DOCUMENTATION OF BEST PRACTICES

IN WASTEWATER REUSE

IN

EGYPT, ISRAEL, JORDAN & MOROCCO

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.....Water is too precious to Waste

The SWIM Programme (2010 – 2014)

Contributing to Sustainable Water Integrated Management in the Mediterranean

Funded by the European Commission with a total budget of approximately € 22 million, Sustainable Water Integrated Management (SWIM) is a Regional Technical Assistance Programme aiming to contribute to the effective implementation and extensive dissemination of sustainable water management policies and practices in the South-Eastern Mediterranean Region in view of increasing water scarcity, combined pressures on water resources from a wide range of users, desertification processes and in connection with climate change.

The SWIM Partner Countries (PCs) are: Algeria, Egypt, Israel, Jordan, Lebanon, Libya[1], Morocco, the occupied Palestinian territory, Syria and Tunisia.

SWIM aligns with the outcomes of the Euro-Mediterranean Ministerial Conferences on Environment (Cairo, 2006) and Water (Dead Sea, 2008) and also reflects on the four major themes of the draft Strategy for Water in the Mediterranean (SWM), mandated by the Union for the Mediterranean, namely: Water Governance; Water and Climate Change; Water Financing and; Water Demand Management and Efficiency, with particular focus on non-conventional water resources. Moreover, it is operationally linked to the objectives of the Mediterranean Component of the EU Water Initiative (MED EUWI) and complements the EC-financed Horizon 2020 Initiative to De-Pollute the Mediterranean Sea (Horizon 2020). Furthermore, SWIM links to other related regional processes, such as the Mediterranean Strategy for Sustainable Development (MSSD) and the Arab Water Strategy elaborated respectively in the framework of the Barcelona Convention and of the League of Arab States, and to on-going pertinent programmes, e.g. the UNEP/MAP GEF Strategic Partnership for the Mediterranean Large Marine Ecosystem (MedPartnership) and the World Bank GEF Sustainable Mediterranean.

The Programme consists of two Components, acting as a mutually strengthening unit that supports much needed reforms and new creative approaches in relation to water management in the Mediterranean region, aiming at their wide diffusion and replication.

The two SWIM Components are:

- A Support Mechanism (SWIM-SM) funded with a budget of € 6.7 million and
- Five (5) Demonstration Projects funded with a budget of approximately € 15 million

For more information please visit http://www.swim-sm.eu/ or contact info@swim-sm.eu

[1] The situation in spring 2012 is that following formal EC decision activities have been stalled in Syria while Libya has officially become a Partner Country of the SWIM Programme

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TABLE OF CONTENTS

1 SCOPE 14

2 IDENTIFICATION OF BEST PRACTICES 14

2.1 CRITERIA 14
2.2 CHALLENGES TO THE IDENTIFICATION OF BEST PRACTICES 15
2.3 SYNTHESIS OF THE BPS 16

3 BEST PRACTICES IN WASTEWATER REUSE IN EGYPT (BY DR. FATMA AL GOHARY) 19

3.1 INTRODUCTION AND OVERVIEW OF WASTEWATER REUSE 19
3.2 IDENTIFICATION OF BEST PRACTICES 21
3.2.1 METHODOLOGY 21
3.2.2 INVENTORY 22
3.3 IDENTIFICATION OF 3 EXEMPLARY BEST PRACTICES IN WASTEWATER REUSE 24
3.3.1 BP1: WASTEWATER REUSE IN REFORESTATION IN LUXOR, BP2: SARABIUM AFFORESTATION PROJECT IN ISMAILIA GOVERNORATE, BP3 KEMA 1 REUSE PROJECT IN ASWAN GOVERNORATE. 24
3.4 DOCUMENTATION OF BEST PRACTICES 25
3.4.1 BP1: WASTEWATER REUSE IN REFORESTATION IN LUXOR 25
3.4.2 BP2: SARABIUM AFFORESTATION PROJECT IN ISMAILIA GOVERNORATE 34
3.4.3 BP3: KEMA 1 REUSE PROJECT IN THE ASWAN GOVERNORATE 36
3.5 CONCLUSIONS AND RECOMMENDATIONS 40
3.5.1 CONCLUSIONS 40
3.5.2 RECOMMENDATIONS 41
3.6 REFERENCES 41
3.7 ANNEX-1 EGYPTIAN CODE FOR USE OF TREATED WASTEWATER IN AGRICULTURE CHAPTER (5) 42
3.8 ANNEX 2 QUALITY OF TREATED WASTEWATER 44

4 BEST PRACTICES IN WASTEWATER REUSE IN ISRAEL (BY DHV) 54

4.1 INTRODUCTION AND OVERVIEW OF WASTEWATER REUSE 54
4.2 IDENTIFICATION OF BEST PRACTICES 55
4.2.1 METHODOLOGY 55
4.2.2 INVENTORY 55
4.3 IDENTIFICATION OF 3 EXEMPLARY BEST PRACTICE IN WASTEWATER REUSE 57
4.3.1 BP1: MEMBRANE BIO-REACTOR (MBR)-BEN GURION AIRPORT 57
4.3.2 BP2: TERTIARY TREATMENT – BE'ER SHEVA WWTP 58
4.3.3 BP3: SOIL AQUIFER TREATMENT (SAT)-SHAFDAN PROJECT 59
4.4 DOCUMENTATION OF BEST PRACTICES 60
4.4.1 BP1: MEMBRANE BIO-REACTOR (MBR)- BEN GURION AIRPORT 60
4.4.2 BP2: TERTIARY TREATMENT - BE'ER-SHEVA WWTP 64
4.4.3 BP3: SOIL AQUIFER TREATMENT (SAT) - SHAFDAN PROJECT 68
4.5 CONCLUSIONS AND RECOMMENDATIONS 72
4.5.1 CONCLUSIONS 72
4.5.2 RECOMMENDATIONS 73
4.6 REFERENCES 73
4.7 APPENDIX: ISRAELI WASTEWATER TREATMENT PLANTS INVENTORY 74

4.8 ANNEX: 1 EFFLUENT QUALITY REQUIREMENTS ("INBAR COMMITTEE" STANDARDS) 80

5 BEST PRACTICES IN WASTEWATER REUSE IN JORDAN (BY MRS. NADIA EL JOUHARY) 82

5.1 INTRODUCTION AND OVERVIEW OF WASTEWATER REUSE 82
5.2 IDENTIFICATION OF BEST PRACTICES. 85
5.2.1 METHODOLOGY 85
5.2.2 INVENTORY 85
5.3 IDENTIFICATION OF 3 EXEMPLARY BEST PRACTICES IN WASTEWATER REUSE 85
5.3.1 BP1: AWARENESS RAISING FOR POLICY CHANGE 85
5.3.2 BP2: SOCIAL ASSESSMENT AND UNDERSTANDING OF THE COMMUNITY FOR ACCEPTANCE OF REUSE OF WASTEWATER IN WADI MUSA 86
5.3.3 BP3: APPLICATION OF PRACTICAL MULTIPHASE APPROACHES FOR TREATED WASTEWATER REUSE WITH WIDER PARTICIPATION AND INVOLVEMENT OF FARMERS IN THE JORDAN VALLEY 87
5.4 DOCUMENTATION OF BEST PRACTICES 88
5.4.1 BP1: AWARENESS RAISING FOR POLICY CHANGE 88
5.4.2 BP2: SOCIAL ASSESSMENT AND UNDERSTANDING OF THE COMMUNITY FOR ACCEPTANCE OF REUSE OF WASTEWATER IN WADI MUSA 92
5.4.3 BP3: APPLICATION OF PRACTICAL MULTIPHASE APPROACHES FOR TREATED WASTEWATER REUSE WITH WIDER PARTICIPATION AND INVOLVEMENT OF FARMERS IN THE JORDAN VALLEY 96
5.5 CONCLUSIONS AND RECOMMENDATIONS 102
5.5.1 CONCLUSIONS 102
5.5.2 RECOMMENDATIONS 102
5.6 REFERENCES 103

6 BEST PRACTICES FOR WASTEWATER REUSE IN MOROCCO (BY PR. REDOUANE CHOUKR-ALLAH) 105

6.1 INTRODUCTION AND OVERVIEW OF WASTEWATER REUSE 105
6.2 IDENTIFICATION OF BEST PRACTICES REGARDING WASTEWATER REUSE IN MOROCCO 108
6.2.1 METHODOLOGY 108
6.2.2 INVENTORY 109
6.3 IDENTIFICATION OF 3 EXEMPLARY BEST PRACTICES IN WASTEWATER REUSE 109
6.3.1 BP1: NATURAL TREATMENT SYSTEMS FOR UNRESTRICTED IRRIGATION: FORAGE, VEGETABLES AND FRUIT TREE CROP PRODUCTION USING TREATED WASTEWATER IN SOUTHERN MOROCCO 109
6.3.2 BP2: WASTEWATER REUSE FOR IRRIGATING MARRAKECH GOLF COURSES: PUBLIC-PRIVATE PARTNERSHIP FOR FINANCING WASTEWATER REUSE INFRASTRUCTURE 110
6.3.3 BP3: BEST PRACTICES ON POLICY AND INSTITUTIONAL FRAMEWORK FOR THE REUSE IN MOROCCO 111
6.4 DOCUMENTATION OF BEST PRACTICES IN WASTEWATER REUSE. 112
6.4.1 BP1: NATURAL TREATMENT SYSTEMS FOR UNRESTRICTED IRRIGATION: FORAGE, VEGETABLES AND FRUIT TREE CROP PRODUCTION USING TREATED WASTEWATER IN SOUTHERN OF MOROCCO 112
6.4.2 BP2: WASTEWATER REUSE FOR IRRIGATING MARRAKECH GOLF COURSES: PUBLIC-PRIVATE PARTNERSHIP FOR FINANCING WATER REUSE INFRASTRUCTURE 122
6.4.3 BP3: BEST PRACTICES ON POLICY AND INSTITUTIONAL FRAMEWORK FOR THE REUSE IN MOROCCO 130
6.5 CONCLUSIONS AND RECOMMENDATIONS 144
6.6 REFERENCES 145

LIST OF TABLES

Table 3-1 Forest locations 22

Table 3-2 Limit values for the Luxor wastewater 29

Table 3-3 Initial effluent test results from the lagoon (baseline)................................29

Table 3-4 Summary of crop tests 31

Table 3-5 Risk reduction measures for farm workers, crop handlers and graduates .32

Table 3-6 Required farm machines and equipment 35

Table 3-7 Recommended crops and their water requirements 36

Table 3-8 Recommended crops and their water requirements 36

Table 4-1 Water quality data of the SAT process in Shafdan 69

Table 4-2 SAT treated water- viruses, phages and spores analyses 69

Table 4-3 Main figures of SAT operation in shafdan 70

Table 4-4: Inventory WWTPs in Israel with construction costs (sorted by capacity) ..74

Table 4-5: Israel effluent quality standards (2010)...80

Table 5-1 WWTPs and corresponding irrigated area..83

Table 5-2 Water quality of the main water sources used for irrigation in the jordan VALLEY..99

Table 5-3 Comparison between conventional agricultural practices and good agricultural practices for cucumber grown under greenhouses 100

Table 6-1 Wastewater treatment and plants and types of reuse in Morocco (2010) 105

Table 6-2 Characterization of wastewater effluents in Morocco 106

Table 6-3 Quality standards for irrigation waters in Morocco 107

Table 6-4 Wastewater treatment technologies and type of reuse 109

Table 6-5 Characteristics of the plant design 114

Table 6-6 Performance of the WWTP of Tiznit (ONEP 2012) 117

Table 6-7 Land structure of the irrigated perimeter in Tizinit (DPA Tiznit 2011) 119

Table 6-8 Agriculture cropping system in irrigated perimeters (DPA Tiznit 2011)....119

Table 6-9 Economic benefit of irrigation with treated wastewater (dmic & sesaer 2012) 121

Table 6-10 Marrakech wastewater treatment plant capacity..................................125

Table 6-11 Marrakech wastewater treatment plant performance 125

Table 6-12 Quality of the treated water after tertiary treatment (RADEEMA 2010) 126

Table 6-13 Energy production and savings in Marrakech WWTP (radeema 2010) ..127

Table 6-14 Moroccan water quality standards for irrigation (groupement D.M.I.C & SESAER note de synthese 2011) 135

Table 6-15 Categorization of water quality for irrigation depending on the elimination of parasite eggs and faecal coliform (Moroccan standard- extract Decree of 17 october 2002) 136

Table 6-16 Wastewater treatment and reuse models of financing 139

LIST OF FIGURES

Figure 3-1 Existing situation of wastewater reuse projects in 2012 21

Figure 3-2 Forest locations in Egypt..23

Figure 3-3 Jatropha flowering and fruiting in Luxor forest...26

Figure 3-4 Jatropha and Khaya in Luxor...26

Figure 3-5 Nursery for producing mahogany seedlings in Luxor................................27

Figure 3-6 General map of the demo site and the surrounding wells........................28

Figure 3-7 Location map 28

Figure 3-8 Crop pattern layout 31

Figure 3-9 Silkworms on mulberry leaves...34

Figure 3-10 Castor plant at different stages of growth 37

Figure 3-11 Jojoba seedlings...38

Figure 3-12 Damage to the irrigation network..38

Figure 4-1 Typical schematic for membrane bioreactor system (submerged membranes)...60

Figure 4-2 Zenon zeewee membrane cassette used in ben gurion wwtp project 62

Figure 4-3 Plant Front with architectural finish (left) and covered effluent reservoir (right) 63

Figure 4-4 Effluent reuse system in the Negev – tertiary system and irrigated fields 65

Figure 4-5 The filtration system..65

Figure 4-6: Typical underdrain system for gravity sand filter (Leopold) 66

Figure 4-7 UV disinfection system (with effluent ponds behind)...............................67

Figure 4-8 Dan Region WWTP and Reclamation site (Shafdan) 68

Figure 4-9 Operation of soil aquifer treatment in Shafdan 72

Figure 6-2 Localization of the Tizinit WWTP 114

Figure 6-3 Plant design layout (Nghira 2009) 115

Figure 6-4 Anaerobic basins (dpa tizinit 2011) 115

Figure 6-5 Facultative basins (DPA tizinit 2011) 116

Figure 6-6 Maturation pond (DPA tiznit 2011) 116

Figure 6-7 Localization of the irrigated perimeters in Tiznit 118

Figure 6-8 Vegetable crops grown using treated wastewater are cooked 119

Figure 6-9 Google earth photo of the marrakech wastewater treatment plant.......124

Figure 6-10 Design layout of the treatment plant of marrakech (RADEMA 2010) ...125

Figure 6-11 Aeration tanks...126

Figure 6-12 Clarification (secondary clarifier)..126

Figure 6-13 Rapid sand filtration 127

Figure 6-14 UV disinfection and chlorination 127

Figure 6-15 Localization of irrigated golf courses in the city of Marrakech 128

ACRONYMS

ABHS	Hydraulic Agencies of Watersheds
ACWUA	Arab Countries Water Utilities Association
BCM	Billion Cubic Meter
BOD	Biological Oxygen Demand
BP	Best Practice
CAS	Conventional Activated Sludge
CFU	Colony Forming Unit
COD	Chemical Oxygen Demand
Dh	Moroccan Dirham
DO	Dissolved Oxygen
DPA	Provincial Delegation of Agriculture
EC	Electrical Conductivity
EEAA	Egyptian Environmental Affairs Agency
EGP	Egyptian Pound
EU	European Union
FEC	Communal Equipment Fund
GAP	Good Agricultural Practices
GIZ	German Development Cooperation
HCWW	Holding Company for Drinking Water and Wastewater
HFDB	Hashemite Fund for Development of the Jordan Badia
IWRM	Integrated Water Resources Management
JFDA	Jordan Food and Drug Administration

JISM	Jordanian Institution for Standards and Metrology
JOD	Jordanian Dinar
JV	Jordan Valley
K	Potassium
KAC	King Abdullah Canal
KTR	King Talal Reservoir
MALR	Ministry of Agriculture and Land Reclamation
MBR	Membrane Bioreactor
MCM	Million Cubic Meters
MF/UF	Micro-Filtration/Ultra Filtration
MOA	Ministry of Agriculture
MOHP	Ministry of Health Protection
MOWI	Ministry of Water and Irrigation
MSEA	Ministry of State for Environmental Affairs
MWRI	Ministry of Water Resources and Irrigation
N	Nitrogen
NGO	Non-Governmental Organization
NIS	New Israeli Shekel
NKE	Non-Key Expert
NSC	Norms and Standards Committee
NTU	Nephelometric Turbidity Units
NWRP	National Water Resources Plan
O&M	Operation and Maintenance
ONEP	Office Nationale De L'eau Potable

P	Phosphorous
PC	Partner Country
PIDWR	Integrated Development of Water Resources Plans
PNA	National sanitation Plan
PPP	Public Private Partnership
Q	Flow
RADEEMA	Government of Morocco, the State Board of Marrakech
RIAL	Water Reuse for Agricultural, Industry and Landscaping Project
SAT	Soil Aquifer Treatment
SBR	Sequencing Batch Reactors
SEEE	Secretary of state in charge of water & environment
SS	Suspended Solids
SVI	Sludge Volume Index
SWIM-SM	Sustainable Water Integrated Management-Support Mechanism
TDS	Total Dissolved Solids
TN	Total Nitrogen
TOR	Terms of Reference
TP	Total Phosphorous
TSS	Total Suspended Solids
TWW	Treated Wastewater
USA	United Sates of America
USAID	United States Agency for International Development
UV	Ultra Violet

WAJ	Water Authority of Jordan
WAS	Waste Activated Sludge
WHO	World Health Organization
WRAP	Water Reuse Project for Agriculture
WRIP	Water Reuse Implementation Project
WUA	Water User Association
WWR	Wastewater Reuse
WWTP	Wastewater Treatment Plant

1 SCOPE

The scope of this activity is to identify best practices related to increased efficiency for wastewater treatment and reuse in partner countries of the SWIM-SM project. Experts were contracted by the implementing consortium to identify national best practices based on criteria listed hereafter.

Since the SWIM-SM project follows an on-demand approach, the selection of countries was based on their request to be included in the activity voiced during the first steering committee meeting of the SWIM-SM project held in Brussels in 2010.

2 IDENTIFICATION OF BEST PRACTICES

2.1 CRITERIA

The process of identification of best practices is based on a set of criteria detailed in the Terms of Reference of the activity and on relevance of the case study to other Partner Countries. Relevance to other countries was based on identified gaps, barriers, and challenges for wastewater reuse in the SWIM PCs.

The BP are moving along the following lines:

1. BP in the installation of a wastewater treatment system including water reuse.
2. BP in the integration of reuse of wastewater in agriculture and groundwater recharge in national policies, strategies and plans of implementation
3. BP in raising awareness and affecting behaviour change at the local farmer or national decision maker level for the reuse of wastewater in agriculture and groundwater recharge.

The selected best practice should have the following conditions:

1. **Technical criteria**

- ✓ The treated wastewater quality should be up to standards using the 2006 WHO guidelines
- ✓ Integration of reuse of treated wastewater into national water policies and strategies when existing
- ✓ The BP should NOT be of experimental/pilot nature
- ✓ The BP should show effectiveness and efficiency in treated wastewater reuse

2. **Impact:**

Depending on the indicators that were used, the impact that the Best Practice had could include one or more of the following parameters:

- ✓ Increase in the use of wastewater for irrigation
- ✓ Decrease in the reuse of potable water for irrigation
- ✓ Integration of wastewater reuse for agriculture and groundwater recharge in national water plans and policies
- ✓ Development of groundwater recharge projects using treated wastewater
- ✓ Farmer satisfaction in the reuse of treated wastewater
- ✓ Any other impacts not listed above

3. **Technical Feasibility (as applicable):**

- ✓ Reliability
- ✓ Need for expertise (low, medium, high)
- ✓ Prospect of success
- ✓ Practicality
- ✓ Any other aspects not indicated above

4. **Financial feasibility**:

Expressed in terms of Benefit/Cost Ratio

5. **Affordability:**

Ability to mobilize resources for the implementation of the BP

2.2 CHALLENGES TO THE IDENTIFICATION OF BEST PRACTICES

Identification of best practices was faced with challenges that varied among the different countries, like:

- **Sparse and not easily accessible data and information**. Accessing data and information was hard in some countries. Information is available mainly through project reports that are not easily accessible in many cases.

- **Not enough research and publications on the specific practice**. Not enough literature developed around the best practice. In some instances, literature was restricted to project publications.

- **Relevance of the practice to the identified needs of the largest number of PCs.** Practices have been selected on the basis of relevance to the largest number of PCs. Relevance has been determined based on needs, gaps and challenges faced by the different countries in the promotion of wastewater treatment and reuse. **Short relative history in reuse**. Although it is documented that Egypt started reuse of wastewater in irrigation in 1910 the actual history of reuse projects in the regions, except for Tunisia, dates back to the last decade.

- **Restricted reuse of wastewater thus reducing the availability of best practices.** In most countries wastewater reuse is only permitted in restricted irrigation. In Egypt, reuse is only allowed for timber and biofuel crops and not allowed for any crop that is edible. In Israel, unrestricted irrigation is only allowed when tertiary treatment is used. These restrictions in the reuse of wastewater on high value cash crops have reduced the number of reuse projects in the region

- **Projects should be operational (not just pilot) and providing up-to-standard quality water**. The selection process of best practices tried as much as feasible to choose projects that are not of pilot nature, but projects that have some history of operation. This requirement did not facilitate the process since the overall history of wastewater reuse in the SWIM PCs is relatively short and consequently pilot project had to be included in the selection due to the inexistence of alternatives. The selected pilot projects, however, have enough data supporting their potential sustainability and feasibility.

2.3 SYNTHESIS OF THE BPS

Under the pillar of non-conventional water, wastewater treatment and reuse in agriculture and possibly other uses is a main constituent of the EU-funded Support Mechanism Component of the Sustainable Water Integrated Management Program (SWIM-SM).

Collecting and disseminating best practices is one of the cross-cutting activities of SWIM-SM. They serve to exchange successful practices between north and south, and south and south.

Consequently, 12 case studies on increased efficiency in wastewater treatment and reuse have been commissioned by SWIM-SM in 4 different countries: Egypt, Israel, Jordan and Morocco. Case studies documented different aspects of wastewater treatment and reuse such as institutional and legal frameworks, technical feasibility, involvement of the private sector, awareness raising and other aspects such as transforming waste into income.

The variability of the best practices is highly dependent on the actual experience and stage of advancement of the country itself in wastewater treatment and reuse. Presenting several examples of the same nature serves to strengthen the idea and provide solid proof of its feasibility. The stories cover high-tech technologies in advanced and economically rich countries to simple wastewater treatment and reuse projects in poor rural areas that have led to increased income and reduced poverty through the development of agriculture, and rural tourism.

In **Egypt**, the main focus of the best practices was on the reuse of wastewater in agriculture and reforestation. The cases covered pilot and non-pilot cases. The selection of pilot projects was due to the restrictive use of treated wastewater and fairly recent wastewater reuse experience. The advantage of reporting on a pilot project is the amount and variability of measured data that accompanies the project. In field visits organized by SWIM-SM under the different training activities, technicians visiting the site and mid-level management staff always requested performance and other data from the visited WWTP or other infrastructure. Interest and conviction in the ability to replicate a project or technology is strongly reinforced by access to related data by the interested party. The remaining case studies report on successful agriculture and reforestation projects in different governorates in Egypt covering different climatic conditions and consequently different crops and trees that are used for timber and other products such as biodiesel. These best practices have shown the economic feasibility of wastewater reuse through recycling of treated effluent for agriculture and reforestation. This is of high interest to all the PCs, especially in rural communities struggling with poverty. The different projects described within the report cover different governorates in Egypt and different plants for different uses.

In **Israel**, the first case covered membrane bioreactors (MBR) as upgrades to existing WWTPs with the study proving the economic feasibility (though conditional on local tariffs) of a technology, generally considered to be expensive. All PCs that already have functioning WWTPs are struggling with a deteriorating quality of effluent due to increased sewage flow to the WWTP caused by increases in population. Space and consequently footprint is a major factor in upgrading and consequently expanding WWTPS. MBRs can, in many cases where the water tariff allows, be a solution to such an expansion. The effluent quality will be upgraded to the required discharge standard with minimal space requirements. The second case reports on a group of farmers who invested in a tertiary wastewater treatment and reuse station since it provided water for irrigation that is cheaper than water provided through the usual suppliers. This case can be of benefit to farmers in the SWIM PCs who are struggling with the availability of rain. Finally, the last case study covers Soil Aquifer Treatment (SAT) using basins, a simple and cheap natural wastewater treatment technology that is feasible, given the proper hydrogeological conditions and availability of data, in countries where ample land space, such as deserts, exist.

In **Jordan**, the first best practice covers the process of change of the institutional and legal aspects of wastewater treatment in Jordan. Of interest, are the tools, drivers and triggers that have caused decision makers to develop such frameworks. The second best practice covered rural development through agriculture, greening of the landscape, and rural tourism triggered by the reuse of the treated effluent from the Wadi Musa Wastewater Treatment Plant (WWTP). The process of transforming the attitude of the local community from complete rejection of the reuse to competition for the resource and the creation of new projects, is of high value; providing a good example for the project countries (PCs) on the importance of understanding the users' community before project initiation, removing the local barriers against reuse and communicating with and closely involving the stakeholders. The third lesson describes a multiphase approach for introducing wastewater treatment. This is of particular relevance to all the PCs. As a quick example, in Morocco's best practice report, the main bottleneck mentioned in wastewater treatment and reuse is the lack of awareness, communication and understanding of community needs.

Last but not least, in **Morocco**, the aspects of reuse using natural treatment systems, Private Public Partnerships (PPP) for treated wastewater reuse in a golf course, and finally an enabling legislative and institutional framework for wastewater treatment and reuse were reported on. They cover simple treatment technologies (lagoons) suitable for rural areas with a possibility for reuse in unrestricted irrigation, PPPs in wastewater infrastructure, an investment and management scheme of interest to PCs and legal and institutional frameworks to enable above successes.

The 12 best practices; covering several aspects related to wastewater treatment and reuse in four project countries, provide the reader with material for reference. The general country and project background material help situate the case study and provide benchmark levels for relevance and ability to replicate in similar situations in different countries.

3 BEST PRACTICES IN WASTEWATER REUSE IN EGYPT (BY DR. FATMA AL GOHARY)

3.1 INTRODUCTION AND OVERVIEW OF WASTEWATER REUSE

Renewable water resources available to Egypt total approximately 57 billion cubic meters (BCM)/year. Around 97% comes from the Nile, with the remainder from precipitation, which is mainly confined to the north coast. The quantity of supply is essentially fixed. Water demand, on the other hand, is increasing. Currently, it is estimated at 72 BCM per year, over 80% of which is used for agriculture. The strategic problem Egypt confronts is that its renewable water supplies cannot be expanded, while at the same time population is growing and the economy is expanding, with associated increases in water requirements. By 2017, the National Water Resources Plan estimates that total water requirements will exceed 90 BCM.

To face the challenge, a National Water Resources Plan (NWRP) has been developed with the objective of describing how Egypt will safeguard its water resources in the future. The plan is based on an Integrated Water Resources Management (IWRM) approach, taking into account the objectives of all water users, covering the years up to 2017. The strategy described in this plan is called “Facing the Challenge.” It is a coherent combination of many measures that will improve the performance of the system. The measures have been classified into three basic pillars. One of these pillars is the development and use of non-conventional water resources such as treated wastewater.

The Ministry of Water Resources and Irrigation (MWRI) is encouraging reuse of treated wastewater in agriculture as part of a general reuse strategy in order to bridge the existing gap between water resources and water demands. In addition, reused wastewater is a part of the country’s water budget, as shown in Egypt’s National Water Resources Plan up to 2017, which calls for the use of 2.4 BCM of treated wastewater for irrigation. This amount is sufficient to cultivate 250,000[2] feddan (approximately 1 billion m^2).

At present, treated wastewater is used for agriculture in Egypt in two ways: 1) Indirect use, by draining it into agriculture drains, as in Delta governorates; 2) Transfer of treated wastewater and its use in irrigating and cultivating the desert background of urban centres, as in border governorates and Upper Egypt. The strategy now is not to pump treated wastewater to agricultural drains but to use it directly for the cultivation of crops.

Egypt has imposed restrictions on how and for what purposes wastewater is used. An inter-ministerial committee approved the Egyptian Water Reuse Code (ministerial

[2] 1 feddan is equal to almost 4000 m^2

decree No. 171/2005) in April 2005. The Egyptian Code for the Use of Treated Wastewater in agriculture and Law 48/1982 impose limits on agricultural uses of treated wastewater. The code prohibits the use of raw wastewater. Wastewater that has undergone at least primary treatment may be used in some applications. The code indicates that whatever the level of treatment, the use of treated wastewater is prohibited in the production of vegetables whether they are to be eaten raw or cooked; in the irrigation of fruit trees if the fruits are to be eaten raw, including grapes and guava and prohibits in all circumstances the use of treated wastewater in the irrigation of export-oriented crops such as cotton, rice, onions, potatoes, citrus, and medicinal and aromatic plants.

For economic and environmental reasons, the Government of Egypt has determined that the use of TWW in agriculture will be scaled up significantly, and that the private sector has to be invited to play a major role in this process, as will the HCWW from the Government side. Egypt plans to use TWW from Cairo and Alexandria to expand the cultivated area in the Eastern and Western Delta by some 230,000 feddan (920,000,000 m2). An additional 20,000 feddan (80,000,000 m2) will be added in Middle Egypt.

Additionally, approximately 81,000 (324,000,000 m2) and 137,500 feddan (550,000,000 m2) of desert land have been consigned to respectively to the Holding Company for Drinking Water and Wastewater (HCWW) and the New Communities. Of these lands—approximately 10,965 feddan (44,000,000 m2) are presently cultivated. The rest are under cultivation Figure 3-1.

The HCWW will provide treated WW of specified quantity and quality (generally treated at the secondary level) at the farm gate for a fixed fee that covers both the use of allocated land and water. The HCWW's on-going program for safely reusing treated wastewater, will help combat the current criminal use of untreated or partially treated wastewater for agriculture. It will also contribute to improving the operational and financial status of the HCWW and its affiliated companies.

