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**Ministry of State for Environmental  
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Egyptian Environmental Affairs Agency**

**LIFE Integrated Water Resources Management  
Task Order No. 802  
EPIQ II: Contract No. EPP-T-802-03-00013-00**

**Task 6: Improved Waste Water Reuse Practices**

# **ENVIRONMENTAL EVALUATION OF USING TREATED WASTEWATER IN AGRICULTURE: LUXOR DEMONSTRATION SITE**

**Report No. 45**

**March 2008**

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**DISCLAIMER**

The authors views expressed in this publication do not necessarily reflect the views of the United States Agency for International Development or the United States Government

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## ACRONYMS AND ABBREVIATIONS

AAU	Agricultural Administrative Unit
AED	Academy for Educational Development (a US-based entity providing USAID-funded assistance regarding environmental education and awareness)
APRP	Agricultural Policy Reform Program
ASC	Alliance Steering Committee
BCWUA	Branch Canal Water User Association
BOD	Biological Oxygen Demand
C	Centigrade
CAD	Computer aided design
CD	Central Directorate
CDA	Community Development Association
CLAC	Central Lab for Agricultural Climate
CLEQM	Central Laboratory for Environmental Quality Monitoring (MWRI)
COD	Chemical oxygen demand
CTO	Cognizant Technical Officer (the USAID person responsible for supervising a technical assistance contractor)
CY	Calendar Year
DAI	Development Alternatives, Inc. (a Washington DC-based consulting firm working with IRG to implement the project)
EEAA	Egyptian Environmental Affairs Agency
EEPP	Egyptian Environmental Policy Program (a USAID-funded program aimed at achieving environmental policy reform)
EMP	Environmental Monitoring Plan
EPADP	Egyptian Public Authority for Drainage Projects (MWRI)
EPIQ	Environmental Policy and Institutional Strengthening Indefinite Quantity Contract
ET	Evapotranspiration
FC	Field Capacity
GB	Gigabyte
GIS	Geographic Information System
GOE	Government of Egypt
GPS	Global Positioning System
GW	Groundwater
GWS	Groundwater Sector
HD	(Aswan) High Dam
hp	Horsepower
IAS	Irrigation Advisory Service
IBRD	International Bank for Reconstruction and Development or World Bank
ID	Irrigation Department
IDS	Irrigation and Drainage System
IIIMP	Integrated Irrigation Improvement and Management Project
IIP	Irrigation Improvement Project
IRG	International Resources Group (a Washington DC-based consulting firm that is prime contractor for the IWRMP)
IRMU	Integrated Water Management Unit
IRs	Intermediate Results
IRU	MWRI Institutional Reform Unit
IS	Information Systems
IT	Information Technology
IWMD	Integrated Water Management District
IWMU	Integrated Water Management Unit (A unit of MWRI)
IWRM	Integrated Water Resources Management
IWRMP	Integrated Water Resource Management Project

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jpg, jpeg	Joint Photographic Expert Group (computing)
KB	Kilobyte
kg	Kilogram(s)
LAN	Local Area Network
LIFE	Livelihood and Income from the Environment (project)
LOE	Level of Effort
M&E	Monitoring and Evaluation
MALR	Ministry of Agriculture and Land Reclamation
MED	MWRI Mechanical & Electrical Department
mg/l	milligrams per liter
MIC	MWRI Ministry Information Center
MISD	Matching Irrigation Supply and Demand
MOE	Ministry of Education
MOHP	Ministry of Health and Population
MOU	Memorandum of Understanding
MSEA	Ministry of State for Environmental Affairs
MWH	Montgomery Watson Harza
MWRI	Ministry of Water Resources and Irrigation
NASA	(United States) National Aeronautics and Space Administration
NGO	Non-governmental Organization
NPK	nitrogen, phosphorus, and potassium (especially in chemical fertilizers)
NSCE	North South Consultants Exchange
NWRC	(MWRI) National Water Research Center
O&M	Operation and Maintenance
OJT	On-the-Job Training
PC	Personal Computer
pH	Potential of Hydrogen ions (measure of acidity or alkalinity)
PM&E	Performance Monitoring and Evaluation
ppm	Parts per Million
PWP	Permanent Wilting Point
RSC/WP	Red Sea Coastal/Water Project (short name for USAID-funded Red Sea Coastal and Improved Water Resource Management Project)
RWS	Relative Water Supply
SIRs	Sub-Intermediate Results
SOs	Strategic Objectives
SS	Suspended Solids
STTA	Short-term Technical Assistance
SWERI	Soils, Water, and Environment Research Institute (MALR)
TA	Technical assistance
TDS	Total Dissolved Solids
TOR	Terms of Reference
TRG	Training Resources Group
TS	Transition State (chemical)
TSS	Total Suspended Solids
TWW	Treated Wastewater
UPS	Uninterruptible Power Supply Device
USAID	United States Agency for International Development
USB	Universal Serial Bus (computing)
WCU	MWRI Water Communication Unit
WDC	MWRI Central Water Distribution Center
WPRP	Water Resources Results Package
WQU	MWRI Water Quality Unit
WUA	Water User Association
WWTP	Wastewater Treatment Plant

