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in

Hamdy A. (ed.).
The use of non conventional water resources

Bari : CIHEAM / EU DG Research
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 66

2005
pages 147-155

DOMESTIC WASTEWATER TREATMENT AND AGRICULTURAL REUSE IN DRARGA, MOROCCO

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SUMMARY - The Municipality of Drarga is located in a semi-arid region near the coast in southwest Morocco. Although the town is located in the Souss River Valley, the river is dry for much of the year and most water for the area is conveyed from the mountains by a network of dirt canals (seguias). Additional water resources for the area have been exhausted due to the construction of Abdelmoumen Dam, a recent drought, migration into the region following electrification, and excessive use of groundwater. At the initiation of the project, the wastewater generated the town was discharged untreated leading to the development of a large cesspool, where it percolated into the soil or evaporated. As part of he Water Resources Sustainability (WRS) project jointly funded by the United States Agency for International Development (USAID) and the Moroccan Ministry of the Environment, a wastewater treatment facility and water reuse system for the area are being developed. At capacity, the wastewater treatment facility will serve an estimated 17,600 people the Municipality of Drarga. The wastewater treatment facility includes influent screening, grit removal, anaerobic lagoons, denitrification lagoons, and flow holding basins. The effluent from the wastewater treatment facility will be passed through recirculating sand filters and reed beds (man-made constructed wetlands) to further reduce solids, organics, pathogens, and nitrogen to World Health Organization WHO) standards for unrestricted agricultural irrigation water. No chemicals or complex mechanical equipment are required in the process. The effluent from the wastewater treatment facility will be stored on-site in lined basins and pumped to local farms for as irrigation water. Crops grown in the local area include alfalfa, clover, corn, bananas and vegetables. The wastewater treatment facility will receive income from the sale of the irrigation water, the sale of reeds and the sale of composted sludge.

Key words: Morocco, USAID, wastewater treatment, water reclamation, water reuse, agricultural reuse, intermittent sand filters, recirculating sand filters, anaerobic lagoons, biogas utilization, reed beds, biological nitrogen removal, fecal coliform removal

SITE SELECTION AND COMMUNITY INVOLVEMENT

The Municipality of Drarga is a rapidly expanding town with an efficient central planning organization. Two large housi1r developments financed by ERAC-Sud are under construction within district limits. The entire town has been electrified, and a w distribution system serves most of the town. In addition, the town has a sewage collection system that covers about 80% of the town's population. The Al-Amal water users association provides the water and sewage services. This organization is headed by a board of directors elected by the citizens of the town. The organization operates two chlorinated drinking water wells, a 60 m^3 water tower, the water distribution network, and the sewage collection system. The water use at each household connection is metered, and the customers pay the quarterly for the amount of water used, in addition to a flat connection fee. The Al-Amal association was interested in the construction of a wastewater treatment facility and indicated a willingness to operate and maintain the facility.