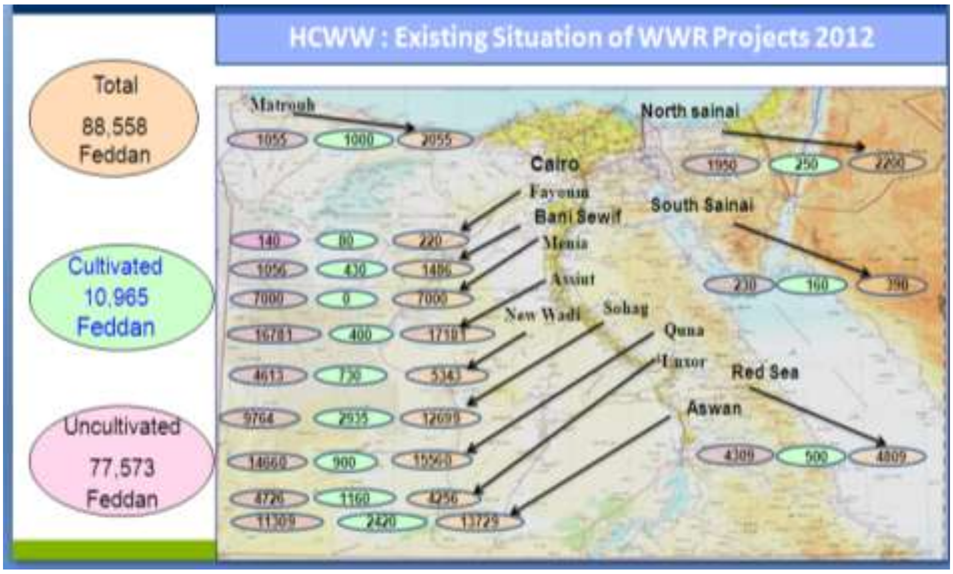

FIGURE 3-1 EXISTING SITUATION OF WASTEWATER REUSE PROJECTS IN 2012

Reuse of treated wastewater in Egypt is highly restricted by legislation. Edible crops cannot be irrigated using treated effluent. Consequently, practices in reuse of treated wastewater are restricted to agriculture for the production of mainly timber, biodiesel and other by-products. This has affected the availability of best practices especially that most projects are still at the pilot stage.

The demonstrated economic feasibility of the reuse projects, coupled with the ease of implementation of such projects, the reduced need for advanced levels of wastewater treatment and accordingly investments since human exposure to treated wastewater is very low makes, the Egyptian practice of irrigating green belts and agriculture- projects to produce timber and biodiesel using treated wastewater a best practice of relevance to most SWIM PCs.

3.2 IDENTIFICATION OF BEST PRACTICES

3.2.1 METHODOLOGY

As mentioned above, reuse of wastewater in irrigation in Egypt is fairly recent and highly restricted. Consequently, the only practices that exist are the reforestation projects and agriculture projects to produce mainly biodiesel and timber in addition to other by-products. The selection of the BPs was based on a review of literature and interviews with key stakeholders to select the best operations.

Although the TORs for this activity have not allowed the use of pilot projects as best practices, it was accepted in the case of countries where wastewater reuse is recent and/or highly restricted such as in Egypt. The pilot activity is simple and is easily reproducible and has shown a positive cost benefit ratio. Of the practices described hereafter, the Sarabium project has become sustainable the remaining two are still in a pilot phase.

The practices are, relevant to all countries that have deserts adjoining to cities (most SWIM PCs) and/or where decision makers and the general public do not accept using treated wastewater to irrigate edible crops.

3.2.2 INVENTORY

Experience of large scale and planned reuse projects to produce wood and other industrial products started mid-1990s. The Ministry of Agriculture and Land Reclamation (MALR) and the Ministry of State for Environmental Affairs (MSEA) established 24 water-reuse projects (Table 3-1 & Figure 3-2) across the country including one in Luxor where they grow African Mahogany (*Khaya senegalensis*), mulberry (*Morus spp*), and Physic Nut (*Jatropha curcas*). So far, these projects have been exclusively government-driven and private sector participation was noticeably absent.

TABLE 3-1 FOREST LOCATIONS

	Governorate	Forest	Area
1	Ismailia	Sarabium	500 Feddans
2	Menoufia	Sadat	500 Feddans
3	Luxor	Luxor	1700 Feddans
4	Qena	Qena	500 Feddans
5	South Sinai	Tour Sinai	200 Feddans
6	Aswan	Edfu	300 Feddans
7	New Valley	Al-Kharga	400 Feddans
8	New Valley	Paris	200 Feddans
9	South Sinai	Sharm El-Sheikh	60 Feddans
10	Dakahlia	Gamasa	150 Feddans
11	Giza	Al-Saf	500 Feddans
12	Aswan	Blanna	1235 Feddans
13	Aswan	Nasr Alnoba	100 Feddans

14	Bani-Swief	Al-Wasta	500 Feddans
15	New Valley	Moot	700 Feddans
16	North Sinai	Arish	200 Feddans
17	Asyout	Asyout	40 Feddans
18	Sohag	West of Sohag	1000 Feddans
19	Sohag	East of Sohag	1000 Feddans
20	Red Sea	Hurgada	200 Feddans
21	South Sinai	Nouiba	200 Feddans
22	Suez	Atakka	400 Feddans
23	Aswan	Allaky Valley	550 Feddans
24	Alexandria	N9	60 Feddans
	Total	**11195 Feddan**	

FIGURE 3-2 FOREST LOCATIONS IN EGYPT

The best operations have been selected from the above list of reuse projects.

3.3 IDENTIFICATION OF 3 EXEMPLARY BEST PRACTICES IN WASTEWATER REUSE

3.3.1 BP1: WASTEWATER REUSE IN REFORESTATION IN LUXOR, BP2: SARABIUM AFFORESTATION PROJECT IN ISMAILIA GOVERNORATE, BP3 KEMA 1 REUSE PROJECT IN ASWAN GOVERNORATE.

The three best practices selected for Egypt fall under the same topic, consequently the three practices where evaluated together against the set criteria in the TORs.

3.3.1.1 Technical Criteria

Using treated wastewater in agriculture and reforestation in Egypt ,

1. The treated wastewater is up to standard. The used wastewater is compliant to standards as shown in the tables in annex 2
2. Reuse of wastewater is integrated in the national plans for wastewater treatment and reuse as described above and stems from the willingness of the government to increase the reuse of treated wastewater.
3. Although the TORs specify non-pilot practices, it was allowed in the case of Egypt due to the national context explained above in the background section.
4. Is effective in the reuse of treated wastewater. Using treated wastewater in reforestation and agriculture does not require advanced treatment systems for wastewater. Reuse is simple through drip irrigation requiring little operation and maintenance with low human contact. The practice is efficient; it is simple in terms of installation and operation and has very low environmental and has health risks.

3.3.1.2 Impact

1. Has led to an increase in the use of wastewater for irrigation in agriculture and reforestation.
2. Is integrated in the national plans for wastewater treatment and reuse as described above and stems from the willingness of the government to increase the reuse of treated wastewater.
3. Can lead to a cost reduction in the treatment of wastewater since the treatment process does not need to be advanced in the absence human contact and consumption of produce
4. The practice can lead to the prevention of pollution through the treatment of wastewater. It can lead to the greening of deserts, the improvement of biodiversity, carbon sequestration, the production of timber, biofuels (reduction of carbon emissions), silk and other bi-

products. It can generate income and improve livelihoods. It has a potential for private sector involvement through a PPP.

3.3.1.3 Technical Feasibility

1. The developed system for treatment and reuse is simple and reliable. The treatment process is simple, the selected plants used in agriculture and reforestation do not require intensive management and the irrigation system, if installed and operated as recommended, is almost hassle free
2. The need for technical expertise is low
3. The prospects of success of this practice are good due to its low requirements for technical expertise, low environmental and health risks and positive economic and financial feasibility

3.3.1.4 Financial Feasibility

The practice has been proven to be financially and economically feasible in the Egyptian context as detailed in the feasibility analysis undertaken by USAID and included in the references of this best practice.

3.3.1.5 Affordability

Resources can be easily mobilized for this practice. Simple low cost wastewater treatment technology can be used. Operation and maintenance requirements are low; it is mainly the running of the irrigation pumps and maintenance of the network and plantations. There is potential for PPPs since the practice is economically and financially feasible.

3.4 DOCUMENTATION OF BEST PRACTICES

3.4.1 BP1: WASTEWATER REUSE IN REFORESTATION IN LUXOR

3.4.1.1 Summary

Treated wastewater, originating from stabilization ponds, is used for irrigating fields of Mahogany, Jatropha and other trees. The practice has led to increased reuse of wastewater in greening deserts and in producing Jatropha and Mahogany. Exposure to users is low and consequently the need for treatment is not elaborate especially in the removal of coliforms. Soil condition and health and environmental risks were closely, almost scientifically, monitored due to the pilot nature of the project.

Results were negative for soil deterioration, infection and pollution. The practice is safe, easy to implement technically and politically.

3.4.1.2 Narrative

In the 1990's MALR established the first manmade forest in Luxor to be irrigated with the output of WWTPs. The planted tree species included: Khaya (African Mahogany), Casuarina, Pine, Eucalyptus, and Jatropha. Extension of the planted area took place in 1997, 1998, and early in the new decade, as the site expanded from 40 feddan (160,000 m^2) to 1,700 feddan (6.8 million m^2). The irrigation system is modified flood and drip irrigation.

Jatropha plantation in Luxor has proved to be better than its counterpart in other countries for many reasons (Figure 3-3 and Figure 3-4). It has a high rate of growth and productivity. Shrubs produce seeds after 18 months of planting seedlings compared with 3 years in other countries. The average yield of one tree is 3-4 kg after 2 years and the older the tree grows, the more the yield increases until it reaches 12-18 kg per tree. Moreover, Biodiesel oil was produced and extracted from Jatropha seeds and when it was refined in UK laboratories, it proved that it has a high productivity level than its counterpart in other countries. A nursery for producing Mahogany trees seedlings at Luxor Forest produces around one million seedlings per year (Figure 3-5).

FIGURE 3-3 JATROPHA FLOWERING AND FRUITING IN LUXOR FOREST

FIGURE 3-4 JATROPHA AND KHAYA IN LUXOR


A nursery for producing Mahogany trees seedling at Luxor Forest, producing around one million seedlings per year

FIGURE 3-5 NURSERY FOR PRODUCING MAHOGANY SEEDLINGS IN LUXOR

Most parts of the *Jatropha* plant are useful. Oil in seeds constitutes about 35-40% during ripping time with 20% saturated fat and 79% unsaturated fat. Oil is not for human consumption, but it is used to produce Biodiesel as fuel. Whether it is used alone or mixed with diesel oil, it can be used for cars with amendments. It is considered environmentally friendly because it does not produce emissions that pollute the environment; moreover it is used for lighting and other industrial purposes. It is worth mentioning that Biodiesel oil has become very important in the European Union countries and the USA. The EU countries mix it (5-8%) with diesel oil for cars and industrial usages.

Jatropha shrubs have many usages; they are used by farmers as fences to protect from animals. Also they protect soil from wind erosion and help in sand dunes fixation.

This project has been selected because it has been designed, implemented and evaluated in a scientific way. It demonstrates the technical feasibility of using treated wastewater (TWW) in agriculture in a manner that is environmentally safe and sustainable. The methodology, the information and recommendations can be considered an example to be followed elsewhere.

The Project managed a 10 feddan water (40,000 m^2) reuse site in Luxor located near the new wastewater treatment plant. The site received treated wastewater from the nearest maturation pond and produced a number of commercial crops including flax, cut flowers and ornamental plants, Jojoba, Jatropha, and Sorghum. The crops were selected according to the list posted under Grade-B of treated wastewater in the Egyptian Code for Reuse of Treated Wastewater in Agriculture (Annex-1 of this BP).

Two years after the demo site was established an extensive environmental evaluation of using treated wastewater in agriculture for five components of the project has been carried out. This covered the following:

Treated wastewater (physical, chemical and biological parameters);

- Soil;
- Groundwater;

- Crops; and
- Health & Safety.

The Demo project titled “Improved Wastewater Reuse Practices,” is a joint activity between the Ministry of State for Environmental Affairs (MSEA), the Ministry of Water Resources and Irrigation (MWRI), and the United States Agency for International Development (USAID). This project is indeed one that can be replicated.

The Luxor demo site occupies a 10 feddan (40, 000 m^2) area located adjacent to the Luxor wastewater treatment plant (stabilization ponds). Figure 3-6 shows a schematic diagram of the demo site and surrounding cultivated forests. The site proper had never been cultivated prior to the construction of the demo site. A location map is shown in Figure 3-7.

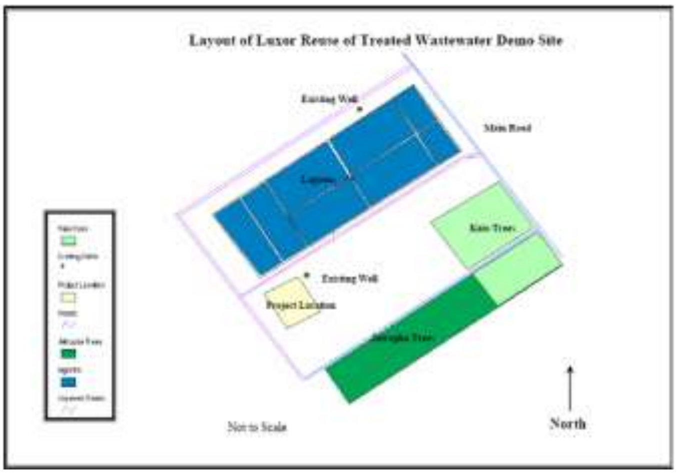

FIGURE 3-6 GENERAL MAP OF THE DEMO SITE AND THE SURROUNDING WELLS

FIGURE 3-7 LOCATION MAP

Water quantity. Continuous flow water meters were installed to measure daily flow discharges from the main and subsidiary irrigation distribution systems. A review of the readings showed that the demo site pumped in a single year 127,000 m3 of treated wastewater from the pond. This is equivalent to 12,700 m^3/feddan/year (3.17 m^3/m^2.year) (assuming a total irrigated area of 10 feddan (40,000 m^2). It has been reported that irrigation efficiency in Luxor can be improved by reducing the total quantities of water pumped (whatever the source). Less water will minimize the risk of groundwater contamination but may require more leaching to offset the impact of accumulated salts.

Water quality. The Luxor demo site was designed to receive wastewater complying with Grade B set by the Egyptian Code. The limit values of which are presented in Table 3-2

TABLE 3-2 LIMIT VALUES FOR THE LUXOR WASTEWATER

Parameter	BOD_5 mgO_2	SS Mg/l	Faecal Coliform MPN/100ml	Nematode eggs/l
Limit value	60	50	5000	1

** For short term use: less than 20 years*

Prior to implementation of the demo project, the Luxor Wastewater Treatment Plant (WWTP) laboratory collected and analysed daily samples from the lagoon effluent over a period of one week (called baseline). The results of the analysis are summarized in Table 3-3. The results indicate that the quality of the treated wastewater was good and complied with the standards.

TABLE 3-3 INITIAL EFFLUENT TEST RESULTS FROM THE LAGOON (BASELINE)

Parameter	Temp.	pH	BOD_5 mgO2/l	COD mgO2/l	DO Mg/l	TDS	TSS	Total Coliform MPN/100ml
Average value	30.2	8.17	25.8	32.8	7.58	466.4	29	3060

Soil monitoring. Before implementing the project, 24 soil samples were collected from eight locations inside the demo site and at three different depths (0-30, 30-60, 60-90). The samples were analysed at the MARL lab in Cairo. Physical tests included particle size distribution and chemical tests included: pH, electrical conductivity, anions and cations, $CaCO_3$, organic matter, and macro and micronutrients. The soil in Luxor prior to the construction of the demo site had the following characteristics:

- Texture: soil is loamy sand to sandy (>90 percent sand)
- Alkalinity: high, pH ranged from 8.05 to 8.45
- Electrical Conductivity: moderate to high (about 5 dS/m)
- Organic matter: very low (expected), OM ranged from 0.03 to 0.53 percent
- Macronutrients: Nitrogen (N) was 60-120 ppm, Phosphorous (P) was 1-5 ppm, and Potassium (K) was 80-170 ppm

Excess irrigation may have contributed to reducing soil fertility as excess water leach sandy soils and thereby displace soil nutrients. While wastewater will bring nutrients to the soil, however, wastewater cannot replenish or restore soil nutrient reserves without adequate soil management practices. As recommended by the Ministry of Agriculture and Land Reclamation: improving soil fertility in reclaimed lands in Egypt requires a battery of soil conditioners including:

- Manure: about 20 m^3 per feddan (followed by deep tilling)
- Sulfur: about 1 tone per feddan (followed by deep tilling)
- Commercial fertilizer (NPK)
- Micronutrients: based on soil conditions and crop requirements

The full tests conducted at the demo site in Luxor in July 2007 showed that:

- Alkalinity had remained high, pH ranged from 8.2 to 8.9
- Total dissolved salts had dropped (from 0.03% to 0.2%)
- Nitrogen had dropped to 20-40 ppm
- Phosphorous & Potassium had increased slightly to 6-9 ppm and 140-242 ppm, respectively

Groundwater. Before implementation of the project, groundwater samples collected from a 20-meter deep (production) well, located 1 km west of the demo site, and near the forested area indicated no faecal contamination. After two years, Coliforms were present in some of the samples taken at the on-site well. The count ranged from absent to 800 CFU/ml.

Crops. Five demonstration crops from Grade B & C of the Egyptian Water Reuse Code were selected for the demo site: flowers and ornamentals, flax, Jojoba, sorghum, and Jatropha. Crop selection was based on a number of factors:

- Water quality of the treated wastewater
- Climate and soil conditions
- EEAA and MALR interests
- Marketing and economic considerations
- Layout of the crop pattern is shown in Figure 3-8.

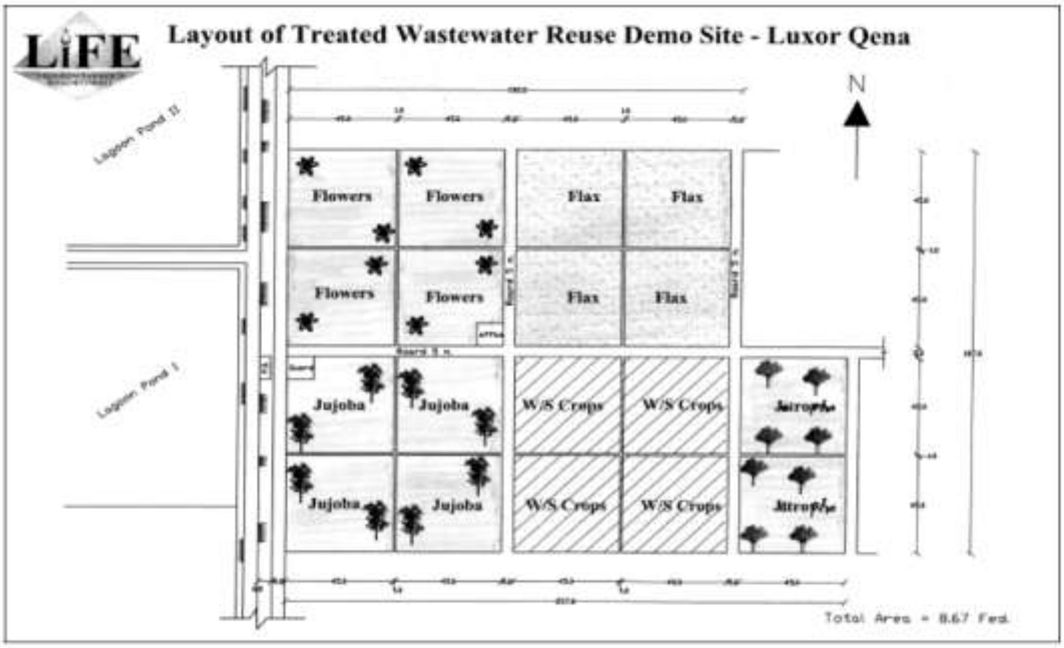

FIGURE 3-8 CROP PATTERN LAYOUT

Crop samples were collected from all the plots except Jatropha. These trees need at least 3-5 years to produce its first mature fruits. Summary of crop tests are presented in Table 3-4.

TABLE 3-4 SUMMARY OF CROP TESTS

Date	Lab	Sample	Parameters
27-Jun-06	CLFF	Flax seeds	Total and fecal Coliform
10-Jul-06	CLFF	Flax seeds	Total bacterial count, total Enterococcus, total fungal count, Norwolk Brius
13-Jun-06	Luxor WWTP	Flax seeds, foliage, stalk and roots	Total Coliform
13-Jun-06	Luxor WWTP	Sorghum foliage, stem and roots	Total Coliform
19-Aug-06	Luxor WWTP	Cow milk*	Total Coliform
30-Aug-06	CLFF	Roses, durenta, sorghum, Flax dried seeds	Total Bacterial count, Coliform count, Enterococcus count and total fungal count
27-May-07	Luxor WWTP	Flax: whole seeds, stem, roots, and crushed seeds	Total Coliform
14-Jun-07	Luxor WWTP	Sorghum: roots, stem and foliage	Total Coliform

The test results showed that:

1. Ornamental plants (roses and Durante), dried and crushed flax seeds, and cow milk showed no microbiological contamination. This result was expected as the harvested parts of the plant, buds and stems, do not come in direct contact with irrigation water.

2. Sorghum stem and roots showed low levels of total coliform (700 and 4,000 CFU, respectively). This result can be expected considering that the sorghum is flood irrigated (furrows) and the green stems drop to the soil at harvest.
3. Flax seeds showed potentially dangerous fungi including Emericella nidulans (producing Strigmatocystin) and Fusarium verticilloides (producing Fumonesins). The source of the fungi could not be determined and cannot be attributed to TWW without further investigations.

Health and Safety. The Project hired graduates to run the demo site (5 graduates the first year and 7 new graduates during the second year). The rationale behind this was to provide on-the-job training for farmers and agricultural students so as to increase the pool of individuals with practical skills in wastewater reuse. In this way, it would be possible to transfer the demo site to the Ministry of Agriculture and Land Reclamation at the end of the Project.

About one month after starting to work in the demo site, all the five graduates of the first group were sent for a medical check-up. The results indicated that the five graduates tested positive for Hepatitis A, but negative on all other tests. Hepatitis A is both food and water born and therefore quite common in Egypt -the graduates may have contracted the virus *before* starting work on site.

After two years, seven new graduates were recruited to replace the first group of graduates working at the demo site, and two from the first group remained thus bringing the total number of students to nine. The new graduates also had a complete medical check-up and they received a formal training course on “Treated Wastewater Reuse Practices”.

A second medical check-up of the graduates was conducted (by that time, there were only four graduates). Tests were done for Typhoid and para-Typhoid, as well as Hepatitis A (HAV-IgG) and B (HAV-IgM). All four graduates tested negative for parasites (Ancylostoma, Ascaris and Amoeba), infectious diseases

Risk reduction measures implemented at the demo site are presented in Table 3-5.

TABLE 3-5 RISK REDUCTION MEASURES FOR FARM WORKERS, CROP HANDLERS AND GRADUATES

Measures	Implementation in Luxor
Training	Organize targeted training program to sensitize farm workers on water reuse hazards and best protection measures
Information signs	Install information/warning signs at suitable locations to caution farm workers and remind them of safety measures
Vaccination	Vaccinate farm workers according to MOHP requirements for sanitation workers involved in treatment plants and networks
Protective boots &	Provide workers with adequate boots and gloves, as well as first

gloves	aid kit and a dedicated wash room
Medical Checkup	Conduct regular medical check-up and lab tests to detect potential infectious diseases related to water reuse (every 6 months)
Stop irrigation	Pursuant to the Code, irrigation must stop two weeks prior to harvest to minimize contaminant exposure by crop harvesters

Source Adapted from Egypt's Water Reuse Code (ministerial decree No. 171/2005

The major conclusions derived from the demo site in Luxor are as follows:

- Two years of continued irrigation using TWW showed no adverse impacts on soil, plant, groundwater and health. Because the project time frame was short, longer-term monitoring would be required to confirm the results.
- Reuse of treated wastewater (Grade B) in agriculture is safe provided precautions are taken and followed through.
- Reuse of treated wastewater in the Luxor demo site did not show any adverse impacts on plant or health during the project period (2 years); and impact on soil and groundwater could not be detected within the project's short timeframe and therefore would require longer-term monitoring. However, during this short time, no adverse impact on soil or groundwater was detected.

Several recommendations were formulated based on the Luxor demo site.

Use advanced irrigation techniques (minimize flood irrigation). While surface (furrow) irrigation is allowed under the Egyptian Water Reuse Code, it is preferable to use drip irrigation to minimize deep percolation and prevent groundwater contamination (as well as leaching of nutrients) especially in sandy soils.

Improve soil fertility when reclaiming new soils. Sandy soils are very nutrient poor and do not hold moisture or nutrients well. If treated wastewater is used on new soils, it is recommended to improve soil fertility by applying soil conditioners (manure) and/or chemical fertilizer such as N,P,K and sulfur. The soil should also be leached to remove salts and deep tilled to loosen soil particles.

Adopt risk reduction measures for farm workers and crop handlers. It is imperative and a legal requirement to train workers and crop handlers on health and safety measures related to water reuse. Other risk reduction measures include information/warning signs and the use of protective clothing (gloves, overalls and boots).

Implement basic self-monitoring tests and report results to MALR and EEAA. Reuse of treated wastewater in agriculture should be carefully monitored. The Egyptian Code for the Reuse of Treated Wastewater in Agriculture stipulates two levels of monitoring: self-monitoring (to be conducted by the farm/project) and inspection (to be conducted by a regulatory body such as MALR and/or EEAA). It is equally important to disclose the test results.

3.4.2 BP2: SARABIUM AFFORESTATION PROJECT IN ISMAILIA GOVERNORATE

3.4.2.1 Summary

The Sarabium project is a mixed afforestation and economic crops production project. The wastewater treatment system, an algal pond, is a natural system. The project demonstrates the economic feasibility of greening the desert with production of economically viable crops irrigated with treated wastewater from a natural treatment system. This is a sustainable project at the present time.

3.4.2.2 Narrative

The afforestation project is located in the Ismailia Governorate; it started in 1998. The cropped area is 950 feddans (3,800,000 m^2) of sandy soil. The crop intensity ratio is 1.58. The irrigation method is drip irrigation and surface flooding in furrows. The cultivated crops are Flax, Kenaf, Jojoba, Cypressus, Jute, Pea Nuts, Khaya, Morus, Concarpus, Eucalyptus, Papyrus, Sisalana, Jatropha. (Figure-9). The economically feasible crops are Flax (350 fd) (1,400,000 m^2), Kenaf (350 fd) (1,400,000 m^2), Jojoba (100 fd) (400,000 m2), and Jatropha (150 fd)(600,000 m^2).

The wastewater treatment plant is an Algal pond. The effluent of which is treated using sand filtration to get rid of the Algae that causes problems with drip irrigation. That is why the irrigation system was changed from drip to flooding in furrows. The wastewater capacity of the treatment plant is 32.85 million cubic meters annually and water requirement is 4.06 million cubic meters per year, i.e. 12.35% of total annual capacity. The quality of wastewater produced is presented in Annex-2.

FIGURE 3-9 SILKWORMS ON MULBERRY LEAVES

The estimated construction cost is EGP[3] 15,120,000 (1,663,200 euro); its maintenance cost is EGP 302,400 (33,264 euro) annually; and annual rent is EGP 30,000 (3,300 euro). Detailed results of the study are presented in Table 3-6 to Table 3-8. The study indicated that the project generates 11.47% financial internal rate of return and 13.55% economic rate of return. According to the available information this project is feasible financially and economically.

TABLE 3-6 REQUIRED FARM MACHINES AND EQUIPMENT

Machine/ Equipment	Unit Price (EGP)	# required	O&M costs (5%) (EGP/year)	Life time years	total value EGP
Tractor 90 hp	105,000	6	31,500	10	630,000
trailer 4-ton	30,000	3	4,500	10	90,000
Front loader mounted on a tractor	20,000	3	3,000	15	60,000
Shredder machine for cutting tree branches	30,000	2	3,000	5	60,000
Electric Saw	3,000	6	900	3	18,000
Ladder	1,000	12	600	3	12,000
Drip irrigation units (a unit = EGP 5,000 per feddan)	5,000	600	150,000	5	3,000,000
Rotary tiller	10,000	3	1,500	7	30,000
Total			195,000		3,900,000

Note: These requirements are based on: one 90hp tractor for 100 feddans; a trailer 4-ton for 200 feddans; a front loader mounted on a tractor for 200 feddans; a Shredder machine for cutting tree branches for 300 feddans; an electric Saw for 100 feddans; one ladder for 50 feddans; and a rotary tiller for 100 feddans. A drip irrigation units per feddan costs EGP 5,000. It is important to mention that also the crop mix for each project affects the required machines and equipment.

[3] 1 Egyptian Pound = 0.11 euros on March 1st 2013

TABLE 3-7 RECOMMENDED CROPS AND THEIR WATER REQUIREMENTS

Seasonal Crop	duration	water requirements	water consumption	Recommended Area (Feddan)	Water needs (Cubic meter)
	month	cubic meter	cubic meter		
Soybean (May - Aug)	3.5	2,229	2,006	0	0
Flax (Nov-Apr) -Surface irrigation	5	2,345	1,407	350	820,750
Canola (Oct - Jan)	3	1,800		0	0
Sunflower (Mar-May)	3	3,063	1,838	0	0
Sunflower (Jun-Aug)	3	3,063	1,838	0	0
Sunflower (Jul-Sep)	3	3,063	1,838	0	0
Kenaf (Mar/Apr-Sep/Oct)	6	4,032	3,629	350	1,411,200
Jute (Mar/Ap-Jun/Jul)	3	4,032	3,629	0	0
Flower (Feb-Jan)	12	1,465	1,319	0	0
Total Farm area (for seasonal crops)				350	
Total cropped Area				700	2,231,950

TABLE 3-8 RECOMMENDED CROPS AND THEIR WATER REQUIREMENTS

Permanent Crop	duration	water requirements	water consumption	Recommended Area (Feddan)	Water needs (Cubic meter)
	year	cubic meter	cubic meter		
Jojoba (harvest third year)	10	7,300		100	730,000
Jatropha (harvest second year)	20	7,300		150	1,095,000
Casuarinas (harvest every 3 yrs)	15	2,797	2,517		0
Sisalana (harvest third year)	20	10,950			0
Total Permanent Crops				250	1,825,000
Grand Total of Farm area (seasonal & permanent)				600	0
Grand Total of cropped area (seasonal & permanent)				950	4,056,950
Capacity of treated wastewater					32,850,000
WW utilization					12.35%
Total farm area (fd)					600
Crop Intensity					1.58

3.4.3 BP3: KEMA 1 REUSE PROJECT IN THE ASWAN GOVERNORATE

3.4.3.1 Summary

The KEMA-1 reuse project has introduced drip irrigation that increases irrigation efficiency and reduces contact between treated wastewater and farmers. It also reduces coliforms by 4 log-units, which consequently reduces the need for disinfection at the wastewater treatment plant. The castor plant, used in this location, has multiple benefits.