## EXECUTIVE SUMMARY

LIFE Integrated Water Resources Management Project has demonstrated the technical feasibility of reusing treated wastewater (TWW) in agriculture in a manner that is environmentally safe and compliant. The Project managed a 10-Feddan water 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 first plantation started in winter 2005. 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.

This report presents an environmental evaluation of the demo site, two years after the demo site was established. The evaluation examined five monitoring groups:

Treated wastewater (physical, chemical and biological parameters);

- Soil;
- Groundwater;
- Crops; and
- Health & Safety.

The results show that:

- Reusing treated wastewater (Grade B) in agriculture is safe provided precautions are taken and followed through
- Two years of continued irrigation using TWW showed no adverse impacts on soil, plant, groundwater and health.
- Because the project timeframe was short, longer-term monitoring would be required to confirm the results.

This report also presents a set of recommendations for reuse of treated wastewater in agriculture.

Recommendations for End-Users include:

- Use advanced irrigation techniques (minimize flood irrigation) on sandy soils
- Improve soil fertility if using treated wastewater on new lands.
- Implement risk reduction measures for farm workers and crop handlers.
- Implement basic self monitoring tests.
- Recommendations for the Government of Egypt include:
- More graduate training on water reuse practices.
- Disseminate pertinent findings on water reuse (EEAA newsletter, TV, journals).
- Monitor the long-term effects of water reuse on biodiversity (especially birds, mammals, and reptiles).

## **I. INTRODUCTION**

### **I.1. Background**

Egypt has been using treated wastewater to produce wood and other industrial products since the early 1990s. The Ministry of Agriculture and Land Reclamation (MALR) and the Ministry of State for Environmental Affairs (MSEA) have to date established 24 water-reuse projects 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 is noticeably absent. An inter-ministerial committee approved in April 2005 the Egyptian Water Reuse Code (ministerial decree No. 171/2005).

IRG and ECODIT designed Task #6 Improved Wastewater Reuse Practices under the LIFE Integrated Water Resources Management Project (LIFE IWRM) to demonstrate the technical feasibility of treated waste water reuse for irrigation in a manner that is environmentally safe and compliant. Over a period of two years, the Project managed a 10-Feddan water reuse site in Luxor, near the Luxor wastewater treatment plant. The site was irrigated using treated wastewater pumped from the nearest maturation pond. The project cultivated a number of commercial crops including Jojoba, Jatropha, Sorghum, Flax, cut flowers and ornamental plants.

### **I.2. Purpose**

The purpose of this report is to review and interpret all test results obtained or collected during the project in relation to preset environmental monitoring parameters; treated wastewater, groundwater, soil, crops and occupational health. The report findings provide a solid basis for replicating water reuse projects on similar lands and under comparable climatic conditions.

### **I.3. Methodology**

To prepare this report, the monitoring team:

- Used the Environmental Monitoring Plan (EMP) for Task 6 which was prepared and approved in November 2005.
- Consolidated and reviewed all test reports pertaining to treated wastewater, groundwater, soil, crops and worker's health.
- Visited the site in Luxor to discuss outstanding environmental issues with the local team.
- Collected additional soil and groundwater samples to complete the environmental evaluation and sent those tests for analysis in Luxor.
- Presented and discussed draft EMP findings with senior representatives from MSEA, MALR, MWRI and USAID, on 16/07/2007.