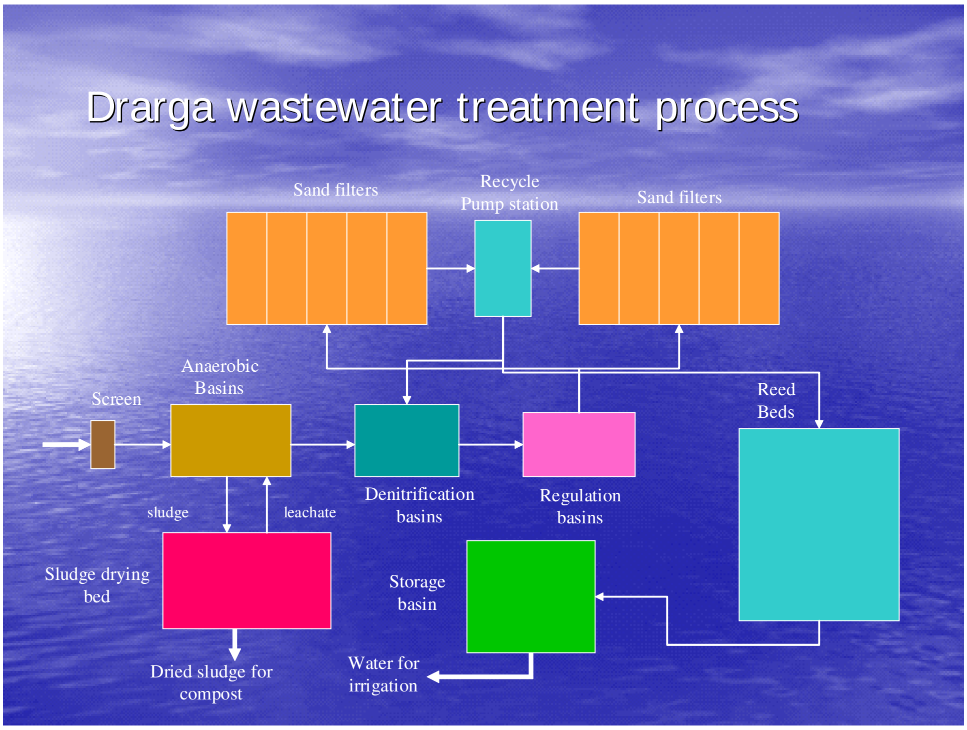
Current discharges of untreated wastewater in the town of Drarga pollute ground water, emit unpleasant odors, and are a threat to public health . Wastewater from the town of Drarga is drained through four drainage or outfall sewers coming from (1) Iguidar and Ikiou; (2) Drarga Centre, eastern part; (3) Drarga Centre, western part; and (4) Talat Izem. Those outfall sewers take the wastewater directly to undeveloped areas, which in some cases are only a few meters from residential areas (outfall 3 and 4). The wastewater accumulates in ponds (particularly for discharge points 1 and 2), and a part of it infiltrates into the ground. These ponds promote the development of parasites and insects and give off unpleasant odors. In addition, nitrogen in the wastewater was identified as a contributor to the high nitrate concentrations in the local groundwater (although agriculture is the primary contributor).

As the first step in the project development, potential sites for the treatment plant were identified and compared. The main evaluation criteria for the selection of the site were as follows:
1. Distance between the site and the population center (impact of odors)
2. Ownership of the site (private or public land)
3. Access to the site
4. Conveyance to the site of untreated wastewater
5. Topography and geology of the site
6. Risks of flooding
7. Risks of polluting groundwater
8. Proximity to users of treated wastewater
9. Room for future expansion

Based on these criteria, four potential sites were established and evaluated. The most favorable site was selected and acquired by the municipality.

WASTEWATER TREATMENT PROCESS DESCRIPTION

Although the treatment plant, designed to meet the year 2020 wastewater flow, during the initial stage of the project, only the facilities necessary to meet the year 2010 design flow are being constructed. Two supplementary projects were also required to implement the wastewater treatment process; construction of flood protection improvements along the Oued Irhzer El Arba (which is subject to seasonal flooding) and extension of the existing sewer system from the four current outfall points to the treatment plant site. A step-by-step description of the treatment plant components follows.



Bypass Chamber: The bypass chamber is the first structure in the wastewater treatment plant. Normally, all of the wastewater flow generated by the Municipality will be treated at the plant. However, during heavy rain events, a large quantity of rainwater May enter the collection sewer system through inflow and infiltration. This rainwater will dilute the strength of the sewage, but it will also increase the quantity of sewage above what the treatment plant is capable of handling. During such periods, the treatment plant will continue to function at full hydraulic capacity, while any additional flow will bypass to the intermediate pump station from where the combined raw sewage and recirculating sand filter effluent will be pumped into the Oued Irhzer El Arba. It is anticipated that this situation will occur very infrequently, and when it does the Oued Irhzer El Arba will be flowing with water which will further dilute the bypassed sewage.

Screening: The first step of the treatment process is to remove large floating and suspended solids, rags, rocks, debris, and other large objects from the influent wastewater. These objects will be captured in the manually cleaned influent bar screen located immediately downstream of the bypass chamber. Influent screening is important because large solids and rags could potentially clog downstream pumps, pipes, and valves if not removed at this time.

Grit Removal: The next step of the treatment process is grit removal, which occurs in two parallel grit removal chambers. Dense solids such as sand or bone fragments will settle to the bottom of this chamber, from which they must be shovelled out by hand. A proportional weir at the end of each chamber maintains a constant flow velocity through the chamber. This constant velocity ensures that biodegradable organic solids, which are typically less dense than grit, will not settle inadvertently in the grit removal chamber.