3.4.3.2 Narrative

The allocated area for forest plantation is 1,118 feddans (4,472,000 m^2) of sandy soil. The irrigation method is drip irrigation. The cultivated crops are Khaya, Ornamental Plants, Eucalyptus, Casuarinas, Jujuba. Castor plants are dominating in the present cultivated consigned land for Aswan Co for Water and Wastewater. The objective is to benefit from the Castor's quadruplicate profits: (i) from seeds that produce biodiesel; (ii) from leaves that feed the Eri silkworms, (iii) from compost derived from crop residues, and (iv) from the plant's trunk, which supplies the Kom Ombo Board Factory with material to complement bagasse. Castor can be planted in poor sandy soils provided it gets sufficient quantities of organic and chemical fertilization.

Castor is a summer crop that is planted in March. The castor plant, at different stages of growth, is shown in Figure 3-10 Jojoba seedlings are presented in Figure 3-11.

FIGURE 3-10 CASTOR PLANT AT DIFFERENT STAGES OF GROWTH

FIGURE 3-11 JOJOBA SEEDLINGS

At the Aswan projects like other projects elsewhere, distribution lines for the drip irrigation networks are not buried but left in the open. These pipes should be buried to protect them from the climate and physical damage (Figure 3-12).

FIGURE 3-12 DAMAGE TO THE IRRIGATION NETWORK

An economic study indicated that the construction cost of this project is EGP 28,173,600; its maintenance cost is EGP 563,472 annually; and annual rent is EGP 55,900. The project generates 10.80% financial internal rate of return and 10.08% of economic rate of return. According to the available information this project is feasible financially at marginal level, but it needs deeper investigation to collect more data and information for detailed analysis.

TABLE 3-9 REQUIRED FARM MACHINES AND EQUIPMENTS; KEMA 1 PROJECT

Machine/ Equipment	Unit Price	# required	O&M costs (5%)	Life time	total value
	(EGP)		(EGP/year)	years	EGP
Tractor 90 hp	105,000	11	57,750	10	1,155,000
trailer 4-ton	30,000	5	7,500	10	150,000
Front loader mounted on a tractor	20,000	5	5,000	15	100,000
Shredder machine for cutting tree branches	30,000	3	4,500	5	90,000
Electric Saw	3,000	11	1,650	3	33,000
Ladder	1,000	22	1,100	3	22,000
Drip irrigation units (a unit = EGP 5,000 per feddan)	5,000	1,118	279,500	5	5,590,000
Rotary tiller	10,000	5	2,500	7	50,000
Total			359,500		7,190,000

Note: These requirements are based on: one 90hp tractor for 100 feddans; a trailer 4-ton for 200 feddans; a front loader mounted on a tractor for 200 feddans; a Shredder machine for cutting tree branches for 300 feddans; an electric Saw for 100 feddans; one ladder for 50 feddans; and a rotary tiller for 100 feddans. A drip irrigation units per feddan costs EGP 5,000. It is important to mention that also the crop mix for each project affects the required machines and equipments.

TABLE 3-10 RECOMMENDED CROPS AND THEIR WATER REQUIREMENTS

Seasonal Crop	duration	water requirements	water consumption	Recommended Area (Feddan)	Water needs (Cubic meter)
	month	cubic meter	cubic meter		
Soybean (May - Aug)	3.5	2,229	2,006		0
Flax (Nov-Apr) -Surface irrigation	5	2,345	1,407		0
Canola (Oct - Jan)	3	1,800			0
Sunflower (Mar-May)	3	3,063	1,838		0
Sunflower (Jun-Aug)	3	3,063	1,838		0
Sunflower (Jul-Sep)	3	3,063	1,838		0
Kenaf (Mar/Apr-Sep/Oct)	6	4,032	3,629		0
Jute (Mar/Ap-Jun/Jul)	3	4,032	3,629		0
Flower (Feb-Jan)	12	1,465	1,319		0
Total Farm area (for seasonal crops)					0
Total cropped Area					0

3.5 CONCLUSIONS AND RECOMMENDATIONS

3.5.1 CONCLUSIONS

In conclusion, the following benefits can be seen from the reuse of wastewater in irrigating forests, trees and shrubs some of are productive such as Jatropha and Castor:

- Cultivating forests and improving environmental conditions with respect to climate and increased biodiversity.
- Reclaiming desert areas, and establishing new communities adjacent to these forests.
- Creating wood industries and adding new income sources of secondary production such as breeding silkworms, silk and Agava sisalana industries, and biodiesel oil and ornamental plants production.
- Participating in solving unemployment problems by providing new job opportunities.
- Safe disposal of wastewater, thus protecting water resources and soil from pollution.
- Satisfying part of the wood demand from locally produced wood instead of imported wood, thus improving the balance of payment.
- Protecting desert areas and new cities from winds, sand dispersions and sandy storms with their associated health and environment adverse impacts.
- Using these forests as domestic tourist sites and as entertainment places for the residents in the new cities.
- Improving air quality and decreasing pollution.
- Transforming treated wastewater to an economic good with added value to national production, resulting in increased national income.
- Return percentage per pound (cost and value) = LE 1.34. Domestic return rate = 15.6%

- Using treated wastewater for irrigation of afforestation projects is simple technically and politically. It can also be financially and economically feasible with multiple benefits if the right crops and tree varieties are selected.
- Simple treatment technologies such as lagoons can deliver adequate quality water for reuse in agriculture especially if drip irrigation is used.
- Soil conditioning might be required in order to improve plant growth.

3.5.2 RECOMMENDATIONS

- Invest in afforestation and productive crops such as Jatropha and Castor using treated wastewater for irrigation as a safe and viable option where restriction on the use of effluent and aversions to treated sewage exists. Local conditions for economic and financial feasibility need to be checked.
- Use sub-irrigation with buried drippers as the recommended irrigation technique for increased water use efficiency and long-term use of the pipe network.
- Use simple, natural, low cost treatment technologies to treat the wastewater and deliver irrigation water that is up to standard.

3.6 REFERENCES

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3.7 ANNEX-1 EGYPTIAN CODE FOR USE OF TREATED WASTEWATER IN AGRICULTURE CHAPTER (5)

Plants and Crops Prohibited from Being Irrigated with treated municipal wastewater & those for which

Irrigation with Such Water is Permissible

This present Code specifies the following use of treated municipal wastewater:

- Whatever was the level of treatment, the use of treated wastewater is prohibited in the production of vegetables whether eaten raw or cooked.
- Whatever was the level of treatment, the use of treated wastewater is prohibited in the irrigation of all fruit trees, the fruits of which are eaten raw such as grapes, guava etc.
- In all circumstances, the use of treated wastewater is prohibited in the irrigation of export-oriented crops such as cotton, rice, onion, potato, medicinal and aromatic plants and Citrus. The list may include other strategic crops to be specified in the administrative decrees, to undermine marketing counter-propaganda.
- The use of treated wastewater is prohibited in irrigating children and school gardens.

Classification of plants and crops irrigable with treated wastewater:

According to this present Code, plants and crops irrigable with treated wastewater are divided into three agricultural crop groups, divided in turn into eleven sub-groups. This classification is based on the review of domestic circumstances to be compatible with the reuse of the treated wastewater at their three levels of treatment. The following Table illustrates the aforementioned classification.

Approved Crop List Irrigated with Treated Wastewater

Grade	Agricultural Group	Recommendations
B	G2-1: Fodder/Feed Crops	Sorghum sp
	G2-2: Trees producing fruits with epicarp	On condition that they are produced for processing purposes, such as lemons, mangoes, date palms and almonds
	G2-3: Trees used for green belts around cities and afforestation of highways or roads	Casuarina, camphor, Athel tamarix (salt tree), oleander, fruit-producing trees, date palms, and olive trees
	G2-4: Nursery plants	Nursery plants of wood trees, ornamental plants, and fruit trees
	G2-5: Roses and cut flowers	Local roses, eagle roses, onions (e.g. gladiolus)
	G2-6: Fiber crops	Flax, jute, hibiscus, sisal
	G2-7: Mulberry for the production of silk	Japanese mulberry
C	G3-1: Industrial oil crops	Jojoba and Jatropha
	G3-2: Wood trees	Khaya, camphor, and other wood trees

Source: Egyptian Water Reuse Code (Table 5-1, Page 20)

3.8 ANNEX 2 QUALITY OF TREATED WASTEWATER

LUXOR GOVERNORATE

Characteristics of the treated WW used for irrigation

July 2010

Parameters	Unit	El-hebeil	Rawageh	New Teba	Ministerial Decree 44//2000 for treated WW use for Agriculture
pH		7.4	6,1	7,5	--
COD	mgO_2/l	160	60	220	80
BOD	mgO_2/l	70	24	90	40
TSS	mg/l	60	18	88	40
TDS	mg/l	420	300	400	2000
Oil&grease	mg/l	10	6	16	10
Chlorides	mg/l	85	75	60	300
Nematoda eggs	Count/l	N.D	N.D	N.D	1
Faecal coliform	MPN/100 ml	$2,1\times10^2$	70	$1,5\times10^2$	1000
Sod. Absorption Ratio	%	5,8	3,9	4,7	20
Cd	mg/l	<0.01	<0.01	<0.01	0,01
Pb	mg/l	<0.01	<0.01	<0.01	5
Ni	mg/l	<0.01	<0.01	<0.01	0,2
Mn	mg/l	<0.1	<0.01	<0.01	0,2
Fe	mg/l	0,3	N.D	0,2	5
Cu	mg/l	<0.01	<0.01	<0.01	0,2
Zn	mg/l	<0.05	<0.05	<0.05	2

April 2011

Parameters	Unit	Elhebeil (1)	Elhebeil (2)	Rawageh	Teba	Ministerial Decree 44/2000
COD	mgO_2/l	220	190	320	138	80
BOD	mgO_2/l	120	96	140	56	40
TSS	mg/l	96	76	150	52	40
TDS	mg/l	480	430	720	300	2000
Oil&grease	mg/l	20	16	31	14	10
Chlorides	mg/l	65	65	115	50	300
Nematoda eggs	Count/l	-	-	-	-	1
Faecal coliform	MPN/100 ml	6×10^2	$1,6 \times 10^3$	8×10^2	6×10^2	1000
Sod. Absorption Ratio	%	5,5	6,5	7,3	3,9	20
Cd	mg/l	<0.01	<0.01	<0.01	<0.01	0,01
Pb	mg/l	<0.01	<0.01	<0.01	<0.01	5
Ni	mg/l	<0.01	<0.01	<0.01	<0.01	0,2

ISMAILIA GOVERNORATE

Sept. 2010

		El takadom	El kantara Sharq WWTP	Fayed	Ministerial Decree 44/2000
pH	-	8	7	7	-
COD	mgO_2/l	114	130	40	80
BOD	mgO_2/l	46	40	12	40
TSS	mg/l	80	40	15	40
TDS	mg/l	12500	900	2350	2000
Chloride	mg/l	11000	200	350	300
Oil & Grease	mg/l	18	10	7	10
Nematodes eggs	Count/l	N.D	N.D	N.D	1
Fecal coliform	MPN/100 ml	30	$2,1 \times 10^{2}$	N.D	1×10^{3}
SAR	(%)	83	8,8	17	20
Pb	mg/l	< 0,01	< 0,001	< 0,001	5
Cd	mg/l	< 0,001	<0,003	< 0,003	0,01
Cu	mg/l	< 0,01	< 0,01	< 0,01	0,2
Ni	mg/l	< 0,01	< 0,01	< 0,01	0,2
Fe	mg/l	4	2,5	1,5	5
Mn	mg/l	0,18	0,13	0,16	0,2
Zn	mg/l	0,05	0,05	0,05	2

Parameters	Unit	El tall el kbeer WWTP	Sarabyoum WWTP	Abou-Khalifa WWTP	AlKantara Garb WWTP	Ministrial Decree 402/ 2009
pH	-	7,5	8,2	7,3	7,4	6 - 9
COD	mgO_2/l	33	72	35	30	80
BOD	mgO_2/l	14,4	26	16,5	13	60
TSS	mg/l	15	48	15	12	50
Chloride	mg/l	N.D	N.D	N.D	N.D	1
Oil & grease	mg/l	4	9	5	5	10
TP	mg/l	0,2	0,3	0,3	0,48	2
Phenol	mg/l	N.D	N.D	N.D	N.D	N.D
TKN	mg/l	2,8	10	2,8	2,8	10
Pb	mg/l	< 0,001	< 0,001	< 0,001	< 0,001	0,001
Cd	mg/l	< 0,003	< 0,003	< 0,003	< 0,003	0,01
Cr	mg/l	< 0,01	< 0,01	< 0,01	< 0,01	0,01
Zn	mg/l	< 0,01	< 0,01	< 0,01	< 0,01	1
Ni	mg/l	< 0,01	< 0,01	< 0,01	< 0,01	0,02
Zn	mg/l	0,05	0,05	< 0,01	0,05	1
Cn	mg/l	N.D	N.D	N.D	N.D	N.D
Fecal coliform	MPN/100 ml	$4,8 \times 10^3$	$2,3 \times 10^2$	90	N.D	5×10^2

April 2009

Parameters	ElAtwany oxidation pond) Secondary treatment-(Agriculture	El-Bosili oxidation pond) Secondary treatment-(Agriculture	Kalh ElGabal oxidation pond) Secondary treatment-(Agriculture	AlMalki oxidation pond) Secondary treatment-(Agriculture	Balana oxidation pond) Secondary treatment-(Agriculture	Kema 1 Activated Sludge - Secondary treatment-Agriculture	Kema 2)Activated Sludge - Secondary treatment-Agriculture	Ministerial Decree 44/2000
Do								
COD	Complying	164	165	Complying	93	157	108	600
BOD	Complying	57	45	Complying	45	48		300
Tss	Complying	86	62	Complying	Complying	83	43	350
TDS	Complying	Complying	Complying	Complying	Complying	Complying	Complying	2500
Oil&grease	Complying	12	10.5	Complying	Complying	Complying	11	undefined
Chlorides	Complying	Complying	Complying	Complying	Complying	Complying	Complying	350
Nematods eggs	Complying	Complying	Complying	Complying	Complying	Complying	Complying	5
Fecalcoliform	Complying	Complying	Complying	Complying	Complying	Complying	Complying	undefined
SAR	Complying	Complying	Complying	Complying	Complying	Complying	Complying	25
H2S	Complying	Complying	Complying	Complying	Complying	Complying	Complying	—
Cd	Comply	Comply	Comply	Comply	Comply	Compl	Compl	0.05

	ing	ing	ing	ing	ing	ying	ying	
Pb	Complying	Complying	Complying	Complying	Complying	Complying	Complying	10
Ni	Complying	Complying	Complying	Complying	Complying	Complying	Complying	0.5
Mn	Complying	Complying	Complying	Complying	Complying	Complying	Complying	0.2
Fe	Complying	Complying	Complying	Complying	Complying	Complying	Complying	undefined
Zn	Complying	Complying	Complying	Complying	Complying	Complying	Complying	undefined

May 2010

Parameters	ElAtwany oxidation pond) Secondary treatment-(Agriculture	Elbosiliaoxidation pond) Secondary treatment-(Agriculture	Kalah El-Gabl oxidation pond) Secondary treatment-(Agriculture	Elhagr - Adfo oxidation pond) Secondary treatment-(Agriculture	AlMalky oxidation pond) Secondary treatment-(Agriculture	Balana oxidation pond) Secondary treatment-(Agriculture	Kema 1 Activated Sludge - Secondary treatment - Agriculture	Kema 2 Activated Sludge-Secondary treatment-Agriculture	—	سلوة (بركاكسدة - معالجة ثانوية) - الزراعة	Ministerial Decree 44/2000
COD	260	264	170	185	102	141	55	204	—	357	80
BOd	120	100	69	42	32	66	30	75	18	50	40
TSS	124	130	98	106	32	96	40	118	14	182	40

TDS	486	1128	890	409	531	472	395	460	515	935	2000
Oil&grease	35	13	64	58	18,1	20	6	45,3	N.D	54.6	10
Chlorides	70	350	250	60	70	90	50	125	90	220	300
Nematods eggs	1	N.D	N.D	N.D	N.D	N.D	N.D	1	N.D	NpD	1
Faecal coliform	2.1×10^4	2.1×10^5	4.3×10^3	2.4×10^4	N.D	N.D	N.D	2.1×10^4	1×10^3	N.D	1000
SAR	4,2	15	18,3	4,6	9,3	8	3,7	5,6	6	6.4	20
Cd	< 0,01	< 0,01	< 0,01	< 0,01	< 0,001	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	0,01
Pb	< 0,01	< 0,01	< 0,01	< 0,01	< 0,001	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	5
Ni	< 0,005	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	0,2
Mn	0,13	0.15	0.16	< 0,05	< 0,001	< 0,01	< 0,01	< 0,05	< 0,05	< 0,05	0,2
Fe	1,5	1,3	0,3	0,01	0,82	0,33	لايوجد	لايوجد	لايوجد	لايوجد	5
Cr	< 0,01	< 0,01	< 0,01	< 0,01	< 0,001	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	0,2
Zn	0,01 >	0,01 >	> 0,01	> 0,01	> 0,001	0,01 >	> 0,01	> 0,01	> 0,01	< 0,01	2

Sept. 2011

Parameter	ElAtwany oxidation pond) Secondary treatment-(Agriculture	Elbosilia oxidation pond) Secondary treatment-(Agriculture	Kalah El-Gabl oxidation pond) Secondary treatment-(Agriculture	Elhagr-Adfo oxidation pond) Secondary treatment-(Agriculture	Slwa oxidation pond) Secondary treatment-(Agriculture	AlMalky oxidation pond) Secondary treatment-(Agriculture	Balana oxidation pond) Secondary treatment-(Agriculture	Sahary oxidation pond) Secondary treatment-(Agriculture	Industrial area Aeration tanks Secondary treatment - Agriculture
COD	96	110	110	90	110	75	80	60	127
BOD	190	270	210	175	210	135	150	125	295
TSS	68	135	76	70	108	50	65	45	136
Oil&Grease	18	26	20	15	20	14	15	10	26
TDS	485	1250	800	375	340	490	475	310	900
Chlorides	75	350	200	50	150	125	75	50	280
Cd	> 0,01	>0,01	> 0,01	> 0,01	> 0,01	> 0,01	> 0,01	> 0,01	> 0,01
Pb	> 0,01	>0,01	> 0,01	> 0,01	> 0,01	> 0,01	> 0,01	> 0,01	0,5
Ni	> 0,05	>0,05	> 0,05	> 0,05	> 0,05	> 0,05	> 0,05	> 0,05	> 0,05
Cr	> 0,01	>0,01	> 0,01	> 0,01	> 0,01	> 0,01	> 0,01	> 0,01	0,7
Zn	> 0,01	>0,01	> 0,01	> 0,01	> 0,01	> 0,01	> 0,01	> 0,01	> 0,01
Mn	0,09	0,09	0,1	0,04	0,09	0,05	0,03	0,03	0,05
Fe	0,8	1,1	-	0,6	0,8	0,4	1,2	0,6	5,7

Nematodseggs	6,5	25	16	5	8	7,7	7,2	3,5	19
Fecalcoliform	700	1400	2100	300	1200	600	180	200	6000
SAR	1	1	1	-	1	-	-	-	-

Sept. 2011

Parameters	Kema1 Activated Sludge-Secondary treatment-Agriculture	Kema 2 Activated Sludge-Secondary treatment-Agriculture	AlAlaky Activated Sludge-Secondary treatment-Agriculture	Ministerial Decree 44/2000
COD	110	120	12	80
BOD	220	290	30	40
TSS	68	80	8	40
Oil&grease	22	30	4	10
TDS	350	390	900	2000
Chloride	65	75	220	300
Cd	> 0,01	>0,01	> 0,01	0,01
Pb	> 0,01	>0,01	> 0,01	5
Ni	> 0,05	>0,05	>	0,2
Cr	> 0,01	>0,01	> 0,01	0,2
Zn	> 0,01	>0,01	> 0,01	2
Mn	0,03	0,03	>0,01	0,2
Fe	1,8	0,7	0,9	5
SAR	5	5,7	10,5	20
Fecalcoiform	1800	1200	1100	1000
Nematodseggs	1	-	-	1

Parameters	AlWasta Sand Filters-Secondary Treatment	Dandel Oxidation pond-Secondary treatment	New Bani Souif Activated Sludge Secondary treatment	Alallma Oxidation pond-Secondary treatment	Ministerial decree 44/2000
pH	7.1	8.9	6.9	7.3	6 - 9
COD	126	200	185	800	80
BOD	50	100	75	390	40
TSS	21	62	51	110	40
TDS	344	2595	3330	2500	2000
Oil&grease	10	23	16.5	56	10
chloride	160	1200	1700	1000	300
Fecal coliform	$1.1\times{}^{3}10$	$1.5\times{}^{3}10$	$2.1\times{}^{2}10$	$2.1\times{}^{2}10$	1000
SAR	7.3	31.7	31.6	22.6	20
Nematodes eggs	Complying	Complying	Complying	Complying	1
Cd	Complying	Complying	Complying	Complying	0.01
Pb	Complying	Complying	Complying	Complying	5
Ni	Complying	Complying	Complying	Complying	0.2
Mn	Complying	Complying	Complying	Complying	0.2
Fe	Complying	Complying	Complying	Complying	5
Cu	Complying	Complying	Complying	Complying	0.2
Zn	Complying	Complying	Complying	Complying	2

4 BEST PRACTICES IN WASTEWATER REUSE IN ISRAEL (BY DHV)

4.1 INTRODUCTION AND OVERVIEW OF WASTEWATER REUSE

The lack of rain has only worsened in recent years, as Israel has experienced its worst water shortage on record. Seven consecutive years of drought, coupled with increased demand from a growing population, have led to the overexploitation of the country's water supply. In fact, water shortage has long been a serious problem for much of the region. As a result, the people of Israel have long sought innovative ways to use every available drop of water, and one of the most advanced ways is reuse of treated wastewater for irrigation instead of fresh water.

Wastewater treatment in centralized wastewater treatment plants (WWTPs) rates today about 92-95%. The reuse of this water is mainly for irrigation through seasonal reservoirs systems and aquifer recharge. All effluent re-use practices in Israel are either for irrigation (mostly, more than 80%), industry (2-3%) and nature preservation in terms of discharging effluent for receiving natural streams.

The common technology method for wastewater treatment in Israel is the Conventional Activated Sludge (CAS) process with its several derivatives. Although the Israeli market is very innovative and encourages new technologies, most investors in this sector, in the form of municipal water corporations or private entrepreneurs prefer more conservative treatment methods as shown in appendix Table 4-4).

This approach has changed in the recent years as more advanced treatments methods (SBR, MBR etc.) are applied in WWTP upgrading processes (a direct consequence of population growth and legislation concerning higher effluent standards).

The new legislation of 2010 for public health concerning effluent standards ("Inbar committee" effluent regulations) forced all WWTP to stringiest effluent quality standards. These advanced regulations push the wastewater treatment sector into the next level in the aspect of using advanced and progressive technologies of wastewater treatment for water reuse (membrane and sand filtration, disinfection and nutrient removal). Using advanced and more developed treatment methods also requires better maintenance and monitoring during the whole treatment process. This may lead to a better function of the WWTP and improved effluent quality and reliability.

4.2 IDENTIFICATION OF BEST PRACTICES

4.2.1 METHODOLOGY

The methodology for selection of best practices in Israel was based on a review of an inventory of existing treatment and technologies and the selection of those most relevant for the SWIM PCs with a priority for rural areas and upgrading of existing wastewater treatment plants.

4.2.2 INVENTORY

In Israel there are few practices that are implemented on municipal scale to treated wastewater reuse:

- **CAS (Conventional Activated Sludge system)-** most of the facilities in Israel use this technology. A CAS system is a series of biological treatment steps that degrade the biological materials from the wastewater.
- **SBR (Sequencing Batch Reactors) -** are processing tanks for the treatment of wastewater in batches. The process biology is similar to CAS but the plant is based on batch reactors instead of continuous flow through several tanks as in CAS.
- **MBR (Membrane Bio Reactor) -** is a biological process that is based on biodegradation in aeration basins, similar to CAS process but with membrane separation instead of clarifiers. This process combines a membrane separation process like microfiltration or ultrafiltration with a suspended growth bioreactor that allows concentration of the biomass in the reactor 3-5 times more than in the CAS process. The membrane separation brings the effluent quality to higher level than tertiary treatment of other filtration systems.
- **Aerated lagoon**- is a holding and/or treatment pond provided with artificial aeration to promote the biological oxidation of wastewaters. The process is extensive and needs much larger volumes and surfaces compared to more modern processes (several retention days versus 10-20 hours). The effluent quality is limited in terms of nutrient removal and most plants cannot produce the required effluent quality according to the new standards.
- **Polishing-** For the removal of additional suspended solids and BOD from secondary effluent, effluent polishing processes are applied. It is most often accomplished using deep granular media filters, much like the filters used to purify drinking water. Polishing filters are usually built as prefabricated units for smaller flow rates (up to 300-500 m^3/h) and gravity sand filters for higher

rates. The filtration stage coupled with disinfection of the effluent is related as "Tertiary Treatment".

- **Soil Aquifer Treatment**- after the preliminary treatment, biological aeration tanks treatment and the sedimentation tanks treatments, the effluent water is infiltrated to sandy soil. The sand that is considered as one of the best natural filters is used as the last filter to the water. In addition, very long retention times in the soil causes decomposition of degradable contaminations and adsorption of others. The water infiltrates to aquifer during a period of several months through soft sand, until it sinks to a solid soil aquifer. After insertion of the water to the soil it can be pumped out in wells and be reused as irrigation water (the quality is similar to drinking water).
- **Effluent management reservoirs**- since wastewater and effluent discharge is the same everyday throughout the year but irrigation is seasonal, there is a need to manage that gap by storage and transfer of water. In Israel there are 320 effluent management reservoirs (including for the Shafdan) that are used for seasonal buffering and water storage. All the effluent management reservoirs have accumulated storage volume of 185 million m^3. In the effluent management reservoirs there are processes that affect the quality of the water: chemical, physical and biological, such as solids settling, oxidation and algae growth. In some of the pumping stations there is an additional water treatment to protect agriculture equipment as small pipes and water dropping equipment.

Regulation- The new legislation of 2010 for public health (effluent quality standard and wastewater treatment rules) concerning effluent standards ("Inbar committee") forced all WWTPs to higher, stringiest effluent standards. These advanced regulations pushed the wastewater treatment sector into the next development level in the aspect of using advanced and progressive technologies of tertiary treatment (filtration, disinfection) and nutrient removal. The main purpose of this public health regulation is to protect on the public health, both by preventing water source pollution from wastewater and effluent, as well as setting irrigation water reuse standards.

Conversion from fresh to reclaimed water - To encourage Israeli farmers to irrigate with reused wastewater, two main incentives were developed for conversion of fresh water allocation with reclaimed water:

The cost of the reclaimed water is dramatically lower than fresh water (about 30-50% lower).

Increasing the allocation of water, for each farmer that connects to water reuse, by a factor of 20% over their former fresh water allocation.

4.3 IDENTIFICATION OF 3 EXEMPLARY BEST PRACTICE IN WASTEWATER REUSE

4.3.1 BP1: MEMBRANE BIO-REACTOR (MBR)-BEN GURION AIRPORT

4.3.1.1 Technical Criteria

1. The treated wastewater quality is up to standard. The MBR process involves a suspended growth activated sludge system that utilizes microporous membranes for solid/liquid separation instead of secondary clarifiers in CAS. This very compact arrangement produces a Micro Filtration/Ultra Filtration quality effluent suitable for reuse applications or as a high quality feed water source for Reverse Osmosis treatment. Indicative output quality of MF/UF systems include SS < 1mg/L, turbidity <0.2 NTU and up to 4 log removal of virus (depending on the membrane nominal pore size). In addition, it provides a barrier to certain chlorine resistant pathogens such as Cryptosporidium and Giardia.
2. Wastewater treatment and reuse is integrated in national policies in Israel
3. The BP is not a pilot operation but an actual wastewater treatment plan at the Ben Gurion Airport.
4. MBRs are efficient and effective in wastewater treatment and reuse. They have a very low footprint and accordingly are very suitable for the upgrade of existing wastewater plant that lack physical space for expansion.

4.3.1.2 Impact

1. The system supplies treated effluent for landscaping, agricultural irrigation, and for industrial needs like cooling towers in the airport thus replacing potable water usage.
2. The system reduces the need for land space.

4.3.1.3 Technical Feasibility

1. MBRs are reliable wastewater treatment technologies if operated properly
2. The need for expertise is high
3. The technology is successful in terms of producing high quality treated wastewater for the use of the Ben Gurion Airport
4. The technology has a low spatial footprint accordingly it is suitable for upgrading existing wastewater treatment plants that have limited availability of land for physical expansion.

4.3.1.4 Financial feasibility

Although MBRs are an expensive technology the cost-benefit ratio is positive when high quality water and low spatial are required.

4.3.1.5 Affordability

The ability to mobilize resources for the implementation of the BP is a little more difficult than conventional technologies, because of complex technology components that are implemented. This implies both to installation and mainly operation. Israeli WWTP market can contain this BP due to existing manpower and experience in other modern plants.

4.3.2 BP2: TERTIARY TREATMENT – BE'ER SHEVA WWTP

4.3.2.1 Technical criteria

1. The treated wastewater produced by the wastewater treatment plant is of a standard that is approved for unrestricted irrigation
2. The BP is an existing project in Beer Sheva
3. The tertiary wastewater treatment plant has produced treated wastewater at a cost that is lower than fresh water.

4.3.2.2 Impact

1. The construction of the tertiary wastewater treatment plant has led to the reuse, by the farmers, of previously discharged treated wastewater and the reduction in the use of freshwater for irrigation.
2. The farmers have a constant supply of irrigation water at a cost lower than that of fresh water
3. The construction of the tertiary wastewater treatment plant has led to investments in agriculture that otherwise were impossible with the lack of water in the Negev desert.
4. A peculiarity of this BP is that the farmers invested from their own funds in the tertiary treatment plant

4.3.2.3 Technical feasibility

1. Sand filtration and UV disinfection are reliable technologies that were able to produce wastewater with a quality suitable for unrestricted irrigation.
2. The need for expertise is medium

4.3.3 BP3: SOIL AQUIFER TREATMENT (SAT)-SHAFDAN PROJECT

4.3.3.1 Technical criteria

1. The treated wastewater through the SAT method is of potable quality.
2. The Shafdan project has been operational since the 1970's.
3. The treated water quality is very high while simple in operation with a low cost where cheap land is available.

4.3.3.2 Impact

1. The SAT unit at Shafdan has produced treated wastewater for reuse and reduced the reliance on freshwater for irrigation in the Negev.
2. Part of the SAT process is groundwater storage in periods of low water demand. The confined aquifer used in for the SAT is recharged with treated wastewater.
3. Agriculture has been developed in the area due to the availability of treated wastewater for reuse.