### **I.4. Report Organization**

This report is organized into three chapters:

1. Introduction
2. Environmental Evaluation
3. Conclusions and Recommendations

## 2. ENVIRONMENTAL EVALUATION

This Environmental Evaluation of Using Treated Wastewater in Agriculture is based on the Environmental Monitoring Plan (prepared by ECODIT) in November 2005. The Plan described five monitoring groups:

1. Group 1: Treated wastewater (quantity, physical, chemical and bacteriological properties)
2. Group 2: Soil
3. Group 3: Groundwater
4. Group 4: Crops
5. Group 5: Workers' Health

Table I below summarizes the EMP including test parameters and frequency.

**Table I Summary of Environmental Monitoring Plan in Luxor**

Group	Parameters	Frequency	Laboratory
Group 1: TWW	Turbidity, BOD, COD, SS, DO, residual chlorine, oil & grease, heavy metals, nematode cells or eggs, E. Coli and/or total coliform	Quarterly (increase frequency of test results show no compliance)	CLEQM, MOHP Lab, And Luxor WWTP Lab.
Group 2: Soil	Organic matter, macro & micro-nutrients, EC, alkalinity, heavy metals	Bi-annual	SWERI
Group 3: Groundwater	Depth to water table, pH, EC, nitrates and fecal coliform	Bi-annual	CLEQM
Group 4: Crops	Basis nutrients (N, P, K), total coliform and heavy metals	At harvest (crop specific)	SWERI
Group 5: Health & Safety	Training on H&S <ul style="list-style-type: none"> <li>• <b>Information/warning signs</b></li> <li>• <b>Medical check-up</b></li> <li>• <b>Vaccination</b></li> <li>• <b>Protective clothing</b></li> <li>• <b>Record keeping</b></li> </ul>	Year 2 One-time (replace if necessary) Pre-employment Pre-employment Daily Weekly	

Facilities and laboratories used for environmental monitoring are presented in Table 2.

**Table 2 Monitoring Laboratories and Facilities**

Item	Laboratory
1	Luxor Wastewater Treatment Plant Lab (WWTP)
2	Ministry of Agriculture and Land Reclamation / Central Lab for Food and Fodder (Giza)
3	Ministry of Agriculture and Land Reclamation / Soil Lab (Luxor)
4	Central Laboratory for Environmental Quality Monitoring (CLEQM) / MWRI
5	El-Amal Medical Lab (Luxor)
6	Luxor International Hospital
7	Ministry of Health and Population Central Lab – Water Dept.

### 2.1. Site Description

The Luxor demo site is located on a 10 Feddan area located adjacent to the Luxor waste water treatment plant maturation ponds. Several other important features are located within a one km radius from the site including vast Jatropha plantations, at least three private wells (one of which is reportedly dry), Khaya plantations, and other units of the treatment plants including facultative

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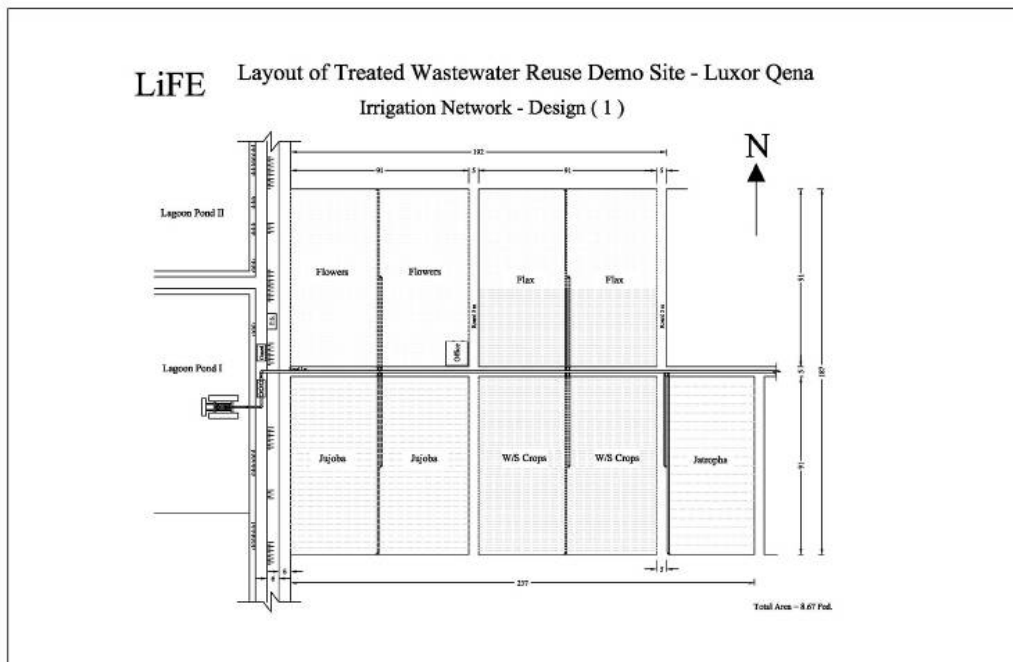
ponds and sludge drying beds. The site proper had never been cultivated prior to the construction of the demo site. A location map is shown in Figure 1