Flow Distribution: There are three flow distribution boxes in the plant: Flow Distribution Box No.1, Flow Distribution Box No.2, and the Nitrate Recycle Flow Distribution Box. These boxes are used to spilt the wastewater flow evenly between all process tanks on line by flow over equal length sharp-crested weirs set at the same height.

In addition, the Nitrate Recycle Flow Distribution Box allows the RSF effluent pumped from the intermediate pump station to be distributed proportionally between the denitrification lagoons and the reed beds. By using stop plates to cover some of these weirs, the operators can achieve a 3:1, 2.4:1, 1.8:1, 1.2:1, or 0.6:1 ratio of nitrate recycle to plant influent. The design nitrate recycle ratio is 2.4 for the year 2010 design and 1.8 for the year 2020 design. The ratio is lower for the future design condition because the nitrogen concentration in the plant influent is expected to decrease with modernization of the area (see Development of Design Criteria, above) .

Anaerobic Lagoons: The purpose of the anaerobic lagoons is to remove COD present in the influent wastewater through anaerobic biological decomposition. At the same time, suspended solids presenting the influent wastewater and the bacteria that grow as a result of the anaerobic activity will settle to the bottom of the lagoon. There are two anaerobic lagoons in the year 2010 design. A third lagoon will be added in the future expansion to the year 2020 design flow. Each lagoon has a volume of 918 m^3 and the units combine to provide a 3.0 day hydraulic detention time (HRT) for the year 2010 design flow, and a 2.3 day HRT for the year 2020 design flow. The anaerobic biological decomposition process generates methane gas and carbon dioxide as a by-product. Floating covers over the lagoon capture this gas. Collection piping carries the gas to a 16 kW engine generator, which converts the energy in the methane gas into electricity .The electricity, can be used to power the operator’s house, laboratory, and selected pumps. Submersible sludge pumps in the bottom of the lagoon can be used to pump the sludge out of the lagoon onto the sludge drying beds for dewatering.

Denitrification Lagoons: The purpose of the denitrification lagoons is to remove oxidized nitrogen (nitrate and nitrite) by the biological process of denitrification. Heterotrophic bacteria operating in an anoxic environment carry out this process. The bacteria require a carbon source to carry out the denitrification process. The carbon source in this application is the COD present in the anaerobic lagoon effluent wastewater. Additional COD can be supplied by directly bypassing a portion of the influent wastewater from Flow Distribution Box No.1 around the anaerobic lagoons. The effluent from the anaerobic lagoons contains most of the nitrogen present in the form of TKN. Therefore, a portion of the effluent from the RSFs (in which the nitrification process has converted ammonia into oxidized nitrogen) must be recycled back to the denitrification lagoons. The Nitrate Recycle Flow Distribution Box accomplishes this. Like the anaerobic lagoons, the denitrification lagoons contain submersible sludge pumps that can be used to pump settled solids out of the lagoons and onto a sludge drying bed for dewatering. There are two denitrification lagoons in the year 2010 design. A third lagoon will be added in the future expansion to the year 2020 design flow. Each lagoon has a volume of 736 m^3

and the units combine to provide a 2.4 day nominal HRT for the year 2010 design flow, and a 1.9 day nominal HRT for the year 2020 design flow.

Flow Holding Basin: The purpose of the flow-holding basin is to store the effluent from the denitrification lagoons until it is time to dose the next sand filter. The sand filters are dosed three time per day, so the combined volume of the flow holding basins are equal to one-third of the total volume of influent flow and nitrate recycle flow for one day. At pre-set intervals during the day, the operators will manually open the sluice gate at the end of the flow holding basin, releasing the contents of the basin to the RSFs. There will be relatively few solids present in the flow leaving the denitrification lagoons, but some additional solids may settle out in the flow holding basins and can be removed periodically by draining the foot of the basin into the recycle pump station. There are two flow-holding basins in the year 2010 design. A third basin wi11 added in the future expansion to the year 2020 design flow. Bach basin has a volume of 360 m^3.

Recirculating Sand Filters: The primary purpose of the recirculating sand filters (RSFs) is nitrification (the biological process by which ammonia is converted to nitrate by autotrophic bacteria under aerobic conditions). Additional reduction of BOD and some degree of denitrification will also take place in the RSFs. The denitrification is possible in portions of the RSF, which do not receive adequate oxygen.