4.3.3.3 Technical Feasibility

1. The SAT in Shafdan has been operational for 40 years. It is a simple-to-use system relying on infiltration basins into a confined aquifer for wastewater treatment.
2. The basin system used in this SAT requires the least expertise in operation compared to other SAT systems such as injection wells.

4.3.3.4 Financial feasibility

The overall water treatment cost for reuse is much lower in life cycle perspective compared to intensive tertiary treatment systems. The governmental tariff for Shafdan effluent is lower for water supply – 50% of the fresh water supply rates (the lowest level is 0.99 NIS/m^3 or 0.25 US$/$m^3$).

4.3.3.5 Affordability

This practice doesn't require special resources for operation beside proper infiltration land because it is based on natural sand filtration. The problem is that the process of the filtration takes a long time (300-400 days) and is spread on vast areas. It is assumed that affordability is dependent on governmental priorities to allocate such land areas.

4.4 DOCUMENTATION OF BEST PRACTICES

4.4.1 BP1: MEMBRANE BIO-REACTOR (MBR)- BEN GURION AIRPORT

4.4.1.1 Summary

The Membrane Bio Reactor (MBR) uses a conventional activated sludge wastewater treatment process, in combination with innovative membrane water/sludge separation techniques. The result is a high-quality effluent, produced by a compact installation, with an excellent cost-benefit ratio. See Figure 4-1 below for schematic of the technology system setup.

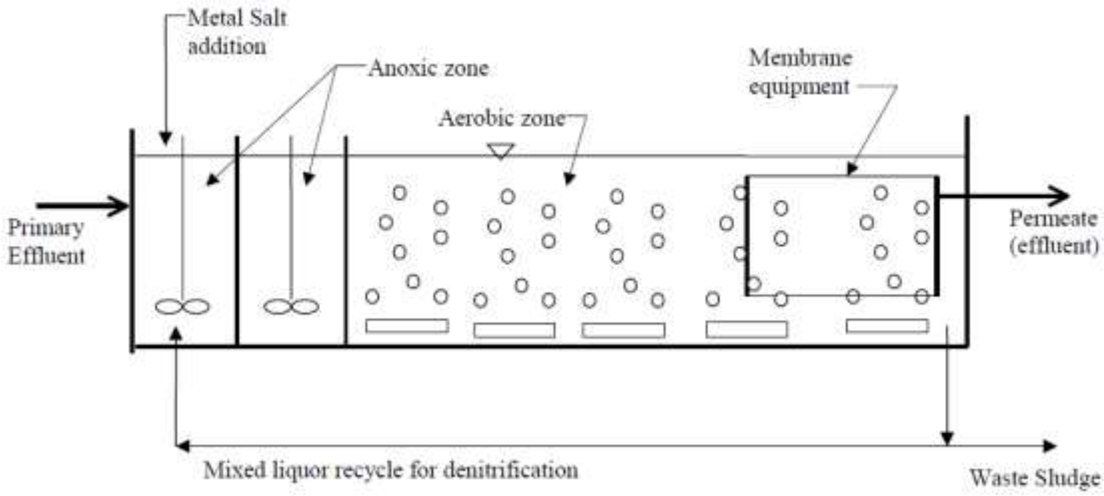

FIGURE 4-1 TYPICAL SCHEMATIC FOR MEMBRANE BIOREACTOR SYSTEM (SUBMERGED MEMBRANES)

The biological processes that take place in an MBR are in principle no different from those of a conventional activated sludge treatment process. Using oxygen, microorganisms in the aeration tanks consume organic compounds and nutrients (nitrogen and phosphate) transforming them into sludge. But then the sludge and microorganisms are filtered out of the water using membranes rather than clarifiers and settling basins. The resulting effluent is of such high quality that it is suitable for unrestricted agricultural re-use as well as industrial re-use.

An example of a project that was successfully implemented in Israel is in the Ben-Gurion airport WWTP. Ben-Gurion Airport went under a major renovation and expansion including completely new facilities during the years 2000-2005 (Named Ben-Gurion 2000). With the renewal of the airport there was a need to plan the environmental infrastructure of all wastewater and waste related facilities. Special care was directed to wastewater treatment that was demanded at the highest possible treatment level with 100% reuse scheme (no discharge of effluent to surface water). The design flow is up to 5,250 m^3/d dry weather. The performance of the project in the Israeli airport is very high, meeting all requirements with virtually no failures. The effluent concentrations are averagely 1 mg/l BOD, 0.1 mg/l ammonia, less than 1 mg/l TSS and turbidity of 1 NTU. The effluent is reused for irrigation of all airport green land and agriculture, as well as cooling towers main water supply.

4.4.1.2 Narrative

The plant was designed for a peak dry weather flow of 3,750 m^3/day (8 million passengers a year), and a phased expansion to 5,250 m^3/day at the final stage (16 million passengers a year). Civil infrastructures were completed for all the phases right up to the final phase and equipment was installed only for the first phase. Inlet conditions include COD level of 1250 mg/l, BOD 650 mg/l, TN 75 mg/l and TP 17 mg/l whereas effluent demand is COD 70 mg/l, BOD 5 mg/l, TN 10 mg/l and TP 0.2 mg/l. TSS is required to be removed to below 10 mg/l.

The process flow diagram of Ben-Gurion airport MBR WWTP includes the following main components:

1. Pretreatment including 6 mm screening and grit and grease removal.
2. Flow equalization of 1500 m^3 divided to 2 chambers.
3. Microscreening (0.75 mm) for protection of the membranes.
4. A biological reactor including a mixed anaerobic tank (for biological phosphorus removal), a mixed and recirculated anoxic tank for denitrification, and an aerobic tank for nitrification and BOD removal. Nitrified mixed liquor is recirculated from the aerobic zone to the anoxic zone, in addition to sludge recirculation from the membrane tank. Aeration in the reactor is achieved with specialized diffusers designed for high air-flows in a limited area. All mechanical systems in the reactor can be taken out for maintenance without emptying the reactor or interfering with the process.
5. Membrane compartments – 4 parallel membrane compartments receiving mixed liquor from the reactor by pumping. Each compartment contains 2 cassettes which are immersed in the liquid and can contain additional cassette according to future needs. The Membranes are hollow fiber Zenon brand with designed flux of 18-24 l/(m^2.h) on average-max flows. The membranes serve to separate the treated effluent from solids in the liquid. Solids formed in the biological process (biological sludge) are separated from the effluent, and returned to the reactor for continued breakdown of the incoming pollutants (Returned Activated Sludge – RAS). Excess sludge produced through the process is periodically wasted from the process (Waste Activated Sludge – WAS). The permeate (the final effluent) is pumped to an effluent tank and from there to the covered effluent reservoir. The membrane cassettes are continuously aerated in order to create constant movement of the membranes, in order to reduce fouling and clogging. In addition, the membranes are periodically cleaned using a permeate

backwash, chlorination in order to reduce biofouling, and chemical cleaning for reduction of chemical sedimentation on the membranes.

6. Excess sludge (WAS) is thickened and dewatered before removal, every few days, for off-site stabilization.
7. Air treatment: the entire system is covered including all process units and tanks, and air withdrawn from the various process units for treatment in a biofilter.

FIGURE 4-2 ZENON ZEEWEE MEMBRANE CASSETTE USED IN BEN GURION WWTP PROJECT

High treatment performance

Compared to a conventional WWTP, which uses an activated sludge process, the MBR equipped WWTP has a significantly higher treatment performance: the effluent produced contains no suspended solids, no bacteria and far less organic and inorganic compounds and nutrients. Also, substances that are difficult to degrade, like pesticides, herbicides and hormone-based medicines, are to a very high degree removed.

Small footprint

With MBRs, there is no need for large secondary settlement tanks. Moreover, the biological component of an MBR-equipped WWTP requires less space than a conventional one, because the concentration of active bacteria is three times higher. The result: an MBR installation has a footprint that is half that of a conventional WWTP. MBR technology is therefore perfectly suited for expanding capacity within confined premises and/or improving the performance of existing WWTPs. In addition, the nuisance of foul odour is eliminated, which is a huge plus for neighbouring dwelling areas.

The effects of small footprint and minimal environmental nuisance were primary demands for the Ben Gurion Airport WWTP project.

Re-useable effluent

Since the MBR treatment process completely removes bacteria (due to pore size smaller than physical size of bacteria – approx. 1 micron) – and other substances to a very high degree – effluent from an MBR-equipped WWTP can be directly re-used for a number of industrial and agricultural purposes, even those involving sensitive crops and aquatic organisms. Israel already takes advantage of this re-use potential in situations, for instance, where raw water quality is low or distances between source and point-of-use are great.

Financial Feasibility

The typical operation costs is around 1.70 NIS (0.43 US$) and capital expense around 2.30 NIS (0.58 US$) for m^3 exclusive VAT, for a plant in the mentioned scale of 5,000 m^3/d. These figures represent some 15-20% higher values than CAS and tertiary treatment technologies. The price of fresh water ranges 2.0-6.3 NIS/m^3 (1.0 US$) for agriculture and about double than that for urban use, with a policy and trend to increase the agriculture cost to reflect real water costs. As consequences, the MBR solution is financially justified in specific regions and circumstances when fresh water consumption is replaced with MBR effluent.

Challenges faced in implementing project and how they were overcome

An example of a challenge in implementing the system was in the project of Ben-Gurion airport: the project includes a wastewater treatment plant (WWTP) based on MBR, a complete effluent reuse system and a solid waste transport station. Due to the proximity of the main airport entrance to the buildings, special site conditions apply to the project. To avoid odour problems and improve the plant's exterior look, the facilities were completely covered by basin covers and buildings with airfoil shaped roofs in accordance with the new airport's architectural language. Furthermore, to improve flight safety, the effluent reservoir was fitted with a floating cover that will prevent the attraction of birds.

FIGURE 4-3 PLANT FRONT WITH ARCHITECTURAL FINISH (LEFT) AND COVERED EFFLUENT RESERVOIR (RIGHT)

Advantages of MBR Systems

- Secondary clarifiers and tertiary filtration processes are eliminated, thereby reducing plant footprint.
- Unlike secondary clarifiers, the quality of solids separation is not dependent on the mixed liquor suspended solids concentration or characteristics. Since elevated mixed liquor concentrations are possible, the aeration basin volume can be reduced, further reducing the plant footprint.
- No reliance upon achieving good sludge settleability (SVI parameter as known in CAS), hence quite amenable to remote operation and increased effluent quality reliability.
- Can be designed with long sludge age, hence low sludge production.
- Produces a MF/UF quality effluent suitable for reuse applications. Indicative output quality of MF/UF systems include SS < 1mg/L, turbidity <0.2 NTU and up to 4 log removal of virus (depending on the membrane nominal pore size). In addition, MF/UF provides a barrier to certain chlorine resistant pathogens such as Cryptosporidium and Giardia. The membrane is a physical barrier for bacteria and same scale solids.
- High reliability of the effluent because the physical block of the membranes.

The disadvantages of the MBR:

- Higher cost of construction and operating because of the membrane systems (more money to get supreme quality of water).
- The membranes are sensitive to materials that plug leading to erosion and physical deterioration.
- Complex technology components that are connected to the membrane make it more complicated for operation and maintenance.

4.4.2 BP2: TERTIARY TREATMENT - BE'ER-SHEVA WWTP

4.4.2.1 Summary

The purpose of tertiary treatment is to provide a final treatment stage to raise the secondary effluent (of activated sludge process) quality before it is discharged to the receiving environment (sea, river, lake, ground, etc.) or reused for irrigation. More than one tertiary treatment processes may be used at any treatment plant. If disinfection is practiced, it is always the final process.

The entire Negev region, which is located just to the east of the Sahara Desert, is extremely arid, with parts of the desert receiving just few inches of rain per year. The Negev farmers were forced to locate an alternative source of water for irrigating their crops. The "Kolchei Hanegev Ltd company" (Negev Effluent company) that is responsible for irrigation of 140,000 donums, decided to take her fate in her own hands. The company built tertiary treatment plant that treats effluent from secondary sewage treatment plant in Be'er- Sheva. The uniqueness of this plant is the fact that its owners and operators are the farmers that use the treated water for irrigation. This fact influenced the process of choosing the technologies, planning and performance of the plant.

FIGURE 4-4 EFFLUENT REUSE SYSTEM IN THE NEGEV – TERTIARY SYSTEM AND IRRIGATED FIELDS

4.4.2.2 Narrative

The farmers in Be'er Sheva decided to build a tertiary wastewater treatment plant in order to get access to water for unrestricted irrigation in a very arid area, the Negev desert.

The technology

The chosen technology included deep gravity platform filtration and disinfection with UV light.

The filtration system includes 6 filters with area of 50 m^2 each. In the first operating step each filtration cell will wash every 48 hours. The back wash procedure lasts 20 minutes for each cell and combines water and air.

FIGURE 4-5 THE FILTRATION SYSTEM

After investigating several filtration alternatives, the company chose the TETRA® DeepBed™ filtration system utilizing TETRA® SNAP T® underdrain filter block technology from Severn Trent Services. The filtration system's treatment capacity is 60,000 m^3/day. In addition to the new filtration technology, a UV system is used downstream for disinfection.

The TETRA DeepBed Filter at Be'er- Sheva consists of six cells, each 17.07 m in length and 2.9 m wide, providing a total area of 300 m^2. The filtration system uses 900 tons of TETRA #5 quartz sand media and 2,500 TETRA SNAP T Blocks, a wastewater filter under drain design. An under drain system is required to support filter media and to separate the filter media from the bottom of the filter. In addition to providing support for the filter media, the under drain system serves two primary purposes: to allow filtered water to pass through to the collection system and to start the distribution of backwash water and backwash air across the filter.

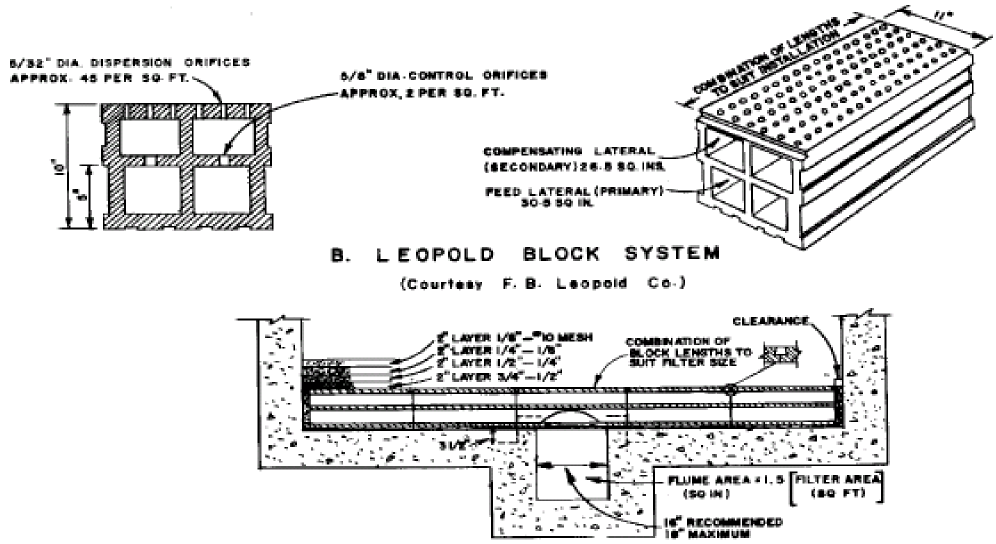

FIGURE 4-6: TYPICAL UNDERDRAIN SYSTEM FOR GRAVITY SAND FILTER (LEOPOLD)

<u>The UV disinfection system</u> is one of the six devices of this kind that were installed in Israel, and is the largest. The device based on low pressure UV lamps and high output of UV radiation, installed in an open canal with gravity flow. The facility is designed to transfer UV radiation dose that is higher than 100 mJ/cm^3, to ensure the required effluent quality for unrestricted agriculture irrigation and for public gardening. The disinfection system includes 3 trains of UV lamps that are installed in series in one canal. This formation allows flexibility for full or partial operating of the system, depending on the changing flow.

FIGURE 4-7 UV DISINFECTION SYSTEM (WITH EFFLUENT PONDS BEHIND)

Types of crops irrigated- in the Negev area the crops that the farmers irrigate with this practice are primarily potatoes, corn, wheat and cotton.

Reason behind implementation of this system

According to Zeev Gottlieb, managing director of MODOtec Advanced Systems, a leading solutions supplier for the water, wastewater and effluent treatment markets, "These farmers had no suitable source of water to irrigate their crops so they decided to take matters into their own hands. In order to provide the tertiary filtration necessary for unrestricted irrigation, the farmers pooled their resources and paid for the construction of an effluent reuse system next to the secondary wastewater treatment plant, with effluent from the plant being treated by the reuse system and then pumped to the fields."

The reuse of wastewater effluent has become a common strategy in the region. Reused effluent is typically used for variety of purposes, especially agricultural irrigation. But for the farmers of the Negev Settlements, a cooperative union of 34 settlements outside of Be'er- Sheva, the quality of reclaimed water from a local wastewater treatment plant was not suitable for "unrestricted irrigation" purposes.

Wastewater flow and irrigation requirements

The facility in Negev is responsible for return of 22,000,000 m^3 treated wastewater a year. The filtration system's treatment capacity is 60,000 m3/day with 90 percent of the effluent used for agricultural irrigation and 10 percent for irrigation of Be'er-Sheva's municipal parks.

Input and output of wastewater quality

The Be'er- Sheva WWTP tertiary system provides treated wastewater of excellent quality that is suitable for unrestricted agriculture irrigation and for public gardening. The inlet water quality is secondary effluent.

Source of funding

The facility in Negev is funded by "Kolchei Hanegev company" (Negev Effluent company) that is responsible on irrigation of 140,000 donams.

4.4.3 BP3: SOIL AQUIFER TREATMENT (SAT) - SHAFDAN PROJECT

4.4.3.1 Summary

The Shafdan recharge-reclamation process is based on intermittent flooding and drying of the spreading basins and subsequent pumping of the reclaimed water from wells surrounding the recharge area. The process is referred to as Soil Aquifer Treatment (SAT). In the SAT process, suspended solids, nitrogen and dissolved organic matter are removed by combined biological, chemical, and physical processes mainly in the unsaturated zone. SAT is a good system for wastewater treatment and reuse when land space is available and an excellent knowledge of the local hydrogeology exists.

FIGURE 4-8 DAN REGION WWTP AND RECLAMATION SITE (SHAFDAN)

4.4.3.2 Narrative

Shafdan Wastewater Treatment Plants

Every year a total amount of about 120.5 million m^3 of secondary treated effluent is recharged in the Shafdan infiltration basin. After period of 300-400 retention days the extra treated water is pumped from the aquifer, in order to prevent it from mixing with drinking water. This water is transferred to the west Negev for irrigation.

Secondary effluent from the Shafdan plant is infiltrated in fields in Rishon Letzion and Yavne. From these fields, the effluent is recharged into groundwater reservoirs (aquifers) where it undergoes natural physical, biological and chemical processes that improve its quality and storage ability.

In the tables below there is a prospect of success of the SAT practice in Shafdan project:

TABLE 4-1 WATER QUALITY DATA OF THE SAT PROCESS IN SHAFDAN

		Raw sewage	Sec. Eff	After SAT	Drinking stand.	Inbar Comm.		
BOD	ppm	430	8	<0.5		10		
COD	ppm	1060	40	10-20		100		
TSS	ppm	380	8	<o.1		10		
TN	ppm	65	20	5-10		25		
NH4	ppm	35	6	0.1		20		
UVabs	cm-1 *10*3	450	212	25				
DOC	ppm	70	12-18	2- 4				
Pt	ppm	14	1.7	<0.02		5		
Det	ppm	8	<0.2	<0.1	1	2		
T.Coli	N/100ml	1.1E8	5.6E5	0	3			
F.coli	N/100ml	1.2E7	1.8E4	0	0	10		
MN	ppb	50	25	30-500	500	200		
Fe	ppb	1,100	80	10-100	1000	2000		

TABLE 4-2 SAT TREATED WATER- VIRUSES, PHAGES AND SPORES ANALYSES

Microbiological analysis*	Units	Method**	05/07 and 06/07 Secondary effluents	05/07 and 06/07 Mey-Dan well #9 (after SAT)
Total Bacteria count (35 °C)	cfu/mL	Heterotr. Plate Count (35 C deg. / 48 hr.)	890,000	340
Faecal coliforms	cfu/100mL	MF	30,000	0
E.Coli	cfu/100mL		400	0
Enterococci	cfu/100mL	Fecal st. MF	4,000.00	0
clostridium spores	cfu/100mL		100,000.00	0
bacteriophages		(amp F+)/10 L	724	0
		(Somatic CN13)/10L	1,249	0
	pfu/mL	(f1MS2)/10L	7	0
Enterovirus	pfu/Vol.	/100 L	14	0

* In the context of the EU project RECLAIM (WP 2)
** All phages, spores and viruses analyses performed by the Health Ministry Lab. Dr. Yosi Manor

Size and type
The Shafdan treatment plant serves the densely populated area of Tel-Aviv and has an annual flow of 135 million m^3. The wastewater is primarily domestic in origin. The industrial part of the wastewater is only 10% of the total flow. The average values of BOD5, COD and TSS are 360, 850 and 400 mg/L respectively. The sewer system collects wastewater from 250 square km area.

TABLE 4-3 MAIN FIGURES OF SAT OPERATION IN SHAFDAN

Total area of infiltration (hectare)	111
Hydraulic load (m/year)	73-150 (210)
Hydraulic load (m/day)	0.2-0.5
Infiltration regime	1-2 day flooding 2-4 days drying
Unsaturated Vadose zone depth (meter)	15-30
Recovery wells – distance from infiltration basins (meter)	100-1500
Depth of recovery wells (meter)	70-150
Retention time in aquifer (months)	3-12
Cleaning cycle (Days)	15 - 30

Types of crops irrigated and water quantity
The quality of the reclaimed water is very high almost as drinking water, making it suitable for all types of crops irrigation like oranges, carrots, potatoes, lettuce, wheat, flowers and more.

Amount of wastewater that has been treated - Between 1974 and 2009, 2 billion m^3 of reclaimed water were treated and supplied, with only 4% of the treated plant effluent being wasted to the sea through Soreq stream.

Challenges faced in implementing project and how they were overcome and remaining challenges
The most common problem associated with recharging using a spreading basin is clogging of the surface by fine-grain sediment suspended in the recharged water and/or by microbial growth.

The basin infiltration rates as well as the performance of the whole SAT process depend greatly on the operational conditions of the wastewater treatment plant and the effluent quality it generates.

When the infiltration rate of a basin is reduced, the flooding of the basin needs to be stopped for as long as it takes to dry it completely. This is followed by ploughing the upper layer by mechanical techniques, to let oxygen penetrate. During this process a large area of the basins can't be used for flooding. This increases as long as the problem of poor quality effluent continues. During this time the treated effluent cannot be recharged and large amounts of effluent flow to the Soreq stream and the nearby sea. In Israel discharging water to a river requires a special permit and high quality standards. This puts the Shafdan at environmental risk of lawsuits and public pressure.

Overview of main operational problems
Bio-fouling of effluent pipelines – before and after SAT
Deterioration in recharge capacity hydrophobicity (under research), low temp, rain.
Release and clogging of filtration systems by Mn and Fe oxides

Input and output wastewater quality
The SAT receives annual hydraulic loads of secondary effluent equivalent to 100 years of rain. Water quality before and after the recharge process is of great concern. Every change in the quality of the water introduced to the basins might plug the fields or cause problems downstream.

Principles of SAT process

- Removal of suspended matter by Slow sand filtration.
- Biodegradation of bacteria, viruses, parasites - die off during the prolonged time, or by adsorption or absence of food.
- Retention time in the aquifer: For unrestricted irrigation quality > 2 weeks, for accidental drinking water Quality > 3 months.
- Chemical precipitation and Immobilization by Ion exchange of Phosphate, DOC, Cu, UVabs (>70%).
- Continues removal of nitrogen by Nitrification and Denitrification

Essential condition for the SAT process

- Secondary effluent quality.
- Sandstone aquifer, with minimum clay layer.
- Intermittent flooding to dry the upper layer and recharge the aquifer with oxygen.
- Seasonal and multi annual water storage system.
- Unsaturated layer – 10-30 meter.
- Minimum clay layers in unsaturated layer (prevents clogging problems, release of Manganese).
- Saturated layer – 50-80 meter.
- Creation of a low water level zone acts as a buffer zone (hydrological depression).
- Create a line of wells between the recharge basins and the coastal line, to avoid water losses to the sea.

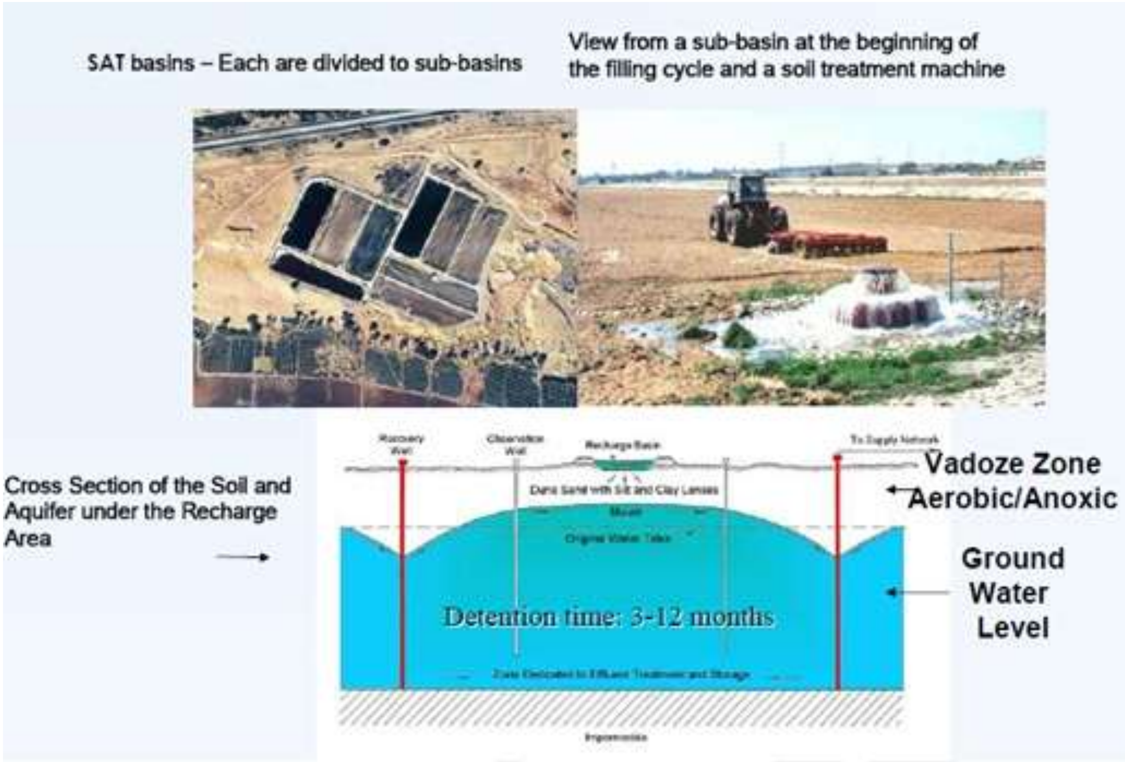

FIGURE 4-9 OPERATION OF SOIL AQUIFER TREATMENT IN SHAFDAN

4.5 CONCLUSIONS AND RECOMMENDATIONS

4.5.1 CONCLUSIONS

In the state of Israel there is a re-use of about 80% of wastewater through purification recovery in wastewater treatment plants and utilization of reclamation systems including groundwater recharge.

- High-tech treatment technologies, such as Membrane Bioreactors, can be economically feasible solutions for upgrading existing wastewater treatment plants without the need for large land space.
- Water tariffs, play an important role in the feasibility of the treatment technology.
- Tertiary treatment of wastewater is a feasible solution for unrestricted irrigation of high value cash crops in desert areas such as the Negev.
- Private sector investments in wastewater treatment upgrades are a proof of the economic feasibility of the solution.

- Soil Aquifer Treatment (SAT) is a wastewater treatment solution that can yield high quality treated water almost potable.
- Although providing a good solution for wastewater treatment, SAT is a technology requiring an excellent knowledge of the local hydrogeology and careful operation, management, and monitoring of performance.

4.5.2 RECOMMENDATIONS

- The use of high-tech wastewater treatment technologies for upgrading existing wastewater treatment plants should be explored as an economically feasible option not requiring a high footprint
- Farmers should explore the economic feasibility of investing in tertiary treatment for unrestricted irrigation of high value cash crops
- Soil Aquifer Treatment is technically feasible slow process natural solution for wastewater treatment that should be approached with extreme care.