The irrigation system consists of a pumping station with a design outflow of 60 m<sup>3</sup>/hour, a filtration unit, and a distribution network. The irrigation network is composed of a 125 mm main line, 75 mm sub-mains, 18 mm laterals, and different sizes of drippers. Figure 2 shows the layout of the demo site irrigation system

**Figure 1: Location Map**



**Figure 2 Irrigation System Layout**



## 2.2. Group I: Treated Wastewater

The Luxor demo site was designed to meet Grade B treated wastewater. The limit values for short-term use (less than 20 years) of treated wastewater are presented in Table 3.

**Table 3 Limit Values for Treated Municipal Wastewater Reused in Agriculture (mg/l)**

Treatment Grade Requirements		A	B	C
Effluent limit values for BOD and SS	BODs	< 20	< 60	< 400
	SS	< 20	< 50	< 250
Effluent limit value for fecal coliform and Nematode cells or eggs (per liter)	Fecal coliform count <sup>(2)</sup> in 100 cm <sup>3</sup>	< 1000	< 5000	Unspecified
	Count of Nematode cells or eggs per liter	< 1	< 1	Unspecified

\* Egyptian Water Reuse Code (Grade B)

### 2.2.1. Baseline

The quality of the treated wastewater in the maturation (and polishing) lagoons was good and compliant before implementing the demo site. The Luxor Wastewater Treatment Plant (WWTP) environmental laboratory conducts routine sampling and analysis of the influent and effluent water. Standard tests include pH, alkalinity, TSS, TDS, TS, BOD, coliform and Chlorophyll A. At the request of LIFE, the WWTP laboratory agreed to collect and analyze daily samples from the lagoon over a period of one week in September 2005 (called baseline). Those test results are summarized in Table 4.

**Table 4 Initial Effluent Test Results from Lagoon (baseline)**

	Temp	pH	BOD	COD	DO	TDS	TSS	Coliform Count
Average	30.2	8.17	25.8	32.8	7.58	466.4	29	3,060

Source: Data provided by Luxor laboratory, September 2005

### 2.2.2. Water Quantity Monitoring Results

Continuous flow water meters were installed to measure daily flow discharges from the main and subsidiary irrigation distribution systems. A summary of the water delivered to the Luxor Demo site are given in Annex B. A review of those readings shows that the demo site pumped in a single year (from 01/01/06 to 31/12/06) 127,000 m<sup>3</sup> of treated wastewater from the pond. This is equivalent to 12,700 m<sup>3</sup>/feddan/year (assuming a total irrigated area of 10 Feddan). The highest quantity was recorded in January (11,940 m<sup>3</sup>) when all the plots were newly planted, and the lowest quantity was in February (7,590 m<sup>3</sup>). An agricultural field with similar soil and climatic conditions would on average consume between 5,000 (drip/sprinkler) to 7,000 (surface irrigation) m<sup>3</sup>/feddan/per year. The high initial water use can be attributed to the need for leaching of the soil and to the fact that several of the crops were irrigated using furrow and flood irrigation instead of drip. It is safe to conclude that irrigation efficiency in Luxor can be improved to reduce 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.