The primary source of oxygen in the RSFs is diffusion of oxygen into the upper layers of the sand from the air. Frequent "tilling" of the sand on the surface enhances this effect. The tilling process involves turning the top few centimeters of sand to expose the bacteria growing on the sand grains to the surface air. The tilling process also breaks up the hard pan of solids and algae that tends to build up on the RSF surface over time. Some oxygen will also enter the bottom of the RSF through the open underdrains. There are ten RSFs built for the Year 2010 design flow. An addition four RSFs will be constructed for the year 2020 design flow. Two RSFs will be dosed at a time for the Year 2010 design, and three at time for the year 2020 design. Each RSF has a surface area of 1560 m^2 and at the design dosing rate of 360 m^3 per sand filter, the hydraulic loading will be 230 mm per dose. Each RSF is dosed once every five dosing period. There are three dosing periods each day. In each dosing period, the slide gate at the end of both flow holding basins is opened, sending a rush of stored wastewater onto the surface of two of the RSFs. The flow of wastewater onto the RSF surface is faster than the liquid can percolate through the sand, so the liquid ponds on top of the sand surface. The ponding results in an even depth of wastewater over the entire RSF surface., which in turn, ensures an even distribution of flow across all parts of the RSF. Over the next several hours , the ponded water percolates through the sand particles, where attached bacteria carry out the nitrification process.

INTERMEDIATE PUMP STATION

The effluent from the RSFs drains into the intermediate pump station. The maximum water level in the intermediate pump station must be kept below the bottom of the RSFs to allow the RSFs to drain completely. Due to the great depth below the ground water surface at this point, submersible wastewater pumps are used to lift the wastewater back up to the surface level. These pumps serve a dual purpose as they also return a portion of the RSF effluent back to the front end of the denetrification lagoons to serve as a source of nitrates for the denitrification process. The intermediate pump station has a large volume so that it can act as a flow equalization point. Even through liquid exits the RSFs at an inconsistent rate (due to the periodic loading method), the RSF effluent flow will be equalized in the intermediate pump station and (when properly adjusted) the pumps will operate at a constant rate throughout the 24-hour period.

Reed Beds: There are two reed beds, each about 2,900 m2 in area. These membrane-lined beds, which are subsurface irrigated with a constant water depth of 1.0 m, wil1 be planted with local varieties of fast. growing giant reeds (qchqlich and aghanim) in alternating rows. The primary purpose of the reed beds is to grow reeds that wil1 be harvested periodically and sold as a source of income for the plant. The reed beds wil1 also remove some nitrogen and other nutrients from the wastewater by uptake into the plants and by biological nutrient removal. This nitrogen removal, however, will be partially offset during many parts of the year by the loss of water through the basins due to evapotranspiration. Thus, although the nitrogen load (in kg/d) will decrease across the reed beds, the change of nitrogen concentration across the reed beds is highly dependent on the percentage of water loss across the reed beds. The concentration can increase or decrease.

Effluent Storage Ponds and Pump Station: There are two effluent storage ponds, each with a volume of 1,014 m3. The effluent flow storage ponds store treated effluent from the plant until the local farmers need it. The effluent pump station pumps treated plant effluent from the effluent flow storage ponds to the farmer' s fields for use as irrigation water. A flowmeter is used to measure the quantity of irrigation water delivered to the farmers. Irrigation water will be distributed among the eligible farmers through a piping distribution network. Valves will be installed at each farm parcel and controlled under the authority of a "gouadier" (according to the traditional rules of the region). Major crops to be developed include alfalfa, clover, corn, bananas, zucchini, pumpkin, cabbage, potato, and onion. Water may be allocated for cereal crops, such as wheat, during certain crucial growing periods (such as the ripening period). The reuse water wil1 provide a significant source of nutrients (nitrogen, phosphorus, and potassium) to the irrigated crops without excessive contribution of nitrates to the groundwater. Excess water which is not required by the farmers will overflow the storage ponds and into the adjacent Oued Irhzer El Arba.