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4.7 APPENDIX: ISRAELI WASTEWATER TREATMENT PLANTS INVENTORY

TABLE 4-4: INVENTORY WWTPS IN ISRAEL WITH CONSTRUCTION COSTS (SORTED BY CAPACITY)

ID	Authority	WWTP	Q design	Q actual	Treatment Method	Effluent Standard	Construction cost	Capex 2011	Unit Capex
			m3/d	m3/d			M [NIS]	M [USD]	[USD/ m3/d]
1	UPPER GALILEE	MISGAV AM	250	250	Aerated lagoon	2	3	0.80	3,191
2	GDEROT	GDEROT	350	-	Activated Sludge	2	6	1.60	4,559
3	GUSH EZION	TKOA	350	200	Activated Sludge	2	6	1.60	4,559
4	RAMAT NEGEV	KEDESH BARNEA	450	150	Stabilization Ponds	2	4	1.06	2,364

5	ESHKOL	MAGEN	500		Aerated lagoon	2	4	1.06	2,128
6	BNEI SHIMON	DVIR	503	300	Aerated lagoon	2	3	0.80	1,586
7	HOF ASHQELON	ZIKIM	540	460	-	2	6	1.60	2,955
8	UPPER GALILEE	AMIAD	550	550	Aerated lagoon	2	2.5	0.66	1,209
9	BINYAMIN REGION	MAALE MICHMASH	580	200	Activated Sludge	2	5	1.33	2,293
10	UPPER GALILEE	KEFAR HANASI	600	600	Aerated lagoon	2	3	0.80	1,330
11	ASHER REGION	EILON	600	400	MBR	2	10	2.66	4,433
12	YEHUDA REGION	NATIV LAMED HEE	600	600	Activated Sludge	2	5	1.33	2,216
13	UPPER GALILEE	GADOT	600	400	Aerated lagoon	2	4	1.06	1,773
14	UPPER GALILEE	MALKIA	650	350	Aerated lagoon	2	3	0.80	1,227
15	HOF ASHQELON	YAD MORDECHAI	650	400	Activated Sludge + MBBR	3	8	2.13	3,273
16	MENASHE	JALAME	700	500	Rotating Biological Contactors	2	9	2.39	3,419
17	YEHUDA REGION	TAL SHAHAR	700	160	Activated Sludge	2	7	1.86	2,660
18	ESHKOL	HOLIT	800	500	Aerated lagoon	2	4.5	1.20	1,496
19	GOLAN	DINUR	800	700	SBR	3	11	2.93	3,657
20	BNEI SHIMON	BEIT KAMA	808	400	Aerated lagoon	2	3.5	0.93	1,152
21		ELKANA	900	700	SBR	3	7	1.86	2,069
22	YOAV	NEGBA	980	600	Aerated and Settling lagoon	2	3	0.80	814
23	UPPER GALILEE	MAAYAN BARUCH	983	350	Aerated lagoon	2	3	0.80	812
24	GUSH EZION	KARMEI ZUR	1000	300	Activated Sludge + MBBR	2	8	2.13	2,128
25	ESHKOL	MIVTIHIM	1013	550	Aerated and Settling lagoon	2	5	1.33	1,313
26	MENASHE	KEFAR GLIKSON	1050	700	Activated	2	10	2.66	2,533

					Sludge				
27	MEGIDO	MEGIDO	1300	600	Settling Basins	2	12	3.19	2,455
28	UPPER GALILEE	BARAM	1300	600	Aerated lagoon	2	4	1.06	818
29	YAVNIEL	YAVNIEL	1300	900	Activated Sludge	2	14	3.72	2,864
30	MIZPE RAMON	MIZPE RAMON	1400	1230	Activated Sludge	2	12	3.19	2,280
31	BINYAMIN REGION	OFRA	1500	500	Activated Sludge	3	14	3.72	2,482
32	UPPER GALILEE	GONEN	1560	400	Aerated lagoon	2	3	0.80	511
33	UPPER GALILEE	HULATA	1600	550	Aerated and Settling lagoon	2	4.5	1.20	748
34	GOLAN	ORTAL	1800	550	Aerated lagoon	2	4	1.06	591
35	UPPER GALILEE	SHAMIR	1800	1800	Aerated lagoon	2	3.5	0.93	517
36	LEHAVIM	LEHAVIM	2000	1000	SBR	2	16	4.26	2,128
37	ARARA (NEGEV)	ARARA (NEGEV)	2000	1000	SBR	2	15	3.99	1,995
38	UPPER GALILEE	HAGOSHRIM	2200	2200	Aerated lagoon	2	3.5	0.93	423
39	UPPER GALILEE	KEFAR BLUM-NEOT MORDECHAI	2350	650	Aerated lagoon	2	3.5	0.93	396
40	GILBOA	MAGEN SHAUL	2400	2000	Aerated lagoon	2	6.5	1.73	720
41	NETOFA	KEFAR MANDA	2500	820	SBR	2	17	4.52	1,809
42	BEIT JAN + MISGAV	FAROD	2600		SBR	3	24	6.38	2,455
43	BUKATA	EL HAMRA	3000	-	lagoon	2	5	1.33	443
44	OMER	OMER	3000	1900	Activated Sludge	2	19	5.05	1,684
45	EIN BOKEQ	EIN BOKEQ	3300	3300	Activated Sludge	2	21	5.59	1,692
46	SHAFFIR	EIN ZURIM	3300	2000	Activated Sludge + MBBR	2	22	5.85	1,773
47	YERUHAM	YERUHAM	3700	2500	Activated Sludge	3	27	7.18	1,941

48	BEIT NETOFA INC	BEIT NETOFA	4000	2500	SBR	2	19	5.05	1,263
49	MAA'LE ERON	MAA'LE ERON	4000	1800	Settling Basins	2	17	4.52	1,130
50	GOLAN	MEITZAR	4000	2400	Activated Sludge + MBBR	3	21	5.59	1,396
51	B.G AIRPORT	B.G AIRPORT	5250		MBR	3	50	13.30	2,533
52	MENASHE	GAN SHEMUEL	5400	3500	Activated Sludge	2	23	6.12	1,133
53	BEER TUVIA	HATZOR-GAN YAVNE	6000	5500	Activated Sludge	2	24	6.38	1,064
54	TIBERIAS	KEFAR HITIM	6000	3000	activated sludge	2	24	6.38	1,064
55	JERUSALEM	HAR HOMA	6000	3000	MBR	3	24	6.38	1,064
56	MIGDAL HAEMEQ	MIGDAL HAEMEQ	6500	6500	Aerated and Settling lagoon	2	12	3.19	491
57	EMEK YIZRAEL	ZARZIR	6500	4200	Aerated and Settling lagoon	2	12	3.19	491
58	ARAD	ARAD	7000	5500	SBR	3	18	4.79	684
59	ASHER REGION	GAA'TON	7300	4300	Aerated lagoon	2	7	1.86	255
60	ZAHAR	ZEFAT, ROSH PINA, HAZOR	8500	7000	Activated Sludge	2	28	7.45	876
61	YAVNE	YAVNE	8750		Activated Sludge	3	32	8.51	973
62	GADERA, SOREQ, ETC	NISGAV	9000	4100	SBR	3	35	9.31	1,034
63	HURA	SHOKET	9000	2500	Activated Sludge	3	35	9.31	1,034
64	EMEK HEFER	NABLUS & TULKAREM STREEMS	9000	7000	Aerated and Chemical Settling lagoon	2	17	4.52	502
65	AFULA	AFULA	9000	7500	Activated Sludge	2	29	7.71	857
66	ZEFAT	ZEFAT	9000	5700	Activated Sludge	2	28	7.45	827
67	BRENER	BRENER	9000	6500	Activated Sludge +	3	37	9.84	1,093

					MBBR				
68	RAHAT	RAHAT	10000	5000	SBR	2	25	6.65	665
69	DIMONA	DIMONA	10000	6500	Activated Sludge	3	40	10.64	1,064
70	SHDEROT	SHDEROT	10000		Activated Sludge	3	45	11.97	1,197
71	NETIVOT	NETIVOT	10000	4900	Activated Sludge	2	34	9.04	904
72	BAKA'A-JAT	BAKA'A-JAT	11250	4000	Activated Sludge	3	38	10.11	898
73	LOWER GALILEE	SADE ILAN	12000	6000	SBR	2	32	8.51	709
74	K. MALACHI & BEER TUVIA	TIMORIM	12000	6850	Activated Sludge	2	36	9.57	798
75	RAMAT HASHARON	RAMAT HASHARON	12000	10000	Activated Sludge	3	45	11.97	997
76	JORDEN VALLY	LIVNIM	12000	5000	Activated Sludge	3	36	9.57	798
77	HOF CARAMEL	NIR EZION	13000	10000	Activated Sludge	2	42	11.17	859
78	EMEK YIZRAEL	HASOLELIM	13500	7200	MBR	3	30	7.98	591
79	HOF CARAMEL	MAAYAN TZVI	15000	8500	Activated Sludge	2	44	11.70	780
80	DROM HASHARON	NIR ELIYAHU	16000	9000	Aerated and Settling lagoon	2	14	3.72	233
81	TIBERIAS	BITANYA	16000	8000	Activated Sludge	3	49	13.03	814
82	LEV HASHARON	TNUVOT	18000	9000	Activated Sludge	3	47	12.50	694
83	MENASHE	UM EL FAHEM-ERON	18000	15000	Activated Sludge	2	44	11.70	650
84	RAA'NANA	RAA'NANA	19500	14000	SBR	3	55	14.63	750
85	KOLHEY HASHARON	KOLHEY HASHARON	20500	7500	Activated Sludge	2	27	7.18	350
86	NAZERETH	TEL ADASHIM	22000	13000	Activated Sludge	2	43	11.44	520
87	BEIT SHEMESH	BEIT SHEMESH	22500	16000	Activated Sludge	2	48	12.77	567
88	NAHARIYA	NAHARIYA	22500	16000	Activated Sludge	2	48	12.77	567

89	BEIT SHEAN	BEIT SHEAN	24000	13000	Activated Sludge	2	48	12.77	532
90	KIRYAT GAT	KIRYAT GAT	24000	16000	Activated Sludge	2	30	7.98	332
91	EILAT	EILAT	24650	24000	Activated Sludge	2	48	12.77	518
92		HADERA	29000	23000	Activated Sludge	2	48	12.77	440
93		KARMIEL	30000	25500	Activated Sludge	3	64	17.02	567
94		KEFAR SABA	33500	27000	Activated Sludge	3	60	15.96	476
95	ASHQELON	AHQELON	35000	22000	Activated Sludge	2	53	14.10	403
96	AKKO	MASAREK	40000	28200	Activated Sludge	3	60	15.96	399
97	ASHDOD	ASHDOD	47000	41000	Activated Sludge	2	120	31.91	679
98	HERZLIYA	HERZLIYA	50000	23000	Activated Sludge	3	74	19.68	394
99	RAMLOD	AYALON	54000	48000	Activated Sludge	2	96	25.53	473
100	BEER SHEVA	BEER SHEVA	54000	44000	Activated Sludge	2	68	18.09	335
101	NETANYA	NETANYA	73000	38500	Activated Sludge	3	90	23.94	328
102	JERUSALEM	SOREQ	120000	84000	Activated Sludge	2	212	56.38	470
103	HAIFA	HAIFA	120000	105000	Activated Sludge	2	-	-	-
104	SHAFDAN	SHAFDAN	400000	360000	Activated Sludge	3	-	-	-

4.8 ANNEX: 1 EFFLUENT QUALITY REQUIREMENTS ("INBAR COMMITTEE" STANDARDS)

MAXIMUM MONTHLY AVERAGES FOR DISSOLVED AND SUSPENDED ELEMENTS AND COMPOUNDS AND FOR DIFFERENT PARAMETERS IN EFFLUENTS FOR UNRESTRICTED IRRIGATION AND DISCHARGE TO RIVERS.

TABLE 4-5: ISRAEL EFFLUENT QUALITY STANDARDS (2010)

Parameter	Units	Unrestricted Irrigation*	Rivers
Electric Conductivity	dS/m	1.4	
BOD	mg/l	10	10
TSS	mg/l	10	10
COD	mg/l	100	70
Ammonia	mg/l	10	1.5
Total nitrogen	mg/l	25	10
Total phosphorus	mg/l	5	1
Chloride	mg/l	250	400
Fluoride	mg/l	2	
Sodium	mg/l	150	200
Faecal coliforms	Unit per 100 ml	10	200
Dissolved oxygen	mg/l	<0.5	<3
pH	mg/l	6.5-8.5	7.0-8.5
Residual chlorine	mg/l	1	0.05
Anionic detergent	mg/l	2	0.5
Total oil	mg/l		1
SAR	$(mmol/L)^{0.5}$	5	
Boron	mg/l	0.4	

Arsenic	mg/l	0.1	0.1
Mercury	mg/l	0.002	0.0005
Chromium	mg/l	0.1	0.05
Nickel	mg/l	0.2	0.05
Selenium	mg/l	0.02	
Lead	mg/l	0.1	0.008
Cadmium	mg/l	0.01	0.005
Zinc	mg/l	2	0.2
Iron	mg/l	2	
Copper	mg/l	0.2	0.02
Manganese	mg/l	0.2	
Aluminum	mg/l	5	
Molybdenum	mg/l	0.01	
Vanadium	mg/l	0.1	
Beryllium	mg/l	0.1	
Cobalt	mg/l	0.05	
Lithium	mg/l	2.5	
Cyanide	mg/l	0.1	0.005

* From soil, flora, hydrological and public health considerations

5 BEST PRACTICES IN WASTEWATER REUSE IN JORDAN (BY MRS. NADIA EL JOUHARY)

5.1 INTRODUCTION AND OVERVIEW OF WASTEWATER REUSE

Jordan is one of the five most water scarce countries worldwide. In 2008, the consumption was 145 m^3/ca.year which is below the 1000 m^3/ca.year, the water poverty line". The total population of Jordan reached 5.87 million in 2008 and is expected to become approximately 7.8 million in 2022.

The agricultural sector consumes more than 62% of the available water quantities putting additional pressure on the already limited resources. The main irrigation water sources are surface, groundwater and treated wastewater. The treated wastewater quantities will increase to reach 256 MCM in 2022 and will play a vital role in the agriculture sector as a renewable and continuous resource. The potential increase of population to be connected to sewer lines from around 64% currently to 69% in 2020, will increase the wastewater quantities to be treated and re-used in agriculture.

The water supply vision calls for the expansion in usage of safe treated wastewater through the construction of new WWTPs, its inclusion in the National Water Budget and its wide use for irrigation purposes. Currently, there are twenty-seven WWTPs that treat about 324,000 m^3/day (118 MCM/year) of wastewater. The Kherbit As-Samra WWTP is the most advanced and largest in the country. In 2010, the total quantity of treated wastewater reused for irrigation in restricted and unrestricted agriculture was 102 MCM comprising 92.35% of the treated wastewater. It is expected that effluent reuse will reach 98% upon the completion of three new WWTPs that will generate 11.2 MCM in 2015 and 22.2 MCM in 2035 of treated wastewater to irrigate the Northern Ghours. In 2011, the total effluent reuse from the 27 existing WWTPs was 110.7 MCM.

70% of the agriculture in Jordan is in the Jordan Valley. The irrigated areas are 35,000 hectares. In 2008 41% was irrigated with treated wastewater compared to 51.4% in 2010. This was a clear indication of the acceptance of farmers of the reuse of treated wastewater. The increase in the area using treated wastewater increases the availability of freshwater from the King Abdullah Canal to be used by the Amman municipal water supply.

Jordan is one of the leading countries in the Arab world in the direct and indirect reuse of treated wastewater. Wastewater reuse gained political commitment as a response to the water scarcity challenge. It culminated in the inclusion of reuse in water policies and strategies and the consideration of wastewater as a useful waste to be included in the National Water Budget, in the 2002 and 2008-2012 Water Strategies, in the Agricultural Document and in the National Plan for Risk Monitoring and Management System for the Use of Treated wastewater in Irrigation published in 2011.

Several measures had been adopted for the safe use of treated water and gained the gradual acceptance and support of policy makers and farmers including: the expansion in connecting the population to sewer lines, the development of National Standards for irrigation water (JS893:2006) in line with 2006 WHO Guidelines, regular monitoring of the treated wastewater by the Central Labs of the Water Authority of Jordan (WAJ), the development of the crop monitoring program, the awareness programs, the training and study tours the exchange of know-how, the institutionalization of the management of the wastewater reuse through the establishment of the Sad Al Ahmar Association, a local NGO in Wadi Musa, the first of its kind in Jordan specialized in effluent reuse.

Farmers participated in implementing reuse projects in Wadi Musa and in the Jordan Valley. Their participation increased their awareness, and their acceptance. Using treated wastewater increased their economic return through the reduction of the use of fertilizer, which led to savings and an increase in the productivity of their farms. The issue faced now is not the acceptance of the use of treated wastewater but supplying the increasing demand for irrigation. High volume, good quality, and reliable wastewater treatment has enabled the Government, with donor support, to demonstrate and extend acceptance of reclaimed wastewater for use in irrigation in the JV and some highland zones. Table 5-1 provides details on the WWTPs and the corresponding irrigated area.

TABLE 5-1 WWTPS AND CORRESPONDING IRRIGATED AREA

No	NAME OF TREATMENT PLANT	DESIGN FLOW M^3/DAY	ACTUAL FLOW M^3/DAY 2010		No. of lease contracts for reuse purposes	Irrigated area/donum	surplus
1	AS - SAMRA	267000	230606.1		34	3990	King Talal Dam
2	IRBID	11023	8132.1		None	-	Jordan River
3	AQABA W.S.P	9000	6707.1		4	1580	-
4	AQABA MECH	12000	9800.2		1	-	-
5	SALT	7700	5290.7		5	99.54	Wadi Shouaib Dam
6	JERASH	3250	3680.8		None	-	King Talal Dam

7	MAFRAQ W.S.P	1800	2008.8		18	660.197	-
8	BAQA’AL-	14900	10208.6		15	436.589	King Tala Dam
9	KARAK	785	1753.4		8	608.93	-
10	ABU-NUSIER	4000	2570.8		1	75	Sail Beerain
11	TAFILA	1600	1380.0		None	-	Ghour Fifa
12	RAMTHA	7400	3488.3		23	1302	-
13	MA’AN	5772	3170.8		8	357.228	Al Wadi
14	MADABA	7600	5172.0		24	1213.3	-
15	KUFRANJA	1900	2763.0		10	811.616	-
16	WADI- AL SEER	4000	3623.8		1	61.82	Kafrain Dam
17	FUHIS	2400	2221.0		1	30	Wadi Shouaib Dam
18	WADI - ARAB	21000	10264.0		None	-	Jordan River
19	WADI- MOUSA	3400	3028.9		38	1069	-
20	WADI - HASSAN	1600	1131.8		1	721	-
21	AKADEER	4000	3907.8		17	1068.654	-
22	TALL- MANTAH	400	300.0		1	111	-
23	AL- LAJJOUN	1000	853.1		-	-	Wadi Al-Lajjoun
24	AL - JIZA	4000	703.9				
25	Al Shoubak	350	100		-	-	
26	Al Merad	10000	1000		-	-	
27	Al Mansourah	50	15		-	-	
	TOTAL AVG.	397532	320758				
	TOTAL MCM/ YEAR	145.09918	117.077				

5.2 IDENTIFICATION OF BEST PRACTICES.

5.2.1 METHODOLOGY

Jordan has 27 WWTPs and a long history of reuse of treated wastewater in agriculture. Three Best Practices (BPs) have been identified based on technical and financial criteria in consultation with Jordanian officials and experts. Meetings were held with officials who are in charge of treated wastewater reuse and with experts who are involved in implementing the demonstration sites in the Jordan Valley and Wadi Musa. After a review of all practices in Jordan, three cases were selected as best practices. The importance of these practices is in the assessment of the enabling environment that led to the behaviour change, the accompanying policy changes, and the acceptance of the reuse of treated wastewater. This is highly relevant to countries that are planning to introduce the reuse of treated wastewater in irrigation.

5.2.2 INVENTORY

Jordan has 27 wastewater treatment plants with around 18 having reuse leases. Jordan has also several soft initiatives such as a crop-monitoring program to encourage consumption and export of crops irrigated with treated wastewater and awareness raising and close stakeholder engagement to effect policy and behaviour change. Exemplary BPs were selected from the above projects and initiatives.

5.3 IDENTIFICATION OF 3 EXEMPLARY BEST PRACTICES IN WASTEWATER REUSE

5.3.1 BP1: AWARENESS RAISING FOR POLICY CHANGE

5.3.1.1 Technical criteria

1. Since the focus of the BP is the enabling environment, technical evaluations on wastewater quality and effectiveness and efficiency in reuse are not relevant.
2. Awareness raising and the close engagement with the decision makers has led to permanent policy changes for wastewater reuse in Jordan

5.3.1.2 Impact

1. The work undertaken with decision makers has led to increased use of treated wastewater and reduced reliance on freshwater for irrigation

2. Wastewater reuse has been integrated in water and agricultural policies and strategies in Jordan
3. Most farmers in the Jordan Valley, where the bulk of agriculture is in Jordan, use treated wastewater for irrigation.
4. The use of treated wastewater has provided additional potable water supplies to Amman.

5.3.1.3 Technical Feasibility

1. Using awareness raising and close engagement with stakeholders for policy changes is always highly recommended. The Jordan case has shown the reliability of the approach
2. The need for expertise is medium; the support of experts in the field to provide the proper info to decision makers is recommended.
3. The success of the approach has been proven through the changes in policy

5.3.1.4 Financial feasibility

Cannot be easily evaluated at this stage

5.3.1.5 Affordability

Awareness raising and capacity development activities usually attract funding easily.

5.3.2 BP2: SOCIAL ASSESSMENT AND UNDERSTANDING OF THE COMMUNITY FOR ACCEPTANCE OF REUSE OF WASTEWATER IN WADI MUSA

5.3.2.1 Technical criteria

1. Using awareness raising and community understanding to induce acceptance of use of treated wastewater in irrigation cannot be evaluated for treated wastewater quality and effectiveness and efficiency of reuse
2. Although the Wadi Musa project was of a demonstration type, the effected changes have become permanent.

5.3.2.2 Impact

1. The awareness raising and community understanding work undertaken has led to the acceptance of using treated wastewater for irrigation.
2. The farmers are highly satisfied and are currently competing for access to treated wastewater for irrigation and the number of leases

for the use of treated wastewater went from one to more then 30 and growing.
3. Unused excess treated wastewater has contributed to the greening of the area and the investment in eco-tourism projects by private operators.

5.3.2.3 Technical Feasibility

1. Awareness raising and community understanding is a reliable approach that has led to the acceptance of the reuse of wastewater by the communities in Wadi Musa.
2. The success of the project required the expertise of an anthropologist.
3. The requested change was achieved and accordingly the approach was successful.

5.3.2.4 Financial feasibility

Financial feasibility is to be evaluated on a long-term basis taking into account expenditures by the project and the income from agriculture and tourism in the region and parallel impacts outside the project area.

5.3.2.5 Affordability

Awareness raising and community engagement are relatively inexpensive activities that tend to easily attract resources.

5.3.3 BP3: APPLICATION OF PRACTICAL MULTIPHASE APPROACHES FOR TREATED WASTEWATER REUSE WITH WIDER PARTICIPATION AND INVOLVEMENT OF FARMERS IN THE JORDAN VALLEY

5.3.3.1 Technical criteria

1. Using awareness raising and close stakeholder engagement to induce acceptance of use of treated wastewater in irrigation cannot be evaluated for treated wastewater quality and effectiveness and efficiency of reuse.
2. The stepwise approach in capacity development and awareness raising has led to policies supporting the reuse of treated wastewater in agriculture by farmers, decision makers and consumers.
3. The BP is not experimental and the changes in policy and in the field are permanent.

5.3.3.2 Impact

1. The stepwise approach has led to the increased use of wastewater by farmers in JVA and has reduced the reliance on potable water.
2. The stepwise approach has led to the adoption of treated wastewater reuse in national policies and strategies.

3. The farmers were very satisfied with reuse and of wastewater in the JVA currently rely on mixed water (fresh and treated effluent) for irrigation.

5.3.3.3 Technical Feasibility

1. The stepwise approach and close stakeholder engagement are reliable approaches to effect policy change as shown in the Jordanian experience.
2. Experts in different fields supported the change.
3. The practice is very successful considering the policy changes it affected.

5.3.3.4 Financial feasibility

A stepwise approach has the virtue of starting small and gradually expanding the scope of activities if successes are secured. Financial feasibility is not estimated as benefit cost ratio from a commercial point of view but from a resource mobilization point of view with spending being linked to successes.

5.3.3.5 Affordability

Resource mobilization for technical assistance activities, especially those delivered through a stepwise approach, is easier then for large projects that commit funds without prior knowledge of the potential for success.

5.4 DOCUMENTATION OF BEST PRACTICES

5.4.1 BP1: AWARENESS RAISING FOR POLICY CHANGE

5.4.1.1 Summary

Exposure of decision makers and users to reliable information, through awareness raising, and constant feedback with information from the field coupled with, donor support, has led to the consideration of treated wastewater as an important resource and to the inclusion of proper provisions for its use in national policies, strategies and plans in Jordan.

5.4.1.2 Narrative

Jordan is one of the leaders in the Arab countries in the reuse of treated wastewater. The inclusion of reuse of treated wastewater in Jordan's water policies and Strategies dates back to 1998.

Since the seventies of the last century, Jordan recognized, at a wide scale, the shortage in water and recommended measures to overcome it. The need to apply an integrated approach at the national scale was also recognized. The water supply vision calls for the use of treated wastewater in agriculture.

The political support to the reuse of treated wastewater has been gradually gained. During the seventies and eighties, there was informal reuse of the treated wastewater from the King Talal Reservoir (KTR) to irrigate the Jordan Valley. Farmers used to use raw wastewater for irrigation at certain times when freshwater for irrigation was not available. The first reuse application was from Ain Ghazal WWTP in 1975.

At the beginning, effluent reuse was confronted with religious misconceptions and beliefs that hindered reuse. To remove the religious barriers and to change the perception and religious beliefs in this regard, a religious Fatwa that allows effluent reuse, was issued by Ibn Baz, a religious leader in Saudi Arabia, and was widely discussed with policy makers and farmers gaining their gradual acceptance.

Other factors that encouraged and contributed to the support of policy makers were the frequent exposure to information, the exchange of knowledge between Jordan's policy makers and other countries on reuse.

Policy makers are frequently provided with information on the status of the WWTPs and their performance.

The existence of technical information based on the opinion of experts, analysis and on applied effluent reuse standards / regulations and guidelines provided strong basis for the confidence of policy makers and their support to effluent reuse.

The donors' community played a vital role in encouraging and building the confidence of policy makers in the reuse of treated wastewater for irrigation purposes in Jordan. This was achieved through different implemented projects and technical assistance programs.

Using treated wastewater in agriculture was mainstreamed into all relevant national policies, strategies and plans. It was included in the Water and Agriculture Strategies and plans and led to consider effluent reuse in agriculture in the water budget. Water Strategies include the 2002 and 2008-2012 water strategy, the National Water Master Plan of 2004 and the Agricultural Document. The National Water Master Plan dedicated one volume for non-conventional water reuse. Another important document is the 2011 National Plan for Risk Monitoring and Management System for the Use of Treated wastewater in irrigation.

Different institutions have a role(s) in effluent reuse:

- The Ministry of Water and Irrigation is the lead ministry for the water sector governance. Among its responsibilities are the national planning of the sector, policy formulation, decision making and monitoring. There are two national entities annexed to the Ministry: the Water Authority of Jordan (WAJ) and the Jordan Valley Authority (JVA). WAJ is responsible for the water resources development and management, water and wastewater services including effluent reuse and public awareness. JVA is responsible for the integrated socio economic development of the Jordan Valley and to provide water for irrigation in the Jordan Valley up to the farms.

- The Ministry of Agriculture (MOA) is responsible for agricultural irrigation, irrigation water quality and extension services. It works in close cooperation with the MOWI on standard setting for treated wastewater reuse.

- The private sector has an important role and provides extension services to the farmers in effluent reuse.

Below are quotes from the water strategies that reflect the development of treated wastewater reuse, farmers and crops safety while reusing treated wastewater and public health.

- *"The reuse of treated wastewater should be 100% in 2022".*
- *"On Resources Development: Wastewater is not and cannot be treated a waste. It is a resource and useful waste. (Policy Paper No.2"Irrigation Water Policy" of February 1998)".*
- *"It will be collected and treated in accordance with standards that allow its reuse in unrestricted agriculture. Proper wastewater treatment process technologies will be adopted taking into consideration energy efficiency and the quality of treated wastewater to be reused in unrestricted agriculture".*
- *"Treated wastewater will be considered as a continuous flow and will comprise an integral part of renewable resources and part of the National Water Budget. A priority will be given for the reuse in unrestricted agriculture".*
- *"Farmers will be encouraged to identify the irrigation water requirements for different crops".*
- *"Farmers will be encouraged to use modern irrigation systems with high efficiency. The safety of farmers and crops will be protected from pollution). The treated wastewater quality will be monitored and the end users will be informed of any deterioration in water quality to avoid using it unless mitigation measures are taken· Public awareness programs to be conducted to encourage the reuse of treated wastewater. Topics will cover proper irrigation methods, agricultural products handling, and risks of exposure to untreated wastewater, the value of treated wastewater and its reuse".*
- *"On resources management: wastewater management will have to take into consideration public health measures and its requirements".*
- *"On Health Standards: the focus will be on public health requirements and the workers health of reuse of treated wastewater".*
- *"On Water Resources Management, the MOWI will prepare a wastewater restructuring plan to provide wastewater collection and its treatment in underserved areas. Institutional strengthening for monitoring, control and implementation of bylaws and regulations related to wastewater. MOWI will*

establish a unit with qualified staff to plan, design, implement and manage wastewater projects and the reuse of treated wastewater".

- *"Jordan will expand the reuse of treated wastewater as it has proven its high potential uses in agriculture, industry and greening urban areas. Expansion as well in the construction of additional wastewater treatment plants".*
- *"Wastewater reuse will have a vital role in securing additional water resources due to the increased generated wastewater and the limited groundwater resources".*
- *"Efficient use of treated wastewater with reasonable cost"*.

The main pillars for the agricultural development strategy included the combating of recurrent drought in Jordan, the exploitation of non-conventional water resources in agriculture production (fodder production and forestry), the increase in local production of fodder, cereals and seed which will require the expansion in the reuse of treated wastewater for fodder production and the issuance of the relevant instruction in this regard including the instructions and by- laws that allow and organize the use of state owned lands by farmer organizations.

For the last two decades, considerable efforts were also made to convince agricultural producers to use treated wastewater as a new and additional resource, ensure that treatment levels aligned with agricultural re-use standards, and convince consumers of the safety of food produced from reclaimed water blended with fresh water.

Below are the laws and guidelines that govern the use of municipal treated wastewater.

TABLE 5-2 LAWS AND GUIDELINES GOVERNING DOMESTIC WASTEWATER REUSE

Standards/Regulations/Guidelines	Issued by	Area of Use
JS 893:2006	JISM	The reuse of domestic treated wastewater
JS 1145:2006	JISM	The safe use of bio-solids
Irrigation Water Quality Guidelines	JVA	Indirect use of treated wastewater
Guidelines for Reclaimed Water Irrigation in the Jordan Valley	JVA	Good agricultural practices in dealing with blended treated wastewater

Guidelines for a safe Crop Monitoring System for Fresh Vegetables	JFDA: Jordan Food and Drug Administration	Methodology for safe sampling and analysis of fresh vegetables.
WHO Guidelines on Wastewater Use in Agriculture 2006	WHO	Safe use of treated wastewater in agriculture

WAJ established the wastewater committee in 2002 and included the reuse of treated wastewater and its compliance with the standards in its agenda. There is regular monitoring carried out by WAJ Central Laboratories for Wastewater Treatment Processes on the influent and the effluent quality. This is essential to build the knowledge on the performance of the WWTP and thus the effluent suitability for irrigation. Information based on scientific research was crucial to build the confidence of policy makers, have better decisions, adopt reuse and include it in national policies and strategies. Effluent quality compliant with standards is also important in building the confidence of farmers.

Due to the demand for effluent by farmers, the MOWI signed 226 lease agreements with farmers for the reuse of reclaimed water in agriculture[i]. The main crops that are irrigated by treated effluent include olive trees, fodder, forestry trees, fruit trees, palm trees, green areas. The total financial revenues reached Jordanian Dinar (1,109,802) (1,220,783 euro) in 2010. The revenues from the effluent cover the operation and maintenance costs of WWTPs.

Ten years ago, a land of around 30 donums (30,000 m^2), planted with olive trees, surrounded al Ekaider Wastewater treatment plant in the north of Jordan. WAJ leased it for 5 JOD/ Donum (5.5 euro/1000 m^2). This amount included the cost of the effluent, the olive trees and the land. Afterwards, the lease for the empty land with no electricity nor water reached JOD 71/donum (78 euro/1000 m^2) plus JOD 11.5 (12.65 euro) for water plus JOD 11.5 (12.65 euro) for electricity per donum per year (per 1000 m^2/year).

