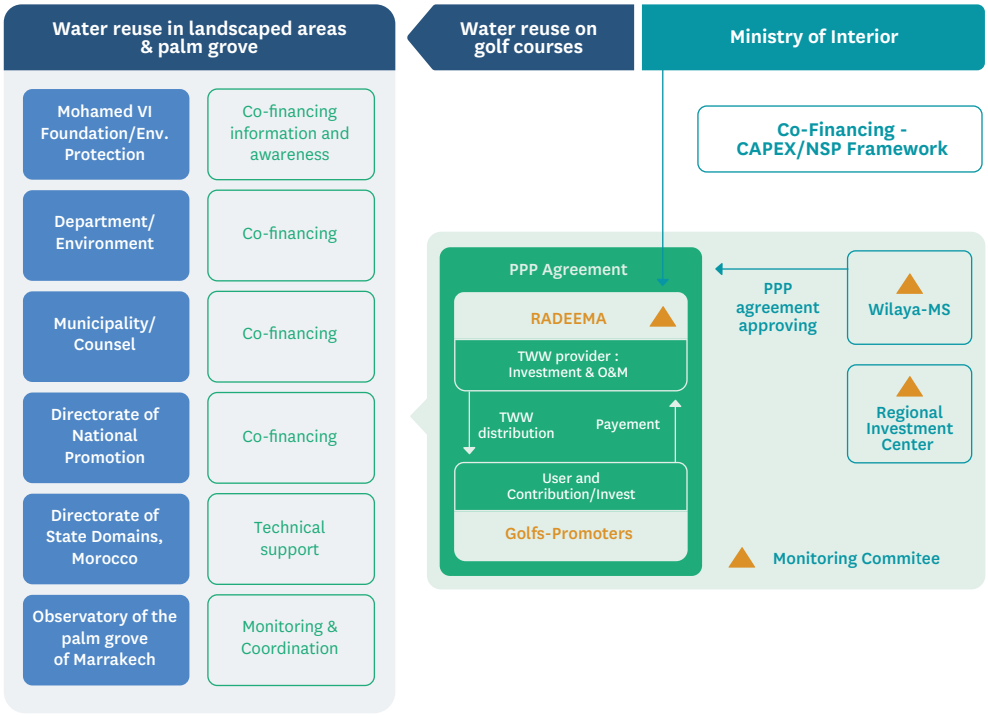

FIGURE 1.4 Stakeholders and management model.
SOURCE: B. Soudi, Institute of Agronomy and Veterinary Medicine (according to the stakeholders' engagements in PPP agreement).
NOTES: Marrakech SAFI (MS), National Sanitation Plan (NSP), Operations and maintenance (O&M), Public-Private Partnership agreement (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)/m^3 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.

Belkouadssi, M. 2016. *Gestion integrée des eaux urbaines de la ville de Marrakech*. ONEE (Office National de l'Electricité et de l'Eau Potable).

Benlouali, H.; Harrouni, M.C.; Fallah, M.; Hirich, A.; Choukr-Allah, R. 2017. Current situation of reclaimed wastewater reuse in golf courses in Marrakech (Morocco): Problems and solutions. *Desalination and Water Treatment* 91: 273–280. DOI:10.5004/dwt.2017.21567

RADEEMA (Water and Electricity Distribution Authority of Marrakech). 2019. *Rapport de gestion*.

Soudi, B. 2012. *Pour BEI_SAFEGE-ONEP. Évaluation Environnementale Stratégique ONEP - Programme Assainissement*.

Soudi, B. 2018. *Appui a la promotion de la réutilisation des eaux usées par le renforcement des aspects institutionnels, réglementaires et financiers, ainsi que des démarches participatives, des mesures incitatives et la sensibilisation*. LDK Consultants Engineers & Planners SA. https://www.swim-h2020.eu/wp-content/uploads/2018/09/SWIM-H2020-EFS-MO-2-Global-Report.pdf

Tahiri, M.; Larif, M.; Quabli, H.; Taky, M.; Elemrani, M.; Midaoui, A.; Khimani, K. 2015. Étude et suivi des performances des traitements, primaire et secondaire des eaux usées de la station d'épuration de Marrakech. *European Scientific Journal* 11(17): 139–154.

Waterleau. 2018. *Le traitement des eaux usées de la ville de Marrakech*. Belgium.

Ziyad, A. 2017. *River basin master plans: planning and water management tools to identify hydraulic projects*. 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).