Table1. P lant performance

Indicator	BOD5 (mg/l)	COD (mg/l)	TSS (mg/l)	NTK (mg/l)	Fecal Coliforms (mg/l)
Entrance	625	1825	651	319	6.3x106
Standard	<30	N/A	<30	N/A	103

Exit	10	75	3.9	10.2	<500

Sludge Drying Beds: The purpose of the sludge drying beds is to dewater sludge produced in the anaerobic lagoons and the denitrification lagoons. The liquid sludge is pumped from the bottom of the lagoons by submersible pumps and onto the surface of the sludge drying beds. The liquid portion of the sludge will evaporate into the atmosphere or drain through the sand in the drying beds into the underdrain below. The underdrain is piped back to the anaerobic lagoon effluent channel. The dried sludge must be removed with a small loader and disposed of or used for co-composting with municipal solid waste. The on-site municipal solid waste/wastewater sludge co-composting project is currently under design through a separately funded project.

There are five sources of nitrogen removal in this treatment system.

- Nitrogen contained in sludge removed from the anaerobic lagoons. .
- Nitrogen contained in sludge removed from the denitrification lagoons.
- Nitrates (from the RSF effluent) recycled in the nitrate recycle flow and denitrified in the denitrification lagoon.
- Ammonia nitrified (converted to nitrates) in the RSFs and immediately denitrified in anoxic regions of the same filter.
- Nitrogen contained in the harvested reeds.

At the same time, the nitrogen concentration through the treatment system is increased by water losses from the system through evaporation, transpiration, and plant uptake. The overal1 result is an antidpated reduction in the total nitrogen across the facility of 70% (in the year 2010) and 63% (in the year 2020).

Impacts of the project

Reduced water pollution

Tests conducted at the plant in 2000 show that the facility was , meeting the targets set for reducing water pollution in Drarga. Table 5 below shows the characteristics of raw wastewater generated by Drarga and the levels after the establishment of the treatment plant. The quantity of treated wastewater generated from the plant is around 400 m^3/day.

Increased Water savings

The treated wastewater fulfills the requirements of World Health Organisation category A, and therefore is suitable for reuse in agriculture without restriction. The WRS project increased farmers awareness on the use of treated wastewater for crop irrigation by developing demonstration plots using drip irrigation. The results of the demonstration plots convinced the farmers of the benefits of using treated water for irrigation. Crops that are irrigated with treated effluents in the demonstrations plots include cereals (wheat and maize), vegetables (tomatoes and zucchini), and forage crops (alfalfa and ray-grasses).

The farmers irrigating with treated water are benefiting in two ways. First, they have access to a guaranteed amount of low-priced water. In addition, they can economize on buying fertilizer since the treated wastewater already contains fertilizer elements needed by the crops. Table 2 summarizes the economic savings of water and
fertilizer for each crop. The total economic savings range from DH 2,222 per hectare for zucchini to DH 5,140 per hectare for maize.

Table 2 Economic saving from irrigating with treated wastewater

Cultivation	Neat Benefit on water	Benefit on fertilizers (2)	Total benefit

	(1) (Dh / year/inhab)	(Dh / year/inhab.)	(Dh / year/inhab)
Tender Wheat	750	1.492	2.242
Corn	1.588	3.614	5.202
Fodder corn	1.568	3.572	5.140
Clover)	774	1.539	2.313
Zucchini	677	1.545	2.222
Squash	611	1.216	1.827
Tomato	1.553	3.542	5.095

PUBLIC PARTICIPATION, INSTITUTIONAL PARTNERSHIP, AND COST RECOVERY

Public participation

The use of a participatory approach has been one of the r cornerstones of the implementation of the Drarga project. At the f beginning of the project, we did a survey on the attitudes of local people with respect to different types of water (bottled water, tap water, well water, and wastewater.) With town eiders, we retraced the history of the community and its relationship to water. We have worked closely with a local water users association that had provided potable water and a sewage network to the town. We have also helped create an association of users of treated water that distributes the treated water from the plant to local farmers.

We have consulted with the population of Drarga at each step of project development. We presented the results of the feasibility study at a stakeholder' s workshop to receive feedback on the technological options presented. We changed the location of the plant site after receiving objections from some inhabitants on the sites proposed in the feasibility study. We also consulted project partners during the environmental assessment and prior to the start of construction. This process of consultation has enabled the project to gain the support of beneficiaries for the project and to have their participation in implementation.