5.4.2 BP2: SOCIAL ASSESSMENT AND UNDERSTANDING OF THE COMMUNITY FOR ACCEPTANCE OF REUSE OF WASTEWATER IN WADI MUSA

5.4.2.1 Summary

A proper understanding of and direct communication with the local community have led to the removal of barriers to wastewater reuse in Wadi Musa. Treated wastewater is the only source of water for irrigation in the area. The trust relationship that was built with the farmers accompanied by the provision of economic incentives have changed the attitude of the local community from hesitation in the use of treated sewage for irrigation to competition for an important resource. The reuse project has contributed to the introduction of the previously inexistent agriculture in Wadi Musa coupled with investments in eco-tourism due to the greening of the area through excess treated wastewater.

The Wadi Musa pilot project is a reuse project that is becoming sustainable and permanent through the increasing number of leases given to famers for reuse of the treated wastewater. Consequently, what was called the Wadi Musa demonstration project can now be considered almost permanent and is not of a pilot nature anymore.

5.4.2.2 Narrative

Wadi Musa is a dry area located in the Ma'an governorate in the south of Jordan and around 10 km to the north of the ancient city of Petra, A UNESCO Cultural Heritage Site. The total population of Wadi Musa is approximately 28,000. Three projects were implemented in Wadi Musa funded by the US Agency for International Development (USAID) to support self-sustainability:

- The construction of Wadi Musa WWTP through the Water Reuse Implementation Project (WRIP 2002-2004).
- The Water Reuse for Agricultural, Industry and Landscaping Project (RIAL 2004-2007).
- The third project is currently under implementation and planned to be completed in 2015 on water reuse and environmental conservation.

The WWTP has been in operation since 2003. The WWTP collects the sewerage from four areas: Wadi Musa including the hotels, Taybeh, Baydah and Al Badoul housing areas. The Wadi Musa WWTP is a community-based project. It is considered as one of the first pilot projects for direct reuse of reclaimed wastewater to irrigate an average agricultural area of 1069 donums (1,069,000 m^2) in Wadi Musa.

The project was awarded two international awards:

- American Academy for Environmental Engineers Excellence in Engineering Awards 2008 (Tarwanhe) http://www.aaee.net/DownloadCenter/E3Winners-2008.pdf
- Honor Award-IWA Project Innovation Award Program for Excellence in Innovative Water Engineering.

The effluent reuse in Wadi Musa was a component of the RIAL Project. It was initiated in June 2004 to build on the experience of working towards sustainable use of reclaimed water resources, the provision of economic benefit, and the support to community development.

The demonstration site of Wadi Musa focused on implementation of direct water reuse for agriculture and landscaping. The specific objectives of the RIAL project included the assistance to establish permanence of water reuse in Jordan, the improvement of the capability for regular monitoring and management of reuse activities, and the improvement of the acceptance of wastewater reuse. The three major tasks of RIAL were: 1)implementation of direct reuse for agriculture and landscaping, 2)institutional strengthening and public participation activities including support to the WREU and 3)public awareness and training events to improve acceptance of water reuse, conservation and pollution prevention in industries.

The Wadi Musa WWTP is administered by the Aqaba Water Company the design flow is 3400 m^3/day while the actual flow was 3028.9m^3/day in 2010. The WWTP treatment process is the extended aeration technology with an efficiency of 98% for organic matter removal. The total generated effluent reached 1.035 million cubic meters and was 100% used for irrigation inside and outside the WWTP location. The quality of the effluent meets the Standards for the Use of Reclaimed Water: JS893:2006, for Categories A, B and C. Only the cut flowers parameter exceeded the allowable levels for Total Suspended Solids (TSS). Sand filters at the pump station can lower the suspended solids level. For the last eight (8) years, the farmers have been provided with a continuous supply of effluent that complies with the Jordanian Standards 386:2006. Excellent effluent water quality exceeding the standards for Class A use (cooked vegetables and parks) despite the fact that farmers do not grow vegetables in Wadi Musa. Results of the analysis of common nutrients and soil show that relevant parameters are within acceptable limits. There is no evidence of salinity build up and heavy metal concentrations are very low.

At the beginning, the project included 2 sites, a 69 donum (69,000 m^2) demonstration site adjacent to the Petra WWTP, and a 1000 donum (1,000,000 m^2) site to be planted by local farmers. The demonstration site has been planted and its irrigation system is fully operational. Work has been initiated on the 2nd site. Lease agreements with local farmers are developed, but not finalized. Currently, 300 donums (300,000 m^2), (about 14) units are under preparation for planting. The project was challenged by the non-uniform topography of the site which was overcome by the adoption of the appropriate irrigation design and cropping system. Other challenges included the clogging of filters faster than expected, and community members and local officials being suspicious of the project objectives.

Engineer Raed Badran said “at the beginning of the project the farmers were hesitant to reuse the treated wastewater and did not accept the idea of using wastewater for irrigation. The religious beliefs relevant to the consideration of treated wastewater as an unclean water source were a major concern for the farmers. The preconceptions were broken down through face to face discussions that built trust.

The Water Authority of Jordan had high level of interaction between experts and local communities. The experts explained the process and showed the local communities the results so that they felt comfortable with feeding their animals and consuming the fruit. Local communities find it normal and natural now to use treated wastewater. WAJ used economic incentives to encourage farmers. The acceptance increased as the farmers started to experience the financial benefits of the effluent reuse.

The Hashemite Fund for Development of the Jordan Badia applied anthropological science to analyse the situation related to the barrier of religious beliefs. Dr. Tarawneh, the anthropologist of the HFDB held meetings with the religious leaders of Wadi Musa and the local communities surrounding the project area and expressed his willingness to drink the effluent in a sign that this water is of good quality for irrigation. This meeting was followed by discussions on the best-accepted practices by the community. The most accepted approach was to irrigate alfalfa, which is indirectly consumed by humans.

The moment the local community understood the benefits of the project a new problem arose; the tribal zones would create a conflict on the right of land use. A major step to resolve this conflict was to understand the tribal system that existed in the project's location. The HFDB carried out a study on the tribal zones and its relevant laws. Findings of the study indicated that three tribes reside in the project area: The Bdoul, The Amarien and the Layathneh tribes. There was no agreement among them to organize land use. Historically, the Amarien tribe were the closest to the land. The study revealed that the Amariens are the ones who have the right to use the land.

A specialized local NGO in effluent reuse "Sad Al Ahmar Association" was established in 2003 and served as Water Users Association (WUA). The mechanism which was used to distribute the farm units depended on the tribal zones. The Military Retirement Association provided the Sad Al Ahmar Association WUA with the names of 10 beneficiaries from Wadi Musa and the remaining beneficiaries were selected based on the tribal divisions in the area. These were the Amarien tribes (consisting of the Salmanyyeen tribe and Shousheh tribes). The leaders of these tribes selected and had consensuses on the names of the beneficiaries.

There were no agricultural activities before constructing the Wadi Musa WWTP and no alternative water resource for irrigation.

44 farmers and their families are directly benefiting from the project. The average size of the family is 7 persons / family bringing the total direct beneficiaries of the project to 308 persons. Currently, there are 120 families registered to benefit from upcoming opportunities from the project. The beneficiary farmers pay JOD 20.0/year (22 euro/year) as a subscription fee, which is an indicator for their high acceptance of the project and their support of the Sad Al Ahmar Association.

The project succeeded to settle the Bedouins in that area and alleviate poverty by creating employment opportunities. The beneficiaries used to be mainly military servants and didn't practice agriculture before. They depended for their income on the pension which is insufficient to support their livelihood.

The total lease agreement was 1 with Petra Authority in 2010, it reached 38 with WAJ in 2012 this is a result of increased acceptance of the project. The financial revenues from the effluent reuse reached JOD 23,411(25,752 euro) in 2010.

Alfalfa is the most profitable crop in Wadi Musa followed by barley and olive. The product is sold in the local market. Jordan imports 90% of the fodder it needs. The total annual value of the Wadi Musa alfalfa reached around JOD 30,000 (33,000 euro). The project contributed to save around JOD 27,000 (29,700 euro) to the national economy.

Farmers plant also maize, sunflower, Sudan grass, and tree crops including pistachio, almond, olives, date palms, lemons, poplars, spruce and junipers. Several varieties of ornamental flowers including iris, geraniums, petunias and daisies are also planted. More than 2,000 trees and 400 shrubs and flowers have been planted to date. The project demonstrated that the yield of maize can grow by approximately 25 per cent over that of maize grown with fresh water, and the yield of sunflowers can rise by approximately 30 per cent. The project has also encouraged farmers to produce fodder for livestock, a practice that reduces the amount of unique flora that grazing animals consume. Farmers grow cut flowers. There is 100% demand by several of Petra's tourist hotels. This added to the economic benefits generated from the project and creating a market for the farmers.

The site is not fenced which reflects a remarkable achievement and a clear sign of the ownership of the project by the local community and their high level of participation and active involvement in the project. The project is self-sustained and serves as a model for replication in other parts of Jordan and in the region.

The project converted the locality from a desert into a green area. A variety of plant species is growing along the Wadi where excess water is discharged. An increased number of species of birds are seen in the area and people claim that there are more animals.

Greening the area was a catalyst for private investment in the tourism sector. There are around four camping projects in the project area owned and managed by the private sector and used by tourists from different nationalities. The project site is a station for local tourism and picnic purposes during weekends and vacations.

5.4.3 BP3: APPLICATION OF PRACTICAL MULTIPHASE APPROACHES FOR TREATED WASTEWATER REUSE WITH WIDER PARTICIPATION AND INVOLVEMENT OF FARMERS IN THE JORDAN VALLEY

5.4.3.1 Summary

A structured multiphase approach based on strong participation by the farmers has resulted in the successful introduction of wastewater treatment and reuse in agriculture in Jordan. Experts used local agriculture practices to adapt the guidelines for reuse of wastewater. Farmers were closely involved in the demonstration activities on the benefit of using treated wastewater in agriculture. They also benefited from awareness campaigns, studies, software, and study tours. Information was provided to decision makers and the consumers through the crop monitoring system. A gradual, build up of knowledge and awareness in a strong participatory approach starting from the field with the farmers and gradually reaching consumers and decision makers has made treated wastewater reuse in Jordan a common and accepted practice.

5.4.3.2 Narrative

The Jordan Rift Valley (JRV) is located west of Jordan and extends from the Yarmouk River in the north to the Gulf of Aqaba in the South for about 360 km, with an average width of 10 km.

The variations in temperature, humidity, and rainfall produced distinct agro-climatic zones. Annual rainfall starts in October and ends in May. Precipitation reaches 350-400 mm/year in the north and drops down to 50 mm/year in the south. The Jordan Valley enjoys warm winters that allow the production of off-season crops. The Jordan Valley (JV) is responsible for about 70% of the agriculture production in Jordan. The annual demand for irrigation exceeds 500 MCM while the annual available water resource in the valley is estimated to reach 250-300 MCM. Around 60 Million m^3 of available water is pumped up to the city of Amman and 20 MCM to Irbid for domestic uses.

The total irrigated lands in JV reach 35,000 hectares. Around 51.4% of the area was irrigated with treated wastewater in 2010 compared to 41% in 2008. This percentage is increasing annually due to the increasing amounts of treated wastewater available from the As-Samra Wastewater Treatment Plant (WWTP), as well as other plants discharging water towards the JV gradually increasing the availability of freshwater from the KAC for treatment and release to the Amman municipal water supply. By 2015, treated wastewater is expected to increase by an additional 76 Mm^3/year, bringing the total wastewater available for reuse to about 180 Mm^3/year, most of which would be used to irrigate fruits and vegetables, other food crops, and tree crops, with a small allocation to support forage and fodder production for livestock. The planted area within As-Samra WWTP area is 3,990 donum (3,990,000 m^2) planted with olive trees and fodder. The number of lease agreements were 34 in 2010. The Southern Ghours planted areas amounted to 50,000 donums (50,000,000 m^2), each donum requires 1000 m^3 of water for irrigation.

The farmers in the Jordan Valley obtain irrigation water from the KAC which receives water from KTR. Almost all farms have an on farm holding pond and almost 90% of the farmers in Jordan Valley practice drip irrigation which is a main factor in reducing possible biological contamination. The use of drip irrigation will reduce the direct contact of the farmers and farm workers with low quality irrigation water. The main crops irrigated by the treated wastewater are fruits and vegetables including: cucumbers, tomatoes, eggplants, potatoes and lettuce

In 2006, GIZ, and through the German- Jordanian Water Program (WP), provided assistance to the Government of Jordan / JVA to establish new services to be provided periodically to the farmers on information relevant to irrigation water quality. The program was implemented over three years in close cooperation with farmers and specialists. It demonstrated a high level of participation and cooperation.

The program adopted a practical and simplified technical information approach through the demonstration sites to show impacts rather than provide verbal information. The involvement of farmers in the demonstration sites provided a solid milestone to increase the farmers' awareness and the on farm best practices in terms of irrigation water efficiency, fertilizers usage, and salinity problems.

The WP implemented four levels as follows:

- Increase farmers' awareness to treated wastewater and train them to benefit from nutrients in the treated wastewater. The results at this level showed savings by more than 50% of the fertilization cost which is equivalent to more than Euro 1000 annually per farmer in the JV.
- Alignment with the international requirements in particular the 2006 WHO guidelines. As a result, a comprehensive national risk monitoring and management plan was established and all stakeholders take part according to their mandate.
- Establishment of a crop monitoring program for crops irrigated with treated wastewater. Crops irrigated with treated wastewater are tested annually for all types of microbiological (E. coli and Salmonella) and chemical contaminants (Heavy metals and Nitrate) by the Jordan Food and Drug Administration (JFDA).
- Development of a national standard for irrigation water in line with the requirements of the 2006 WHO guidelines and at the same time consideration of the socio-economic situation of the country.

The crop-monitoring program is an outcome of this work; it became a state-owned program implemented independently by JFDA after it was fully supported by GIZ. This was a major tool to support decision makers and their decision for more exploitation of treated wastewater and the increasing of the areas irrigated with treated wastewater in the light of the fact that 100% of the tested crops (400 samples) met the international acceptable limits. At the same time, it assured farmers and consumers that reuse of treated wastewater is a safe practice.

The WP carried out an in-depth analysis of the intensive farm monitoring data that covered on farm activities over three successive years for 30 selected farms. The practices of farmers were documented against different international references on weekly basis in order to assess their practices relevant to irrigation, fertilization, salinity problems, occupational health issues and crop yields. A main finding is that farmers are aware of the reuse of treated wastewater and salinity problems. Over-irrigation and over-fertilization, by 10-30% and 100% respectively, were documented in all monitored farms. Results of soil analyses proved that soils in the JV are rich in phosphorus (P) and potassium (K) but are very poor in nitrogen (N). Based on the above-mentioned main results, agronomical guidelines were jointly prepared with the assistance of specialists from different institutions. The guidelines offer extension workers and farmers guidance on good agricultural practices, occupational health, and proper irrigation including crop water requirements, scheduling, as well as fertilization.

As a result of the work with farmers and JVA, the WP supported JVA in the creation of new services to provide, on a monthly basis, farmers with information on irrigation water quality. The data sheet aims at updating farmers on irrigation water quality changes. The sheet is accessible by all farmers. It includes simplified technical interpretation of the water quality analysis that enable farmers to adjust their fertilization processes taking into account the quality of their water. Table 5-3 shows the significant difference in water quality between the two main water resources used for irrigation in the Jordan Valley: fresh and reclaimed water. The WP calculations, which were confirmed by demo sites, showed that nutrients in the treated wastewater contribute no less than 20-40% of the actual crop demand.

TABLE 5-3 WATER QUALITY OF THE MAIN WATER SOURCES USED FOR IRRIGATION IN THE JORDAN VALLEY

Water Source	EC-range (ds/m)	Average Values (mg/l) for NPK		
		N	P	K
KAC	1-1.2	1.4	0.23	10.5
KTR	2-2.8	18.6	3.9	26.1

Source: Guidelines for reclaimed water irrigation in the Jordan Valley, 2006).

Demonstrations trials were carried out in close cooperation with farmers to provide practical evidence on the differences between good agricultural practices (GAP) and the common practices of farmers relevant to irrigation and fertilization.

Over a period of three years, demonstrations were conducted on various crops, under both open field and greenhouse conditions and in different areas in the Jordan Valley. Farmers were engaged in the trails to assess the contribution of dissolved nutrients contained in reclaimed water in crop nutrition.

Each demo site comprised two distinct and separate plots identical in all conditions except fertigation (irrigation and fertilization) management. On one plot, farmers implemented the WP recommendations where the amounts of irrigation water and fertilization were based on the actual crop requirements. On the other plot, 5 farmers applied their common practices. Table 5-4 shows the differences between good agriculture practices (GAP) and the farmers' usual practices. The results of the demo sites showed that farmer's common practices lead to overuse of P and K three and seven times more, respectively. Fertilization methods, usually used by farmers, cost more than JOD 150 per donum (165 euro/1000 m^2) in comparison to JOD 62.8 (63.5 euro) when farmers apply the WP recommendations.

The results proved that farmers could save up to 60% of fertilization costs. Consequently, comprehensive agronomic guidelines addressing aspects of irrigation; fertilization and occupational health were developed to serve as didactic materials for both extension workers and farmers.

TABLE 5-4 COMPARISON BETWEEN CONVENTIONAL AGRICULTURAL PRACTICES AND GOOD AGRICULTURAL PRACTICES FOR CUCUMBER GROWN UNDER GREENHOUSES

Parameter		Conventional practices	GAP	Difference
Appearance	Similar			0
Yield (ton/du) (ton/ 1000 m^2)		14.8	15.3	+0.5
Fertilizers cost JOD (€)		155.5 (170)	62.8 (70)	-92.7 (- 100)
Fertilizers Quantities (Kg/du)	N	57.4	56.6	-0.8
	P	13.4	6.3	-7.1
	K	40.4	5.6	-34.8
Irrigation (m^3/du) (m^3/1000 m^2)		510	495	-15

Source: Guidelines for reclaimed water irrigation in the Jordan Valley, 2006).

The results of various demonstration trials and the content of guidelines were disseminated among the target groups by using different tools ranging from simple posters to complex software. The main messages have been communicated using simplified visual illustrations and extension tools of good agricultural practices.

Bilingual fertigation software was also developed to calculate both the irrigation and fertilization requirements taking into consideration the status of nutrients in soil, the water quality information, the crop information and other factors to enable users to build reasonable fertigation programs and to increase the efficiency of fertigation.

60% of the fertilizers have been saved. The software also calculated the fertilizer requirements and irrigation water scheduling. The software was verified through sets of demonstration trials in cooperation with farmers and the Ministry of Agriculture (MOA) extension workers. The results proved that farmers and extension workers could benefit from the software.

The results from the demo sites and the recommendations from the guidelines were disseminated among the target groups (farmers, extension workers and agricultural input suppliers) through training sessions, training-of-trainers for extension workers, field days and local info trips. The WP trained more than 1000 farmers on the current situation of the water sector in Jordan, on technical matters related to irrigation, on fertilization, and on water quality. Field trips were organized to other sites like Kherbit As Samra WWTP in a trial to change the farmers' perception on reuse of treated wastewater in irrigation. The training included field days to inform participants on water resources including treated wastewater. An indicator of success is the increased irrigated area with effluent reuse reaching around 51.4% of the irrigated area in 2010 compared to 41% in 2008.

Public concerns relevant to the risk of biological and heavy metal contamination have been raised regularly. These concerns had been addressed through the establishment, by the WP and JFDA, of a state crop-monitoring program. The main aim is to monitor crops produced with reclaimed water. A multidisciplinary working group developed guidelines for the crop-monitoring program, which sets test procedures and the parameters to be tested as well as acceptable contamination limits. Tests include pathogens like *E. coli*, *Salmonella* and heavy metals like Cd and Pb as well as nitrate (JFDA Guidelines, 2010). According with the guidelines, samples of different crops cultivated in JV are tested on an annual basis. The crop-monitoring program analysed, biologically and chemically, over three consecutive seasons, 379 samples of crops. The results confirmed that the on-farm risk management measures, such as the use of drip irrigation, were very effective barriers not only in mitigating but also in eliminating risks of crop microbiological contamination. Only 1 sample was contaminated with E.coli and 2 samples were contaminated with Salmonella. All the contaminated samples were leafy crops.

A practical guideline for the safe reuse of treated wastewater in irrigation was developed in November 2011. It is prepared to assist extension workers, engineers and farmers to obtain useful information on the reuse of treated wastewater in irrigation.

A National Committee with representation from different involved institutions adopted the National Risk Management System. A National Plan for the reuse was prepared.

The Water Users Association (WUA) has a good and smooth communication with the different NGOS in the Jordan Valley. 22 WUAs in JV have been established in 2010. The MOWI/JVA usually arrange for their officials to meet with the farmers via the WUA. The NGOs are a good tool for awareness raising and outreach to farmers. This allows for more interaction between the farmers and the decisions makers and increases trust and cooperation between farmers and JVA. Many of the NGOs invite farmers to meetings relevant to the dissemination of information on the reuse of treated wastewater.

5.5 CONCLUSIONS AND RECOMMENDATIONS

5.5.1 CONCLUSIONS

Open communication, understanding, awareness raising, participation and dissemination of reliable information have led to the extensive use of treated wastewater in irrigation in Jordan. Relevant policies, strategies and plans have been amended or drafted by convinced decision makers in order to encourage reuse of treated effluent to irrigate crops in the Jordan valley, Wadi Musa and other places. The same tools for change have helped in the transformation of the attitude of farmers from hesitation to competition for the use of treated sewage in irrigation. The crop-monitoring program was an excellent tool for consumer acceptance of crops irrigated with treated wastewater.

5.5.2 RECOMMENDATIONS

The following recommendations are presented below to respond to the above conclusions:

1. Raising awareness, dissemination of reliable information, exposure to international experience should be used as tools for policy change at the level of decision makers.
2. Understanding, provision of simplified technical information, demonstration of benefit, and participation are tools to convince farmers to use treated wastewater.
3. Crop monitoring programs should be setup in order to encourage consumers to purchase crops irrigated with treated wastewater.

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13. Ministry of Water and Irrigation/ Jordan Valley Authority (August- September 2004):The Third country Training Programme for Water Resources Management. http://www.jica.go.jp/iraq/english/activities/pdf/training06_01.pdf

6 BEST PRACTICES FOR WASTEWATER REUSE IN MOROCCO (BY PR. REDOUANE CHOUKR-ALLAH)

6.1 INTRODUCTION AND OVERVIEW OF WASTEWATER REUSE

Morocco has been facing a severe drought for the last twenty years; therefore, the need was apparent for the decision-makers at the highest political levels to find new solutions to the challenges of water resources management that are getting pressing. Within this framework, great efforts to reduce demand needed to supplement the search of increased water supplies, under drought condition and increased population growth, looking for additional water. The reuse of treated wastewater could contribute to fill the gap, and reduce water resources pollution.

In the last three decades, the annual volume of wastewaters in Morocco has almost tripled. It has increased from 48 in 1960 to 700 million m³ in 2010. It is expected that this volume may reach about 900 million m³ in 2020. So far there is limited planned reuse of reclaimed water in Morocco, given that only 25% of the collected wastewater undergoes any treatment. The actual treated wastewater volume is 177Mm^3 per year (Table 6-1).

TABLE 6-1 WASTEWATER TREATMENT AND PLANTS AND TYPES OF REUSE IN MOROCCO (2010)

Treatment levels	Treated wastewater		Reused wastewater		Raw sewage	Type of reuse
	(Mm^3/year)	%	(Mm^3/ year)	%	(Mm^3/ year)	
Primary	37	5	0	0	700	Agriculture, golf course, groundwater recharge and industry
Secondary	84	12	47	56		
Tertiary	56	8	33	59		
Total	177	25	80	45		

Most of the treated wastewaters present salinity higher than 2 dS/m and precaution should be taken for their reuse Table 6-2. Sometimes the salinity of the effluent could reach up to 5.5 dS/m, which is the case of the Agadir treatment Plant (Fishery industry dump their effluent in the city network with no pre-treatment). In 2010 there were more than 62 wastewater treatment plants in Morocco, mostly serving small and medium-sized towns located in the interior or the country. Treatment levels reached by these plants are as follows:

- Plants with primary level of treatment.
- 40 plants with secondary level of treatment.
- 16 plants with tertiary level of treatment.

TABLE 6-2 CHARACTERIZATION OF WASTEWATER EFFLUENTS IN MOROCCO

Parameters	Small centres (less than 20,000 inhabitant)	Average Centres (Between 20.000 and 100,000 inhabitant)	large cities (more than 100,000 inhabitant)	National average
BOD_5 (mg/l)	400	350	300	350
COD (mg/l)	1000	950	850	900
TSS (mg/l)	500	400	300	400
EC dS/m	2.0 – 3.0	2.0 – 2.8	1.8 – 5.5	

Compared to the overall water use in Morocco, reclaimed water can only provide a fraction of the country's increasing water needs. Furthermore, there is no regulatory framework for water reuse and no established system to recover the costs for reclaimed water from users. The country's largest reuse project is located in Marrakech, where reclaimed water from a 90,000 m^3/day plant will be reused primarily to irrigate golf courses.

Reuse of wastewater has not received much attention by the policy/decision makers due to lack of viable models with necessary research and technology support. Strong policies and legal framework at the national and state levels and sufficient trained manpower in the urban local bodies are required.

The application Decree (N°2-97-875, dated February 4, 1998) acting as water law 10-95 related to the use of wastewaters indicates that no wastewater can be used if it has not been beforehand recognized as treated wastewater. The use of raw wastewaters is thus forbidden.

The Norms and Standards Committee (NSC) acting under the National Environment Council is setting objectives for the quality of receiving environment (QUALITY NORMS). The NSC comprises representatives for all relevant ministerial departments. The Moroccan norms for water uses in agricultural irrigation are summarized in Table 6-3.

TABLE 6-3 QUALITY STANDARDS FOR IRRIGATION WATERS IN MOROCCO

Parameters	Limit Values
BACTERIOLOGICAL	
Fecal Coliform	1000/100ml *
Salmonella	Absence in 5 L
Cholera Vibrio	Absence in 450 ml
PARASITOLOGICAL	
Pathogen	Absence
Eggs, Parasite cysts	Absence
Ancylostoma larva	Absence
Flurococercaires of Schistomosa hoematobium	Absence
PHYSICO-CHEMICAL	
Mercury Hg mg/l	0,001
Cadmium Cd mg/l	0,01
Arsenic As mg/l	0,1
Chrome Cr mg/l	0,1
Lead Pb mg/l	5
Copper Cu mg/l	0,2
Zinc Zn mg/l	2
Selenium Se mg/l	0,02
Fluorine F mg/l	1
Cyanide Cn mg/l	1
Phenol	3
Aluminium Al mg/l	5
Beryllium Be mg/l	0,1
Cobalt Co mg/l	0,05

Iron Fe mg/l	5
Lithium Li mg/l	2,5
Manganese Mn mg/l	0,2
Molybdenum Mo mg/l	0,01
Nickel Ni mg/l	0,2
Vanadium V mg/l	0,1
Physicochemical parameters	
Total Salinity totale (STD) in mg/l	7680
Electrical Conductivity (EC) dS/m at 25°C	12
Sodium (Na)	
surface Irrigation (SAR)	9
Sprinkler Irrigation (mg/l)	69
Chloride (Cl)	
surface Irrigation (mg/l)	350
Sprinkler Irrigation (mg/l)	105
Sulfate ($SO4^{2-}$) en mg/l	250
Nitrate Nitrogen (N-NO3-) in mg/l	30
Bicarbonate (HCO3-) Sprinkler irrigation in mg/l	518

Wastewater Treatment and reuse in Tiznit area: Forage, vegetables and fruit three crop production using treated wastewater in southern of Morocco

6.2 IDENTIFICATION OF BEST PRACTICES REGARDING WASTEWATER REUSE IN MOROCCO

6.2.1 METHODOLOGY

The identification of best practices was based on an extensive literature review and meetings with stakeholders

6.2.2 INVENTORY

The following Table 6-4 summarizes some national reuse projects and **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.** shows their localization within the Kingdom of Morocco:

TABLE 6-4 WASTEWATER TREATMENT TECHNOLOGIES AND TYPE OF REUSE

Project	Treatment technique	Type of Wastewater Reuse	Treatment capacity (m^3/day)
Marrakech	Activated Sludge	Golf Irrigation	90720
Agadir	Infiltration-Percolation	Golf Irrigation	50000
Ben Slimane	Aerated Stabilization pounds	Golf irrigation	5600
Biougra	Natural Lagons + Infiltration-	Underground recharging	1600
Tiznit	Natural Lagons	Agriculture crop production	4900

6.3 IDENTIFICATION OF 3 EXEMPLARY BEST PRACTICES IN WASTEWATER REUSE

6.3.1 BP1: NATURAL TREATMENT SYSTEMS FOR UNRESTRICTED IRRIGATION: FORAGE, VEGETABLES AND FRUIT TREE CROP PRODUCTION USING TREATED WASTEWATER IN SOUTHERN MOROCCO

6.3.1.1 Technical criteria.

1. The natural treatments system in Tiznit delivers treated effluent that can be used in unrestricted irrigation.
2. Reuse of treated wastewater is integrated in the national policies and strategies of Morocco
3. The Tiznit treatment and reuse system is in operation
4. The lagoon treatment technology is cheap and easy to operate and maintain. The possibility of unrestricted irrigation of high value crops with an extended season increases the potential revenue from agriculture and consequently, the feasibility of the investment if water tariffs cover investment and operation costs.

6.3.1.2 Impact.

1. Increased wastewater reuse for agriculture with unrestricted irrigation and reduced reliance on freshwater
2. Farmers have developed agriculture projects using the treated wastewater
3. The project has led to the reduction of poverty and unemployment in Tiznit

6.3.1.3 Technical feasibility

1. Lagoon systems are easy to operate and maintain and are highly reliable in producing the required quality of treated effluent.
2. The need for expertise is low since it is a natural treatment system. The only mechanical component is a pump used to deliver water to lands upstream of the WWTP.
3. The system has shown success in delivering water of appropriate quality for irrigation and in satisfying farmers who have invested in agriculture.
4. The project is successful and can be replicated due to its low cost and simplicity of operation.

6.3.1.4 Financial feasibility.

The practice has been reported to be financially feasible.

6.3.1.5 Affordability.

The main variable to assess affordability is the cost of land and the cost of resources. This is highly variable among different countries.

6.3.2 BP2: WASTEWATER REUSE FOR IRRIGATING MARRAKECH GOLF COURSES: PUBLIC-PRIVATE PARTNERSHIP FOR FINANCING WASTEWATER REUSE INFRASTRUCTURE

6.3.2.1 Technical criteria.

1. The WWTP in Marrakech delivers treated effluent that can be used in the irrigation of golf courses.
2. Reuse of treated wastewater is integrated in the national policies and strategies of Morocco
3. The Marrakech treatment and reuse system is in operation
4. The Marrakech WWTP is financed through a PPP between the state and golf operators resulting in increased reuse of treated wastewater and reduced financial burden on the state.

6.3.2.2 Impact.

1. Increased wastewater reuse for irrigating golf courses and reduced reliance on freshwater.

2. The increased availability of irrigation water through treated effluent has contributed to the development of Golf tourism in Morocco.

6.3.2.3 Technical feasibility

1. The PPP for financing the WWTP is successful
2. The treatment system is reliable requiring medium expertise for operation and maintenance
3. The PPP is successful; it fulfils the need of the public sector in treating and disposing of treated effluent and the need for irrigation water by the private tourism sector.

6.3.2.4 Financial feasibility.

The practice has been reported to be financially feasible. Externalities such as carbon footprint, reduction in the use of freshwater, etc. have been factored in and show positive results.

6.3.2.5 Affordability.

The affordability of the investment is dependent on the use of water and the price paid by the operators of the golf courses compared to the price of freshwater and including all externalities.

6.3.3 BP3: BEST PRACTICES ON POLICY AND INSTITUTIONAL FRAMEWORK FOR THE REUSE IN MOROCCO

6.3.3.1 Technical criteria.

1. Developing policy and institutional frameworks for wastewater treatment and reuse, includes the issuance of standards for treatment, discharge and reuse. Most countries are making use of the WHO 2006 guidelines.
2. Developing a policy and institutional framework ensures integration of wastewater treatment and reuse in relevant national water and other policies and strategies
3. The policy and institutional frameworks have been developed are in use in Morocco
4. The developed policy and institutional frameworks in Morocco are considered to be highly effective and one of the best in the region.

6.3.3.2 Impact.

The policy and institutional frameworks increased the use of treated wastewater and reduced reliance on fresh water.

6.3.3.3 Technical feasibility

The development of a policy and institutional framework cannot be evaluated technically

6.3.3.4 Financial feasibility.

The return on investment of policies and strategies is an assessment that can be done after an application period.

6.3.3.5 Affordability.

Support can be provided to countries planning to overhaul their policy and institutional frameworks.

6.4 DOCUMENTATION OF BEST PRACTICES IN WASTEWATER REUSE.

6.4.1 BP1: NATURAL TREATMENT SYSTEMS FOR UNRESTRICTED IRRIGATION: FORAGE, VEGETABLES AND FRUIT TREE CROP PRODUCTION USING TREATED WASTEWATER IN SOUTHERN OF MOROCCO

6.4.1.1 Summary

The Biological System in Tiznit based on Anaerobic, facultative and maturation lagoons is an effective treatment technology leading to a good quality effluent that complies with WHO guidelines to be used without restriction for irrigation. This successful practice in the south of Morocco demonstrates that water reuse can be reliable, commercially viable, socially acceptable, environmentally sustainable and safe. In this particular project, cereals, cooked vegetables, fodder crops (namely alfalfa) and fruit trees were irrigated. The boosted productivity of the treated wastewater irrigated lands is significant with the direct beneficiaries being farmers, whose income, standards of living and economic status were elevated, thereby reducing unemployment and poverty. The cost of the treatment plant was about 4.8 million Euros and the reuse project to construct the pumping station and distribute the reclaimed water to farmers was 1 million US dollars. The cost recovery will be based on the fee of reclaimed water of 0.7 Dh/m^3 (0.06 euro/m3) that will be managed by the farmer association.

6.4.1.2 Narrative

The wastewater treatment is located in the West side of the city of Tiznit, in the southern part of Morocco (see fig 2). It occupies a surface area of 39 hectares, and it was first operated in 2006. The total cost of the plant was 41 Million Dirham (3.8 Million Euros). Part of the cost (70%) was supported by ONEP through a German cooperation (KFW) and the rest was paid by the municipality who offered the land (Daoudi 2011).

The region of Tiznit suffers from a water stress. The average rainfall is 150 mm per year. In this context of scarcity, the major concern is, in fact, protecting resources and conserving water for the region. Treatment and reuse of treated wastewater in agriculture is thus presented as a key solution. This allows exploiting a resource with additional water available at all times. Reducing operating costs by minimizing chemical fertilizer is also to consider.

Among the strengths of the project, the position of the wastewater treatment at the periphery of the city located in the middle of an urban area with a surface area suitable for agriculture. In addition, the seasonal peak water production with the return of Moroccans workers from Europe coincides with rising water needs of crops. It should also be noted that the station can operate year round without the need for storage; even when the rainfall is low and the temperatures are high. In addition, the water quality fully meets the rotation proposed by the local cropping systems.

For the implementation of this treated wastewater reuse project in Tiznit, several steps have been taken. A monitoring committee was first created; It is led by the Provincial Delegation of Agriculture (DPA). An agreement between all stakeholders, including the health department, was developed with well-defined responsibilities. Most of the farmers will use drip irrigation as a suitable technique to irrigate their crops, because of the water quality and low volume of water available. The government will subsidize 100% of the investment needed for drip irrigation system. Therefore, it is possible to double the surface to be irrigated with treated wastewater by the year 2015. 9 Million DH (about 1 million US dollars) was invested in the reuse project to pump the effluent to the irrigated areas and install the irrigation network. The hydro-agricultural development is funded by the Agricultural Development Fund (source: Fiche projet de la REUE de la ville de Tiznit)

FIGURE 6-1 LOCALIZATION OF THE TIZINIT WWTP

(Source: Optimisation de la réutilisation dans l'agriculture cas de Tiznit)

The treatment plant was designed for an average flow of 4900 m^3 for the first phase and 5800 m^3 for the second phase Table 6-5. The treatment plant is a natural lagoon system Figure 6-2, using a primary treatment (3.1 days retention time in an anaerobic basin), and secondary treatment (24.3 days retention time in a facultative basin), and a tertiary treatment (12.21 days retention time in the maturation pond).

TABLE 6-5 CHARACTERISTICS OF THE PLANT DESIGN

Designation	Unit	1st Phase (2010)	2nd Phase (2015)
Capacity	capita	65.700	78.850
average flow	m^3/day	4.900	5.800
BOD_5	Kg/day	2.550	3.300
SS	Kg/day	3.000	3.800

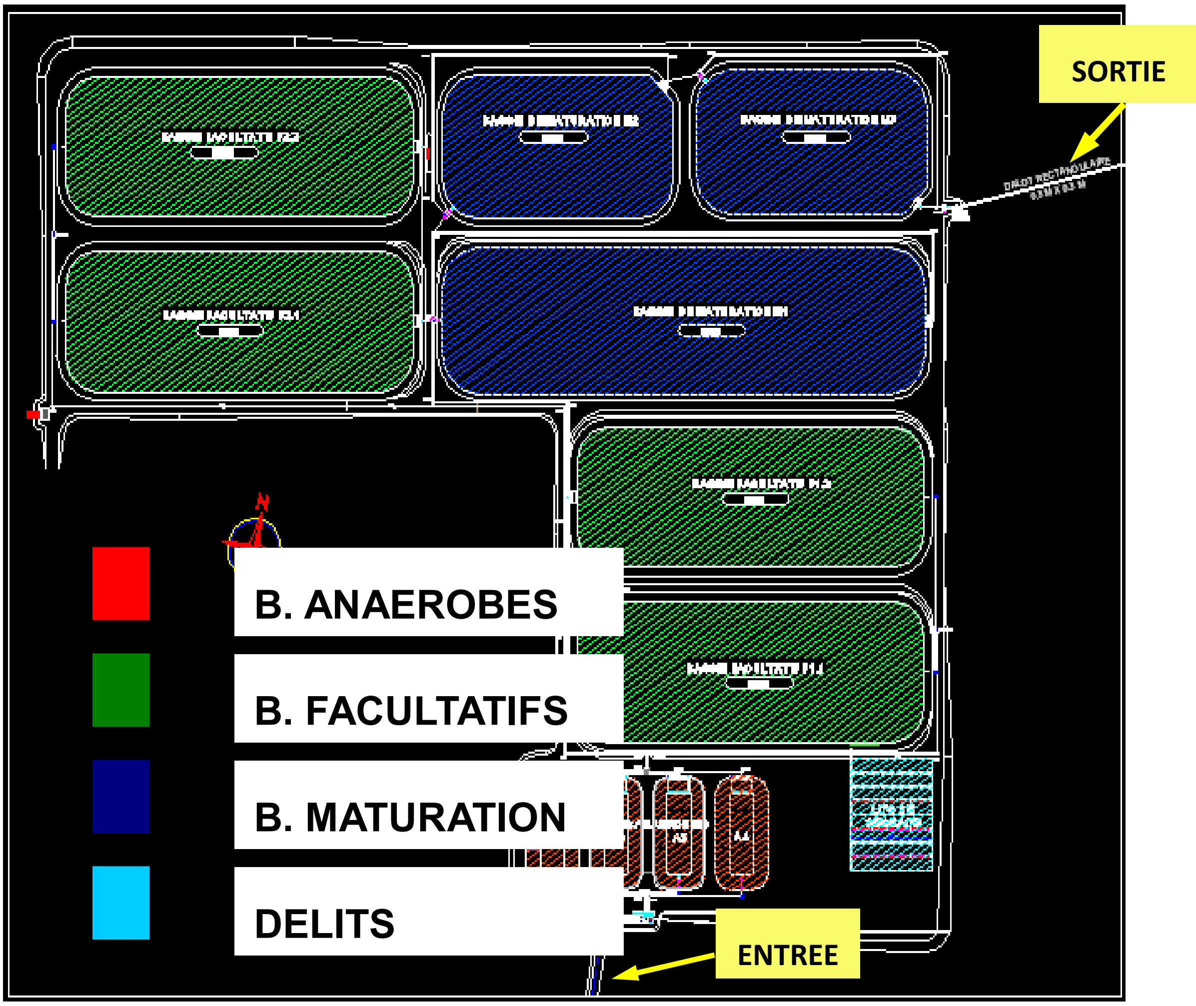

FIGURE 6-2 PLANT DESIGN LAYOUT (NGHIRA 2009)

The plant has four anaerobic basins arranged in parallel (see Figure 6-3). Each basin has a volume of 3 845 $m^{3,}$ a surface area of 960 m^2 and a depth of 4.0 m

FIGURE 6-3 ANAEROBIC BASINS (DPA TIZINIT 2011)

The effluents of the anaerobic basins will flow directly into a 4 parallel facultative basins (2x2) in order to eliminate helminthes eggs (Figure 6-4). Each facultative basin has a volume of 29 750 m^3, a surface area of 17 00 m^2, and a depth of 1.75 m

FIGURE 6-4 FACULTATIVE BASINS (DPA TIZINIT 2011)

The tertiary treatment is ensured by 3 maturation basins (Figure 6-5) arranged in series. Two small maturation basins have a volume of 13 500 m^3 and a total surface area of 11 250 m^2 with a retention time of 3 days each, and one large basin with volume of 28 800 m^3 and a surface area of 2 400 m^2 with a retention time of 6.21 days.

These Maturation basins reduce the faecal coliforms to less than 1000 CL/100ml.

FIGURE 6-5 MATURATION POND (DPA TIZNIT 2011)

Based on the WHO guidelines, these lagoon systems, under arid conditions, deliver treated effluent that can be used with no restriction for irrigation. The fecal coliform was always less than 200Units per 100 ml, and there were no Helminthes eggs after the maturation pond (Table 6-6). The salinity of the effluent is less than 2 dS/m, and it is rich in nitrogen and phosphorous, thus reducing the cost of fertilizers for the farmers

TABLE 6-6 PERFORMANCE OF THE WWTP OF TIZNIT (ONEP 2012)

Sampling point	Entry of the plant	Exit of the plant
T° of the water in C°	25,9	25 ,6
T° of the air in C°	23,0	26,0
pH	7,98	8,78
Fecal Coliform Nlp/100ml	1,6 10^7	200
Conductivity dS/m	1.5	1.73
O_2 dissolved mg O_2/l	0,0	3,8
BOD_5 mg O_2/l	520	70
COD mg O_2/l	-	46
SS mg/l	532	52

Two locations are using the treated wastewater of the Tiznit Plant. One is located downstream of the plant (Attbane) where treated wastewater could be conveyed by gravity, and the second zone in the upstream (Doutourga) where the effluent is pumped using a pumping station (Figure 6-6). A third zone that could be also irrigated by 2015, (Targa N'Zit) is located close to the second zone. The two farmers associations of these zones (Attbane & Doutourga) built a pumping station with the financial help of the state authority of the city of Tiznit, which will help them to distribute the treated effluent and the drip irrigation system to each farmer to save water. Each farmer will have a water meter and will pay the association a fee at the end of the month at a rate of 0.7 Dh/m3. These revenues will allow the association to pay for the electricity and the operation and maintenances of the pumping station.

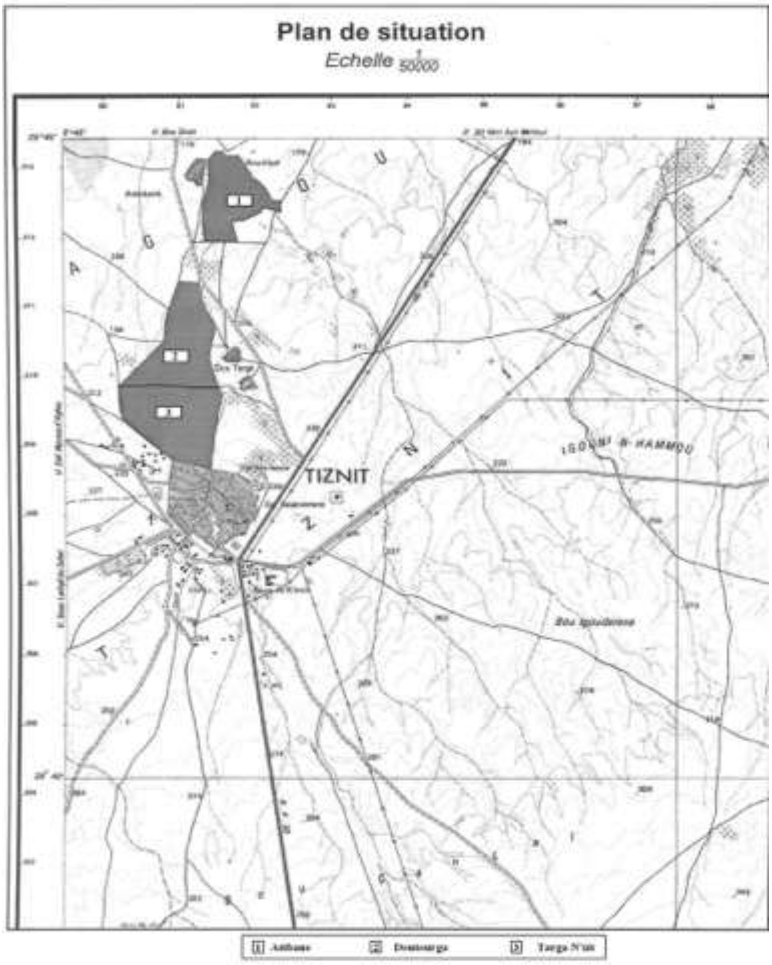

FIGURE 6-6 LOCALIZATION OF THE IRRIGATED PERIMETERS IN TIZNIT

(Source : Épuration et réutilisation des eaux usées de la ville de Tiznit a des fins agricoles)

The farmers of the areas of Attbane and Doutourga were organized in agricultural irrigation associations in order to facilitate awareness programs on the best practices for reusing treated wastewater. The total of the farmers plots were 665 with average size of 0.65 ha (Table 6-7).

The cropping system (see Table 6-8 & Figure 6-7) is based on fruit crops (olives & Pam trees), Cereals (Wheat & barley), vegetable crops and forage crops (Beans, cauliflower, Artichoke, alfalfa).

TABLE 6-7 LAND STRUCTURE OF THE IRRIGATED PERIMETER IN TIZNIT (DPA TIZNIT 2011)

Number of plots	665
Total irrigated area	433 ha
Average acreage of the irrigated plots	0,65 ha

FIGURE 6-7 VEGETABLE CROPS GROWN USING TREATED WASTEWATER ARE COOKED

(Source: Optimisation de la réutilisation dans l'agriculture cas de Tiznit)

TABLE 6-8 AGRICULTURE CROPPING SYSTEM IN IRRIGATED PERIMETERS (DPA TIZNIT 2011)

Sole	**Rotation**	Crops	% Irrigated area
Sole 1	Fruit crops	Olive threes	50
Sole 2	Cereals	Wheat/barley	25
Sole 3	Forage & legume	alfalfa/ forage Faba beans & Green beans	25

Within the Tiznit area, wastewater reclamation and reuse has contributed to the food security of the region by producing alfalfa, forage maize, olive, citrus, and cooked vegetables for several years using treated wastewater. In Morocco, the inclusion of wastewater reuse in its National Water Strategy since 2000 signalled the placing of a high priority on the value of reclaimed water. The high-quality treated wastewater coming out of the treatment plant and being used to irrigate alfalfa and olive trees demonstrates the safe and effective use of reclaimed water in irrigating high-value crops.

Water is playing a central role in curbing poverty and supporting economic development and stability of several regions of Morocco. The water imbalance is becoming more severe throughout the years, worsened by climate change in the country. As a result, the government of Morocco implemented various projects in order to satisfy water demands by integrating wastewater reuses as an additional water resource. The local agriculture extension service provided a great support to the dissemination of the best practices for the reuse of treated wastewater and the precautions to prevent any health risks for the farmers and the consumers, as well as for the protection of the soil and ground water deterioration.

The high competition between water use sectors: agriculture, industry, and tourism are leading to the use of marginal water in Agriculture. Non-treated wastewater reuse is a common practice since 1980; because of the increasing water demand, the succession of dry seasons (more than 5 years of drought) and increasing aquifer salinity. It is estimated that Tiznit, by the year 2020, will reuse 100% of the treated wastewater In the Agriculture sector.

This demonstrates that the reuse of treated wastewater in the region of Tiznit is reliable, commercially viable, socially acceptable, environmentally sustainable and safe.

The direct beneficiaries from this project and its expansion are the farmers and society, whose income, standards of living and economic status were remarkably elevated, almost reducing unemployment and poverty.

The productivity of the lands irrigated with reclaimed water was substantial. In fact, the processed wastewaters bring fertilizing nutrients and save inputs and increase the yield of the crops. Table 6-9 sums up the economic gains behind using treated wastewaters in agriculture. This chart is based on the performances obtained in Ouarzazate and Ben Sergao projects.

TABLE 6-9 ECONOMIC BENEFIT OF IRRIGATION WITH TREATED WASTEWATER (DMIC & SESAER 2012)

Cultivation	Neat Benefit on water (1) (Dh / year/ha)	Benefit on fertilizers (2) (Dh / year/ha)	Total benefit (Dh / year/ha)
Bread 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

(1) Calculated based on the cost of the pumping water in the Souss Massa area (0.7 Dh)

and the price of the treated wastewater (0.5 Dh)

(2) Calculated based on the value of the fertilizer content of the treated wastewater

Thus far, socio-economic indicators point to the positive impact of this pioneering project and its success, most evidently portrayed by increased income per family, elevated standards of living and economic situation of the local community and farmers. Hence, it can be stated that, in terms of financial viability, these projects have proved to be successful and sustainable, where revenues from fodder and fruit tree crops are high enough to cover the direct production costs and to provide an attractive income. This Water Reuse Project for Agriculture has created the opportunity for the local community groups to take responsibility for water management, while improving general efficiency and system performance and reducing costs for the farmers and the Government. The farmers worked towards solutions to increase their income and raise their standards of living, with great transparency within their local community.

This successful best practice could be replicated and is of a considerable potential for other regions of Morocco, as well as other Mediterranean countries, as they have similar climates and food security needs. Another very important lesson learned is related to the operational performance, and good public communication which are fundamental to the success of any water reuse project. It can only realistically be promoted where investments in wastewater collection and treatment systems have already or are soon to be made. Also, one of the most important lessons learned is that, to enable the Moroccan people to feel confident with re-used water for irrigation, it was imperative to establish trusted institutions to ensure that the highest standards of health and safety.

Lessons learned: This project provides

1. food (Cereals & vegetables) to the city.
2. It is cost effective and production is less costly.
3. It provides employment to the poor.
4. It creates a buffer between urban & rural area.
5. It provides oxygen in the environment.
6. It restores biodiversity.

6.4.2 BP2: WASTEWATER REUSE FOR IRRIGATING MARRAKECH GOLF COURSES: PUBLIC-PRIVATE PARTNERSHIP FOR FINANCING WATER REUSE INFRASTRUCTURE

6.4.2.1 Summary

The wastewater treatment plant of Marrakech was built with the aims to protect the environment, to sustain tourism and urban development of the city and to satisfy the water requirements (24 000 m^3/day) of 17 Golf courses and city landscaping. The State and RADEEMA provided 70% of the cost (125 Million US $) and the private sector provides the rest. The plant uses activated sludge for the secondary treatment, and a tertiary process using sand filtration, and Ultraviolet lamps. This year, the station will mobilize 33 million m3 of reclaimed effluent quality respecting the WHO guidelines (BOD5 15 mg/l, SS 10 mg/, Fecal coliform< 200U/100 ml, Intestinal nematodes < 1 egg/l). Energy recovery from biogas contributes to the reduction of greenhouse gas emissions and cover 45% of the electrical energy needs the plant. Even though, the region of Marrakech-Tensif is defined as an area of water stress, this project for the reuse of treated wastewater can guarantee a balance between the two conflicting requirements, namely the economic and touristic development of the city and the preservation of water resources.

6.4.2.2 Narrative

The region of Marrakech, with a strong growth in urbanization, tourism, irrigation, and population will suffer from increases in water demand. Therefore, a partnership between the Government of Morocco, the State Board of Marrakech (RADEEMA), the tourism and golf course developers, and the municipality launched a joint wastewater treatment and reuse project. Under this scheme, treated wastewater (approximately 90 720 m^3/day) will be routed to irrigate golf courses and the palm grove as well as urban green spaces. The project will allow the city to triple its area dedicated to golf courses, with long-term plans to irrigate golf courses exclusively with treated wastewater. The project’s treatment processes are made up of activated sludge followed by tertiary treatment using rapid filtration, UV and Chlorine disinfection. Investment costs as well as those of the complementary treatment of the WWTP were provided by the State subsidies and RADEEMA (70%) through its own financing and a loan from the Communal Equipment Fund (FEC). The remaining investments (30%) were borne by the private sector (RADEMA 2010).

Operating expenses related to tertiary treatment, pumping and transportation of treated wastewater to golf courses will subsequently be subject to an agreement between RADEEMA and the private promoters (Each golf course will invest 30 million Dirham to get connected to the reclaimed water network) and will pay, each month, a fee (personal communication) corresponding to the amount of treated water consumed at a fixed price of 2.5 Dh (1 Euro = 11 Dh).

This Example demonstrates the potential of private sector engagement in terms of financing as well as building, operating and maintaining infrastructure. Concession agreements with the private sector therefore should be considered as a potential option for sustainable reuse of treated wastewater infrastructure. This also demonstrates that a system using an effective treatment technology leading to a good quality effluent, and recycling over 30 million cubic meters of water annually, and contributing to the overall increase of wastewater reuse, and involving the end users (golf courses manager, municipality) in the design and management of this project, has permitted the achievement of sustainable wastewater treatment and reuse.

The plant is located in the North-East of the city of Marrakech, on the road to Safi city, in the central part of Morocco. (See Figure 6-8). It occupies a surface area of 40 hectares, and it was first operated in 2008 for the first phase and 2012 for the second phase. The total cost of the plant was 41 Million Dirham (3.72 million euro) (Part of the cost (70%) was supported by the Water district RADEEMA and the state subsidies and the rest was paid by the golf course private companies and the municipality offered the land.

FIGURE 6-8 GOOGLE EARTH PHOTO OF THE MARRAKECH WASTEWATER TREATMENT PLANT.

The treatment plant of Marrakech was built in two phases (Figure 6-9); the first phase had only systems for pre-treatment, primary treatment, sludge treatment, and energy recuperation (Figure 6-9), and in the second phase the secondary treatment and the tertiary treatment using UV and chlorination disinfection were added. The plant treats about 100 000 m^3 per day of raw influents with an organic load of 58 Ton per day (Table 6-10).

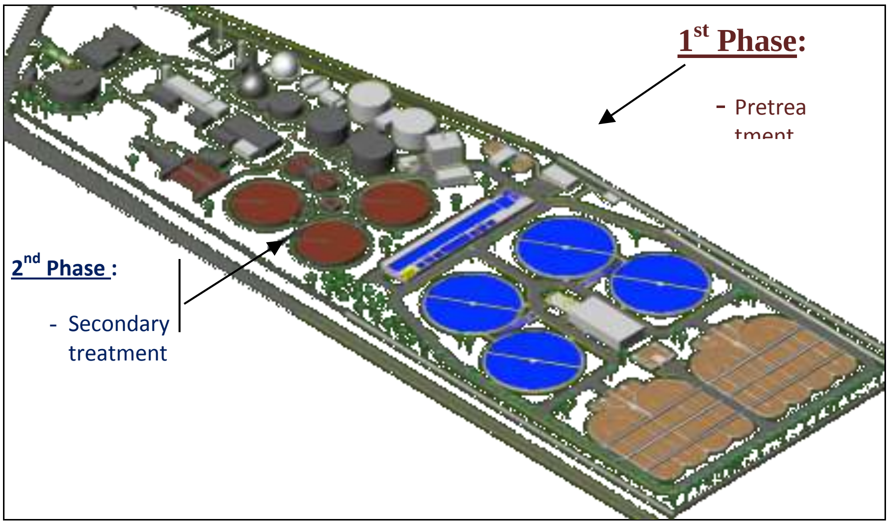

FIGURE 6-9 DESIGN LAYOUT OF THE TREATMENT PLANT OF MARRAKECH (RADEMA 2010)

TABLE 6-10 MARRAKECH WASTEWATER TREATMENT PLANT CAPACITY

Flow	90720 m^3/day
SS	53 t/day
BOD_5	58 t/day
COD	144 t/day

TABLE 6-11 MARRAKECH WASTEWATER TREATMENT PLANT PERFORMANCE

Quality parameters	STP Inlet	Primary treatment	Secondary treatment	Tertiary treatment
SS (mg/l)	584	200	30	5
BOD5 (mg/l)	640	430	30	10
TKN (mg/l)	120	120	5	5
TP (mg/l)	22	22	20	10
Fecal Germs	10^7 U/l	10^7 U/l	10^6 U/l	Less than 200 U/l

FIGURE 6-10 AERATION TANKS

FIGURE 6-11 CLARIFICATION (SECONDARY CLARIFIER)

The Objective of the tertiary treatment is to reach the required quality for reclaimed water (A » level) reuse for landscape irrigation (lawn, golf course) according to WHO guidelines.

Process:

Quick sand filtration followed by Ultra Violet disinfection with chlorination

TABLE 6-12 QUALITY OF THE TREATED WATER AFTER TERTIARY TREATMENT (RADEEMA 2010)

BOD_5	15 mg/l
SS	10 mg/l
Fecal germs	< 200U/100 ml
Intestinal nematodes	< 1 egg/l

FIGURE 6-12 RAPID SAND FILTRATION

Figure 6-13 UV disinfection and chlorination

The project is designed for energy efficiency; the biogas production will provide about 40% of the energy needed by the Plant (Table below) and contribute to carbon emission reduction and environmental protection.

TABLE 6-13 ENERGY PRODUCTION AND SAVINGS IN MARRAKECH WWTP (RADEEMA 2010)

Construction Phases	2nd phase	1st phase
Biogas production (Nm^3 /d)	20’000	11’000
Generated electricity (KWh /d)	30’000	16’000
STP consumption (KWh/d)	65’000	12’000
Savings in barrels of oil equivalent / day	24	10
Generated heat (KWh /d)	44’000	22’000
Digestion heat requirements (KWh /j)	40’000	20’000
Savings in barrels of oil equivalent / jour	32	16

Reduction of Greenhouse gases (t.eq.CO_2 /year)	66’000	36’000

This additional water resource will be targeted to irrigate 17 Golf courses touristic, and the Palm groove green belt, as well as the greening of the city. These areas account for about 1200 hectares and will require 24 Mm^3/year. This project will also need 60 km of Pipes and 4 Pumping Stations.

FIGURE 6-14 LOCALIZATION OF IRRIGATED GOLF COURSES IN THE CITY OF MARRAKECH

In Marrakech, a partnership between the Government of Morocco, the State Board of Marrakech (RADEEMA) the tourism / golf course developers, and the municipality launched a joint wastewater treatment and reuse project. Under this scheme, treated wastewater (approximately 100 000 m^3/day) will be routed to irrigate 17 golf courses and the palm grove as well as urban green spaces. The project will allow the city to triple its area dedicated to golf courses, with long-term plans to irrigate golf courses exclusively with treated wastewater. The project’s treatment process utilizes activated sludge followed by tertiary treatment by rapid filtration and UV disinfection.

Several benefits could be listed for this project:

- It does satisfy the increased water requirements for new golf courses.
- It allows the mobilization of a renewable resource for landscape irrigation.
- It does preserve underground water resource – strategic resource
- It does comply with the Moroccan integrated management of water resources strategy

- 33 Million m^3/year of reclaimed wastewater will be available additional alternate resource for the region of Marrakech
- Similar project are underway in other region of Morocco (Agadir, Ben Slimane)
- The replication of the same project in the Mediterranean region is feasible
- The species of vegetation planted (grass, trees);
- The nutrient needs of these species;
- The theoretical reclaimed water supply volume in the field (average);
- The hydraulic retention time of the storage facilities (as a long retention time will diminish the nutrient content in reclaimed water).

With respect to Northern Africa, it must be stated that reclaimed water is sometimes the only resource available for irrigation. Hence, several of Morocco's 20 courses (e.g., those in Marrakech) and Tunisia's 10 courses (e.g., Tunis) are being irrigated with reclaimed water. Hence, in consonance with the expansion of golf tourism in Mediterranean areas, it is certainly evident that reclaimed water will be necessary for irrigating those facilities, which in turn makes it clear that the development of reuse practices for irrigation of golf courses is becoming increasingly necessary.

In several countries, notably those in the Mediterranean, golf development has been pinpointed as a target of the environmental activists on the grounds of a supposed excess of water and land consumption, as golf courses are often associated with luxury resorts, real estate developments and other land-consuming infrastructures.