INSTITUTIONAL PARTNERSHIP

Another key element of the Drarga pilot project was the establishment of an institutional partnership. At the outset of the project, we created a local steering committee made up of all institutions involved with various aspects of water management at the local level (Wilaya of Agadir, RAMSA (Water Utility), ORMVA/SM (Irrigated Perimeter Authority), Regional Hydraulics Department, Commune of Drarga, Ministry of Environment, ONEP (Regional Potable Water Agency), Ministry of Health). The role of the steering committee was to follow each step in the implementation of the pilot project and to provide assistance, when necessary, based on their specific area of expertise. For example, the Department of Hydraulics conducted the hydrogeologic study of the site, the Ministry of Environment assisted with the environmental impact assessment, the Irrigated Perimeter Authority helped with the creation of the water users association.

In December 1998, a collective agreement was signed between the project partners that contribute directly to the pilot project. The purpose of the collective agreement is to clearly spell out the roles and responsibilities of each partner. The partners and their respective contributions are listed below:

- Wilaya of Agadir : Mobilizes local institutions and facilitates administrative procedures;
- WRS project : finances the building of the wastewater treatment plant, the reuse network, undertakes all technical studies, and provides technical assistance to the Commune of Drarga;
- Ministry of Environment supports WRS with the involvement of its staff in the studies conducted by WRS;
- ERAC-Sud : a local government housing development agency that ,has a large new development in Drarga finances the main collector to transport Drarga' s wastewater to the plant, the widening of Oued Laarba to provide flood control for the site, and compensation for non-titled farmers that were using the site; and

- The Commune of Drarga that manages the wastewater treatment plant and provides technical and financial reports to a technical oversight committee.

After the completion of construction, we set up the technical, oversight committee that acts as a watchdog over plant operations. The Commune of Drarga will provide quarterly technical and financial reports to the committee. The technical reports include results from sampling and analysis data collected at the site to ensure that the plants performance meets specific pollution abatement targets and that the water provided for reuse meets WHO standards. The financial reports include statements of expenses and revenues.

COST RECOVERY

The Drarga wastewater treatment and reuse project was conceived with cost recovery features in mind. In Morocco, nearly seventy percent of wastewater treatment plants are not functioning due to lack of spare parts and poor cost recovery .The Drarga project includes several cost recovery features. The plant itself generates a number of products that have a market value:

- Treated wastewater is sold to farmers for irrigation;
- Reeds from the reed beds are harvested and sold twice a year;
- Residual sludges from the anaerobic basins are pumped, dried, and combined with organic wastes from Drarga to produce compost;
- The methane gas from the anaerobic basins is recovered and converted to energy to run pumps at the plant, thereby reducing electricity costs.

In addition to the products from the plant, the Commune is committed to raise revenues to pay for the operations, maintenance, and replacement costs of the plant. These revenues include:

- An increase of 1 Dirham ($0.10) per cubic meter to the water and sewage tariff;
- An increase of 2,000 Dirhams ($150) to the one time sewage connection charge for new connections.

These revenues, combined with revenues from the plant are deposited into a special account that is independent of the Commune's general budget and is dedicated to the wastewater treatment plant. This account is further divided into two sub-accounts : (1) an operations account for current expenses, and (2) an extension and renewal account in which money is saved to pay for the replacement of equipment and the future expansion of the wastewater treatment plant.

The project provided the Commune of Drarga with a spreadsheet model to manage all financial aspects of the plant.

The WRS team assisted the Commune in the implementation of the cost recovery mechanisms for the Drarga plant. Activities implemented include the following:

- Opened a special account to manage the costs and revenues of the Drarga wastewater plant;
- Installed a new billing system for water and sewage at the plant, using a computer equipment and software package that wil1 enable the Commune of Drarga to track expenses and revenues of the wastewater treatment plant;
- Organized an association of treated wastewater users, who wi11 purchase the treated water from the Commune and therefore contribute to the payment of part of the operation and maintenance expenses of the plant.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the support of the many individuals who have helped with this project. Important members of the project team included Jean Tilly, Joseph Karam, and Xavier Guillas of ECODIT, Dipankar Sen and Rip Copithorn of stearns & Wheler, and Doug Abbott of Abbott & Associates. We would like to extend special thanks to Bani Layachi of the Moroccan Ministry of Environment; Mohammed Aliman, president of the Drarga Al Amal water users association and also Brahim Zergdi president of the Municipality of Drarga ; the director of ERAC Sud; and the Wali of Agadir.

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