Certainly, given the increasing availability of treated and reclaimed water and the water needs of golf courses, the future development of the sport in areas without surplus water resources will predictably depend upon the use of reclaimed water. Its use for irrigation is essential, not only because of the lack of water resources, but also due to the increasing criticism of the use of conventional water resources and the improvement of the tools that guarantee the safe use of reclaimed water. This source must then become one of the basic resources of the Mediterranean golf courses.

Morocco has been facing a severe drought for the last twenty years; therefore, it was apparent for the decision-makers at the highest political levels that there is a need to find new solutions to the challenges of water resources management that are getting pressing. Within this framework, great efforts have been developed to reduce demand and search for new water supplies, to face drought and increased population growth. The reuse of treated wastewater could contribute to fill the gap, and reduce water resources pollution.

6.4.3 BP3: BEST PRACTICES ON POLICY AND INSTITUTIONAL FRAMEWORK FOR THE REUSE IN MOROCCO

6.4.3.1 Summary

The Moroccan Government decentralized responsibility for water supply and sanitation services to the municipalities, and left to them the right to choose how to manage service provision from a menu of several choices. Morocco has introduced autonomy and privatization to urban water supply and an ambitious sanitation national plan with an objective to reduce total water pollution by 60% was developed. A strategy for handling wastewater from the source to the users has been developed. The operational performance of the chosen technology to treat wastewater, sound institutional arrangements, conservative cost and cost effectiveness of wastewater reuse, realistic reclaimed water sales estimates, and good public communication are fundamental to the success of some of the water reuse projects in Morocco.

6.4.3.2 Narrative

Within the context of increasing scarcity and degradation of water resources, wastewater reuse (WWR) appears as a good alternative for Morocco to reduce the gap. The WWR can indeed have several types of benefits, which vary depending on the circumstances, including: (i) the elimination of the impact of the wastewater treatment plant effluent discharge into the natural environment, (ii) the recovery of an additional water resource for different possible reuses, and, consequently,(iii) conservation of fresh conventional water resources of the highest quality (required for demanding uses such as drinking water). WWR possibilities in Morocco include agricultural irrigation, watering golf course, municipal landscaping, groundwater recharge and industrial uses (Bourziza & Makhokh 2011)

In Morocco, it is the Regional Council that is legally responsible for the management of water resources. The King Hassan II launched a national policy for water in 1967 with the construction of dams to irrigate over 1 million hectares of land by 2000 and to give the whole population access to drinking water. Morocco currently has 130 large dams. In June 2001, King Mohamed VI launched an appeal for the implementation of a modern water policy.

The major problem affecting water resources management concerns the pollution of surface and ground waters and the lack of recovery and treatment of wastewater on the outskirts of major cities. Therefore, promoting WWR goes through the establishment of a regulatory framework, institutional and financing specific projects of wastewater reuse, with close collaboration of the Ministries of Water and Environment, Public Health and agriculture.

Recently the results of a study on wastewater reuse strategy by the Ministries of Water and Environment helped clarify:

1. The potential demand and development of WWR in Morocco

2. The objectives and the implications of a national strategy for the WWR
3. Funding models and conditions of financial support from the state (financial sustainability)
4. The needs of the institutional framework and specific regulations WWR
5. Technical options and operational costs (processing, storage, application)
6. The need for stakeholder awareness
7. The coherence of the institutional framework for industrial discharges

Morocco has worked to manage irrigation with wastewater for several decades through several pilot projects (Ouarzazate, Bensergao, Drarga). However, since early 2005, the general approach has been to treat the wastewater of major cities and to reduce by 60% the water pollution at the national level by the year 2020 (Mohamed RIFKI 2010). This program covers 260 cities and urban centers, totaling a population of more than 10 million, and the amount of investment for this program is 43 billion Dirhams, which is equivalent to about 5 billion US dollars.

Given the diminishing per capita freshwater supply, the increasing dominance of effluent in the water balance, the overloading of wastewater treatment plants, local riparian water rights, and the need to protect domestic and export produce markets, effectively managing water reuse, including enforcement of existing regulations, has become increasingly challenging.

Moroccan government has set a policy and institutional framework which contributed successfully into the overall increase of wastewater reuse all over the country. This review presents the adopted strategy, the legal and institutional framework improvement, to achieve an environmental and social protection for the reuse of treated wastewater.

The Moroccan Water Strategy

Due to droughts and water scarcity, the state of the assets in terms of water supply and sanitation, the complex and fragmented water sector institutional framework, Morocco has developed a water sector strategy which provided answers to these issues and led to the issuance of the Water Law of 1995.

The National Water Strategy was approved by the government in 2009 (Bourziza & Makhokh 2011). It states that the reuse of wastewater is an important non-conventional water resource, and its recovery should be placed in the context of nationally integrated water resources. The main provisions of the strategy for promoting Reuse revolve around the following:

Integration of the feasibility studies of reuse projects as part of the National Liquid Sanitation Program (PNA). The approach includes three stages: a scoping study, a feasibility study and a detailed implementation study. This three-step approach allows and facilitates a rapid screening of projects that are more realistic and feasible;

Development of tertiary treatment as an additional step to promote non-restrictive reuse in agriculture;

Building reuse options such as watering lawns, municipal use and irrigation of hotel gardens, industrial reuse, groundwater recharge and inter-seasonal storage;

Improved coordination between various stakeholders involved in the sanitation projects, and reuse of treated wastewater;

Capacity management of water resources and private sector involvement in the activities of reuse;

Increased awareness to gain public support and overcome the reluctance to wastewater reuse;

Attenuated negative impacts associated with reuse, by choosing appropriate and reliable techniques;

Establish a program and monitor the quality of ground water and strengthen health control and hygiene measures in irrigated areas reusing treated wastewater

The elements of the strategy and action plans

This water strategy was reinforced by the National Plan for Water, which incorporates wastewater in the overall supply of mobilized water resources. It also examines the overall potential of wastewater reuse on a national scale. The Integrated Development of Water Resources Plans (PIDWR) updated periodically by ABHS (Hydraulic Agencies of Watersheds) integrates wastewater in calculating the overall water balance at catchment level and examine the potential for wastewater reclamation particularly in agriculture. In principle PIDWR studies related to the reclamation of potential wastewater at the watershed scale must include:

- A study of the "market" of sewage. This includes: a study on the wastewater reusability; conventional alternative water supplies (costs); survey of potential users of wastewater and informing potential users.
- Developing Reuse scenarios taking into account technical and socio economic aspects.

The National Sanitation Program (PNA)

The National sanitation Plan (PNA: Plan National d'Assainissement) contributes to the strategic planning of the WWR in Morocco by a broad reflection on the objectives of a national policy WWR, and its implications. WWR strategy can be envisaged only as part of a strategy for the conservation and protection of resources, itself embedded in a clear policy of demand management (Mohamed RIFKI 2010). The development of WWR is rarely economically justified before implementation of water saving programs. Sustainable WWR projects require strict regulation of withdrawals for other resources that need to be preserved.

The Ministry of Interior and the SEEE (Secretary of state in charge of water & environment) manage the National Sanitation Plan (PNA). The program integrates treatment and reuse of wastewater remediation projects. The PNA over a period up to 2020 identifies priorities for sanitation (Mohamed RIFKI 2010) and wastewater treatment and establishes financial arrangements for projects. Program funding is provided by state grants, financial contributions of donors (WB, EIB, KfW, AFD...) as well as input from sanitation department managers (Boards, ONEP Commons Etc.).

Sanitation Fund and Liquid Waste Wastewater – FALEEU

This fund is managed by the Ministry of Interior to be used by the municipalities and rural communes as a loan with a very low financial rate to promote investment in wastewater sewerage network and treatment plant.

Policy Options for the use of NCWR based on cost benefit analysis

The wastewater reuse projects in Morocco focuses on four components, namely agricultural, landscape, industrial reclaimed water reuse and institutional capacity building. The agricultural component aims at further developing the sites close to the wastewater plant, and involving the end users (Farmers association, private holders) to achieve sustainability. The landscape component established sites in several cities (Marrakech, Agadir, Ben Slimane, Essaaouira) to promote the use of treated wastewater for irrigation of urban landscaping and golf courses, while the industrial component targets the Phosphate industrial sector to encourage resources conservation, pollution reduction, and the promotion of an Environmental Management System framework approach. The national programme on reuse, also engages in institutional strengthening and public participation activities, and public awareness and training events to improve acceptance of water reuse. Furthermore, part of the PNA project has included the development of sustainability plans, addressing financial, marketing, environmental and technical aspects of the reuse sites in the future. This is achieved through working with stakeholders and local agencies government to address and formulate the national policy on the role of reuse in Morocco.

Actually, Morocco produces 700 million cubic meters of domestic wastewater containing 360,000 tons of organic matter, 43 % of this amount will be produced by coastal cities.

It is forecasted to reach 900 million by the year 2020 (source: Country report for the Expert Consultation on Wastewater Management – Morocco).

In 2011, Morocco had 62 sewage treatment plants that treat 25% of the wastewater produced by urban areas. Treatment levels reached by these plants are as follows:

- Plants with primary level of treatment;
- 40 plants with secondary level of treatment;
- 16 plants with tertiary level of treatment.

Improving the legal framework

The legal and regulatory framework for wastewater reuse

The actual legal bases for wastewater reuse activity are complete, and appropriate, but the problem is their implementation and their effective implementation. This can be naturally also linked to the fact that among the many texts that exist, some are partly contradictory and are designed in order to respond to an integrated resource management approach. In this context it is already planned to launch a process to amend the Water Act of 1995. The proposed revisions to the Act have been submitted to the ICE in 2008 and introduced for ratification in 2009 (Source: Country report for the Expert Consultation on Wastewater Management – Morocco).

The Water law 10/95 has provided a number of legal provisions aimed at regulating the reuse of wastewater. Among the most important provisions are the following articles:

Article (84): imposes restrictions on wastewater reuse in agriculture whenever its quality doesn't meet quality standards.

Article (57): imposes a prior permit on wastewater reuse. This article also authorizes the hydraulic watershed (basin) agency to provide technical and financial assistance to promote wastewater treatment and reuse;

Article (51): on the establishment of standards for water quality for irrigation and other uses. These standards are developed by the Norms and Standards Committee, established by decree and revised every ten years or whenever the need arises. The ABH (Hydraulic watershed agency) are required by the Water Act to take measures to ensure that water quality meets Moroccan standards.

Article (54): restricts wastewater disposal into the environment without treatment;

Article (52): imposes a prior permit for wastewater disposal.

Moroccan standards and guidelines for the REUSE OF treated wastewater

In 1994, The High Council for Water and Climate set recommendations aimed at promoting the reuse of wastewater by adopting nationally consistent policies including sanitation, water treatment and reuse of treated wastewater (Reuse), and establishing institutional structures and regulatory measures (MEDA-EURMED 2009). In terms of health standards and regulations in agriculture Reuse, the Council recommended the following: "It is necessary that Morocco sets standards based on data accumulated from pilot experiments and other countries experiences as well as recommendations and guidelines from international organizations.

The Water law 10/95 has provided a number of legal provisions aimed at regulating the reuse of wastewater. Article (51): on the establishment of standards for water quality for irrigation and other uses. These standards are developed by the Norms and Standards Committee, established by decree and revised every ten years or whenever the need arises. The AHB (Hydraulic watershed agency) are required by the Water Act to take measures to ensure that water quality meets standards (MEDA-EURMED 2009).

Since 2002, Morocco has specific wastewater reuse regulations (Bourziza & Makhokh 2011)the decision n° 1276-01 of 10 chaabane 1423 (17 octobre 2002) jointly established by the Ministry of Equipment and the ministry in charge of water and the environment sets standards for irrigation water.

Morocco has adopted fully the World Health Organization and Food and Agricultural Organization guidelines. The Moroccan standards of water quality for irrigation must meet the quality standards set out in the tables below (Table 6-14 and Table 6-15)

TABLE 6-14 MOROCCAN WATER QUALITY STANDARDS FOR IRRIGATION (GROUPEMENT D.M.I.C & SESAER NOTE DE SYNTHESE 2011)

Parameters	limits Values
bacteriological Parameters	
Fecal Coliform	1000/100 ml
Salmonella	Absence in 5 l
parasitological Parameters	
Pathogen Parasites	Absence
Helminthes Eggs	Absence
Suspended solids in mg/l	
Surface Irrigation	2000
Drip and sprinkler Irrigation	100
6.4.3.2.1 Nitrate nitrogen (N-NO3-) in mg/l	30
Bicarbonate (HCO^{3}-) Sprinkler irrigation mg/l	518
Sulfate ($SO4^{2-}$) in mg/l	250

The Moroccan guidelines have been adapted to local conditions. In Fact, different levels of accepted quality will give incentives for an improvement in wastewater quality over time. Viable options based on different treatment levels for different uses of wastewater (including food and non-food crops, landscaping and groundwater recharge) have been assessed accounting for the parameters of the Moroccan social acceptance.

ONEP in collaboration with FAO, developed codes of practice containing certain provisions for not impairing the quality of groundwater, for the prevention of leaching from storage, and for the selection of application periods in terms of weather conditions (Soudi & Xanthoulis 2007). The code of practices also includes criteria for crop selection; and the selection of the appropriate irrigation method. The choice of wastewater irrigation application method depends on the quality of the effluent, crops to be grown, farmers' tradition, background and skill of the farmers and the potential risk to workers and to public health. Localized irrigation techniques, e.g. bubbler, drip, trickle offer farm workers the most health protection because they apply wastewater directly to the plants roots.

TABLE 6-15 CATEGORIZATION OF WATER QUALITY FOR IRRIGATION DEPENDING ON THE ELIMINATION OF PARASITE EGGS AND FAECAL COLIFORM (MOROCCAN STANDARD- EXTRACT DECREE OF 17 OCTOBER 2002)

Category	Condition of realization	Exposed group	Intestinal nematode (arithmetic average of the number of eggs per liter	Fecal coli forms (geometrical average of the number per 100ml)	Techniques of treating waste water susceptible to assure the desired microbiological quality
A	Cultures consumed uncooked, sport areas & public gardens (c)	Workers & public consumers	Absence	1000/100ml and Stop irrigation 2 weeks before picking & discard falling fruits	Series of stabilization's water basins designed in a way enables us to obtain the desired microbiological quality or any other equivalent treatment.
B	cereal, industrial & fodder crops, pastures & trees (d)	Workers	Absence	Any criteria is not recommended	Keeping the waste water in the basins of stabilization for 8-10 days, or using any other technique that allows us to carry out an equivalent elimination of helminthes & fecal coliforms.

C	category B, if workers and public are not exposed	none	Without object	Without object	Treatment should be carried out according to the technique of irrigation, but at least a primary purification should be made.

Cost recovery and tariff for wastewater reuse

The efficiency of operators

Improving the performance of operators by reducing operating costs generates greater cash flow margins for sanitation. Although the performance of management operators is addressed in the overall context of regulatory reform in the sector, it has been initiated by short-term measures, starting with the establishment of bench marking of national and of conditional subsidies for efficiencies. However, due to staff costs and relatively contained energy, productivity gains, operators should not fundamentally alter the funding equation of PNA (MEDA-EURMED 2009). Fees on the potable water consumer considered as a polluter have been set, and the actual tariff of 2 dirham, will rise to about 3.5 dirham in 2020 (Personal communication).

Fees for recycled wastewater

Concerning recycled water, currently, there is no formal procedure for implementing fees on the reuse of wastewater. In fact, specific contracts or bilateral contracts between producers of treated wastewater and end users are established. Examples of bilateral contracts between the producer of treated wastewater (RAMSA, RADEMA) and the golf course owners in Agadir and Marrakech was set for a price of 2.5 Dh per m^3 (1 Euro = 11 Dh). Other contracts are set between the farmers and their association for a price of 0.7 Dh per m^3 in the case of Tiznit.

Institutional framework for non-conventional water resources

Organization and agencies involved in wastewater reuse management

The Moroccan Government decentralized responsibility for water supply and sanitation services to the municipalities, and left to them the right to choose how to manage service provision from a menu of several choices (ACWUA Report 2010: Wastewater Reuse in Arab Countries). Morocco has also introduced autonomy and privatization to urban water supply. In 1995, the focus of water sector policies shifted to demand management, resource protection, and expansion of service in rural areas. In fact, an ambitious sanitation national plan with an objective to reduce total water pollution by 60% was developed.

The creation of different institutions or entities with separate lines of authority and accountability has made it possible to define clear commercial objectives for the water supply providers. Also, the establishment of a rigorous and independent monitoring regime allowed the continuous assessment and comparative evaluation of the different water supply provider performance.

All large cities and many urban centers delegated the provision of water supply to specialized operators decades ago, and this urban market segment is now fairly evenly distributed among private concessionaires with 38 percent of the market share, ONEP with 28 percent of the market share, and Regiswith 31 percent of the market share. Rural water supply remained part of core municipal functions until the mid 1980s and mid 1990s, respectively, with functions gradually delegated to ONEP with almost all the towns establishing an agreement with ONEP.

The National Potable Water Board, (Office national de l'eau potable: ONEP)

This is a financially autonomous public water enterprise that plays an important role in planning and executing the Government's strategic water sector goal. It produces 80 percent of the bulk water supply in the country, provides retail water supply and sanitation services in medium and small towns, and is currently responsible for developing rural water supply. In an effort to consolidate managerial, technical, and financial resources in a national agency for potable water production ONEP took over responsibility for bulk water production. Since January 2004, ONEP has been solely responsible for achieving the Government's rural water supply objectives to provide potable water access to rural populations (MEDA-EURMED 2009).

Private concessions for the distribution of water and sanitation

In April 1997, a 30 year concession for the distribution of water, sewerage and electricity service was announced between the municipalities of Casablanca and Mohammedia and LYDEC, an international consortium controlled by the Suez group. This concession was followed by another concession in 1999 by negotiation for the Rabat and Sale capital metropolitan area, and by competitive bid concessions in Tangiers and Tetouan in 2002.

Roles and responsibilities for wastewater treatment and reuse

There are four institutional frameworks for the management of wastewater in Morocco:

Direct Boards Management (municipal utilities): they implement sanitation facilities while operation and maintenance are performed by municipal services;

Management by Autonomous Boards (Regies): The management of sanitation facilities is provided by Autonomous Boards in charge of water and electricity supply. Currently, this form of management has been chosen in sixteen cities and centers: Agadir, Fez, Oujda, Marrakech, Beni Mellal Meknes, El Jadida, Kenitra, Larache, Nador, Settat, Safi, Soualem, Sahel, Sidi Rahal Chatii, Drouais;

Delegated management to private concessionaires: The sanitation service (in addition to drinking water and electricity) is delegated to private international companies under a concession contract. Indeed, four concessions have been given to companies to manage sanitation in Casablanca (Lydec), in the Wilaya of Rabat-Sale (REDAL) and in the cities of Tangier, Tetouan and its coastal zone (VEOLIA).

Management by the National Office of Drinking Water (ONEP): Since September 2000, ONEP has been in charge of sanitation in some small and medium centers where it insures water distribution services.

Financing models for wastewater treatment and reuse in Morocco

Agencies responsible for sanitation management like ONEP and the Autonomous Boards resort to loans with national or international banks to complete the financing of wastewater treatment projects (70% of projects cost for cities of more than 50,000 inhabitants and 50 % of projects cost for cities of less than 50,000 inhabitants). The rest of the funding needed to complete the funding of the program will be provided by users through tariffs that will rise from an average of 2 dirham in 2005 to about 3.5 dirham in 2020.

TABLE 6-16 WASTEWATER TREATMENT AND REUSE MODELS OF FINANCING

	Finance	Operators	Cost recovery
Sanitation and Treatment at the regulatory level	The state	Water and sanitation managers: local communities,, ONEP, Authorities, Private Dealer	Sanitation charges to consumers
Complementary purification **Distribution** **Reuse in: golf courses** **Landscaping, groundwater recharge, industries uses**	The state, ABH, end users - Ministry of Agric, end users - end users, Commune -SEEE, ABH -Ministry of Industry, end users	Water and sanitation managers - end users - end users -ABH - end users	Total or partial recovery through the distribution of purified water to the end users

Environmental and social protection for treated wastewater reuse

Targeted health education is the most realistic, practical and cost effective measure to reduce health risks associated with wastewater use in agriculture. Policymakers in

Morocco are convinced that the use of wastewater is a reality that has to be accepted. They are provided with enough data on the food security, income generating capacity, health and nutrients aspects of wastewater use in agriculture. A strategy for handling wastewater from the source to the users has been developed.

Public acceptance generally dictates that, in addition to irrigated agriculture, which is likely to continue to be the largest user, reclaimed water can be effectively used for environmental restoration and enhancements, irrigation of green areas (parks, golf courses, sports fields), urban development (waterfalls, fountains, lakes), road cleaning, car washing, firefighting, toilet flushing, and/or industrial uses, but not for potable water supplies

It is recommended to enhance local participation in planning the operation of sanitation facilities, involving at best (i) end-user projects, which should contribute to the design of interventions, either directly through participatory approach, or indirectly, through elected representatives in local government- (e.g. boards or ABH including elected part of the boards) (ii) local communities, to whom section 39 of the municipal Charter has assumed the responsibility for drinking water and sanitation, (iii)the decentralized state and municipal and provincial level in case of existence (iv)local NGOs familiar with the terrain.

Communication, awareness raising and capacity building activities

Trainings

With the Training Center, ONEP has a good foundation in key activities of training and development techniques. The training activities are oriented to different end users to provide different information:

Farmers: provide information through interactive learning methods on health risks associated with wastewater use, information and technical assistance on proper crop selection in relation to wastewater quality, irrigation techniques, protective clothing (boots), personal hygiene, washing crops before marketing, group organization for on field sanitation and washing facilities; preventing damage to soils and ground water

Consumers: Inform them on proper washing; cooking or blanching of vegetables; and sufficient cooking time for fish farmed with wastewater; necessity of paying for treatment of household wastewater as they are the producers of this wastewater.

Tradesman: use of clean water for freshening products (vegetables) on the market; ways for minimizing contamination risks during transport and processing.

Local authorities: to help them understand the implications of wastewater use and the role they can play in minimizing the risks.

The NGO’s and media may have to play a vital role in this exercise, if authorities are slow to take the lead.

Workshops

Several workshops on the local experiences on wastewater reuse and guidelines for safe uses of this non-conventional water in Agriculture, landscaping and industries were organized by the Ministry of water and environment to all concerned by these activities and end users. Also, several universities (Univ Caidi Ayad Marrakech, Univ Ibno Zohr Agadir, Institute of Agronomy and Veterinary Hassan II Agadir, and others) have organized several national and international workshops, conferences on the treatment and reuse of wastewater)

6.4.3.3 CONCLUSION

The conditions for the economic and financial sustainability of projects will depend on policies related to treated wastewater reuse, including:

- Development of quality standards and applications that are adapted economically
- The development of feasible financing strategies, including ad-hoc grants from the state, with the objectives of cost recovery integrating the fact that the WWR is also justified by the non-monetary benefits.
- The development of a regulatory framework with a strong incentive for the use of treated wastewater to the exclusion of other conventional resources locally available to be conserved.
- An awareness program for stakeholders

Replicability of theses institutional framework

These solutions could be replicated in other Mediterranean countries, as they have similar climates and food security needs. Another very important lesson learned is related to the operational performance, sound institutional arrangements, conservative cost and cost effective, realistic reclaimed water sales estimates, and good public communication which are fundamental to the success of any water reuse project. It can only realistically be promoted where investments in wastewater collection and treatment systems have already or are soon to be made.

One of the most important lessons learned is that, to enable the Moroccan people to feel confident with re-used water for irrigation, it was imperative to establish trusted institutions to ensure the highest standards of health and safety.

Unfortunately several constraints, including economic, institutional, health and environmental problems, are restricting the sustainable and safe re-use and recycling of wastewaters in the Morocco. This will require concerted efforts supported by regional and international organizations, to make a real change and increase the low volume of reused treated wastewater, which represent less than 5% of the total generated wastewater in the whole country.

Factors Impeding the Implementation of Water Reuse Strategies in Morocco

Even though, great effort at the policy level has been achieved, we still need to develop the organizational aspects, in order to follow up on the implementation of the national quality standards. In some cases, the outflow of wastewater treatment systems does not meet the required standard either because standard operating procedures are not followed or because there is no qualified personnel to control and monitor the whole treatment procedure. The local competent authorities in Morocco are in some regions not capable of being aware at all times of all data and information concerning the treatment plants. One prerequisite for the control and monitoring of all the activities taking place in relation to treatment and reuse is to reinforce trained personnel of the authorities and the operators at the regional and local level.

In the case of wastewater reuse systems; in some regions of the country, the aspects related to monitoring and system evaluation should be reinforced. This is mainly due to the shortage of trained personnel, the lack of monitoring equipment and the relatively high cost required for monitoring processes. However, ignoring monitoring parameters and/or performing monitoring irregularly and incorrectly could result in serious negative impacts on health, water quality and environmental and ecological sustainability. In addition, it is important to introduce at the local and regional level appropriate organizational measures in order to systematically warn wastewater reuse managers of breakdowns that may occur in the wastewater treatment plants, in order to avoid the flow of non-appropriate treated wastewater into the irrigation distribution network (Choukr-Allah and Kampa, 2007).

The choice of appropriate wastewater technology could alleviate the finance and monitoring problems. Wastewater treatment plants are generally capital-intensive and require expensive, specialized operators. Therefore, before selecting and investing in wastewater treatment technology, an analysis of cost effectiveness needs to be made and compared with all conceivable alternatives. Simple solutions that are easily replicated, that allow further up-grading with subsequent development and that can be operated and maintained by the local community are often considered the most appropriate and cost effective (this is the case of Tiznit wastewater Plant). The choice of a technology will also depend on the type of reuse. The selection of the reuse option should be made on a rational basis. Reclaimed water is a valuable but a limited water resource; so investment costs should be proportional to the value of the resource (Choukr-Allah 2004 WASAMED Workshop). The site for reuse must be located as close as possible to the wastewater treatment and storage facilities. The selection of technologies should be environmentally sustainable, appropriate to the local conditions, acceptable to the users, and affordable to those who have to pay for them.

The Moroccan Government should invest more in allocating the required funds to support applied researches to find sustainable wastewater treatment processes adaptable to the socioeconomic and climatic conditions of each region.

Most treated wastewater reuse activities are driven by water stress and water scarcity, which in turn strive for efficiency in terms of both allocation and more rational use of water. While treated wastewater reuse is justified by social and environmental aspects, the reality of the situation is that its use must be encouraged in relation to the bulk of available resources. Marginal cost pricing can reduce excessive water use and pollution as well as ensure the sustainability of wastewater treatment project. Setting appropriate tariffs for treated wastewater provides an important incentive mechanism to encourage its reuse.

From a demand viewpoint, knowing how much, different users would be willing to pay for the treated wastewater is important. Under this premise, rates for treated wastewater would be based on what the market could uphold, without taking into account the costs required. The willingness to pay for different customers varies depending on the expected economic return. Moreover an increased awareness of the benefits of wastewater reuse amongst the public can lead to increased demand and also induce consumers to state a higher willingness to use and willingness to pay.

Enhance public awareness and participation

This is the bottleneck governing the wastewater use and its perspective progress. To achieve general acceptance of re-use schemes, it is of fundamental importance to have active public involvement from the planning phase through the full implementation process.

Some observations regarding social acceptance are pertinent. For instance, there may be deep-rooted socio-cultural barriers to wastewater re-use. However, to overcome such an obstacle, major efforts are to be carried out by the responsible agencies. ORMVA's and DPA agencies have an important role to play in providing the concerned public with a clear understanding of the quality of the treated wastewater and how it is to be used. Dissemination of best practices for wastewater reuse, and the reuse of treated wastewater in agriculture should be based on the following:

Crop selection and certification of produce: Variations in absorption of certain chemicals by crops, salt tolerance, makes crop selection a suitable strategy, in the absence of market forces, which discourage crop restriction.

Improving irrigation practices: Irrigation techniques, which wet only the roots and not the leafy part of vegetables, were suggested as good practice for minimizing risk of contamination. Drip systems and any other technique applying water close to the root systems should be suggested. There is a further advantage in that there will be less infiltration of nitrogen into groundwater. Rotating wastewater application over fields if this is possible is another means to limit over-fertilization and pollution of groundwater. Avoiding irrigation with wastewater in the two weeks before harvest can minimize the risk from pathogen contamination of leafy vegetables, but this necessitates a fresh water source accessible to farmers, which is rarely possible in these peri-urban situations.

6.5 CONCLUSIONS AND RECOMMENDATIONS

The reuse of treated wastewater in the Mediterranean region needs clear political support and the development of appropriate strategies in the context of each country's overall water resources policy to promote this practice. The actual reuse projects raise several doubts concerning the sustainability of these practices, and there is need for rethinking how to integrate the recycled water in the water management at the whole Mediterranean Basin (Salgot & Montserrat 2007).

Commitment to wastewater reuse should be part of the proclaimed water policy and strategy in all Mediterranean regions (Choukr-Allah & Hamdy 2005, Choukr-Allah 2007, Salgot & Montserrat 2007). The lack of the organization of the reuse sector should be examined seriously in order to identify the proper institution to implement the regulations and to develop the sector in line with existing regulations and preserve the environment and protect the health of the consumer. Mediterranean countries should develop a comprehensive plan of action for reusing treated wastewater, with clearly assigned roles, and that is complemented by periodic reviews and follow-up.

Mediterranean governments should concentrate on demand-driven planning of reuse projects, and a good example for this is the partnership developed between the golf course of Agadir, and Marrakech in Morocco and the water agencies in those cities to supply them with continuous treated wastewater (Choukr-Allah R. 2008). This demand for treated effluent is driven by the scarcity of this resource in Marrakech, and to the high salinity of the ground water in Agadir area.

Mediterranean countries should also develop a platform of dissemination of the lessons learned from existing facilities in the Mediterranean region leading to improved information on the economic and financial benefits (volumes and percentage of treated wastewater reused, approximate benefit to the water economy, cost recovery the reuse system).

The private public partnership in wastewater treatment and reuse should be encouraged. In fact, the contractual arrangement between a private and a government entity (central or sub-national) for providing an essential service to the public allow the sustainability of the system. The goal is to provide the service more efficiently and at a lower cost. The following attributes are necessary for a Sustainable Framework for Public or Private

1 Roles must be clearly defined and incentives must be internally consistent – when in conflict, the financial trade-offs must be explicit.
2 Risks should be allocated to the party that is most capable of managing such risks.
3 Third-party agreements should be utilized to hold responsible parties accountable and to convert implicit charges to explicit ones.

4 Agreements should be arms-length and enforceable by transparent regulatory framework.
5 There must be an appropriate balance of power – no one party should have overwhelming authority.
6 Every situation is unique – requiring its own assessment and adaptation of standard PPP Models

The nature of a given PPP scheme is largely dictated by how much users would be "willing to pay" for this service. Design efforts should shift to "demand" driven approaches where affordability and willingness to pay drive the technical options and potential involvement of the private operators.

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