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### 2.2.3. Water Quality Monitoring Results

Routine samples of TWW were collected from the treatment plant and sent to different laboratories for testing during the program. Table 5 presents summary of the test schedule.

**Table 5 Summary of Tests Conducted on TWW**

Laboratory	Date of Sampling	Parameters
Luxor WWTP*	Routine (every 10 days)	BOD, COD, TSS, total coliform
Central Lab for Environmental Quality Monitoring (MWRI)	2005: May, Sep 2006: Feb, Mar, Aug, Nov, Dec	Physiochemical, major cations and anions, trace metals, microbiological
Ministry of Public Health (MOHP)	2007: Mar, May	BOD, COD, TDS, TSS

\* Samples collected by the WWTP personnel

In the period from September 2005 (baseline) through June 2007, the quality of the TWW was **generally compliant**, below or near Egyptian limit values, for Grade B under the Egyptian Water Reuse Code.

To minimize travel distance, it was decided during later stages of the pilot project to conduct water sample analysis at the water lab of the Ministry of Health and Population, in Luxor. Those tests, while not complete (total coliform was missing), produced BOD and TSS results that were slightly higher than the results reported by the WWTP lab or CLEQM. Those values were also slightly above their limit value. For example:

- BOD was 69-104 mg/l (std is 60)
- TSS was 64-140 mg/l (std is 50)

A comparison of the values for turbidity and TSS *before* and *after* the filtration units showed an appreciable drop in those values. For example:

- Turbidity dropped from 7.89 to 5.14 NTU (Mar 2006)
- TSS dropped from 132 to 92 mg/l (Aug 2006)
- Turbidity dropped from 18.3 to 8.34 NTU (Nov 2006)

The sand filters are therefore reducing suspended solids in treated wastewater and help prevent clogging in the irrigation network.

## 2.3. Group 2: Soil

### 2.3.1. Baseline

In October 2005, the Project collected 24 soil samples from eight locations inside the demo site and from three different depths (0-30, 30-60, 60-90). The samples were analyzed at the MARL lab in Cairo:<sup>1</sup> physical tests were conducted on all 24 samples (8 locations) and chemical tests were conducted on 9 samples (3 locations). Physical tests include particle size distribution and chemical tests include: pH, electrical conductivity, anions and cations, CaCO<sub>3</sub>, organic matter, and macro and micro nutrients. 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)

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<sup>1</sup> Ministry of Agriculture/Agricultural Research Centre/Soils, Water & Environment Research Institute (SWERI)/Unit of Analysis & Studies. Giza, Cairo.

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- 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 ranges 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

### 2.3.2. Monitoring results

Partial soil tests were conducted in October 2006 (to investigate the causes of poor growth in the sorghum plot) and a complete soil test was in July 2007. Table 6 presents a summary of the test program.

**Table 6 Summary of Soil Tests**

Laboratory	Date of Sampling	Sampling Method	Parameters
Regional lab for soil fertility, Luxor (MALR)	October 2006	One sample only from sorghum plot (depth 0-30)	pH, percent salts, CaCO <sub>3</sub> , major cations and anions, and macro nutrients (Nitrogen, Phosphorous, Potassium)
Regional lab for soil fertility, Luxor (MALR)	July 2007	Samples collected from 3 locations (A, B, C) and from three different depths (0-30, 30-60, 60-90), plus one composite sample (0-30)	

The sample collected from the sorghum plot in October 2006 showed that:

- N had dropped from 60-120 ppm (baseline) to 10 ppm just before harvesting the crop;
- P had increased from 1-5 ppm (baseline) to 22 ppm before harvesting the crop; and
- K had remained unchanged (130 ppm compared to 80-170 prior to planting).

It can be concluded that one sorghum cycle depleted soil nutrient reserves; that soil fertility, already low before planting, had declined even further. This is not surprising considering that the soil is sandy (and therefore has a very low cation exchange capacity) and soil organic matter is close to nil (organic matter preserves soil moisture and prevents nutrient leaching). Excess irrigation may have contributed to reducing soil fertility as excess water will leach sandy soils and thereby displace soil nutrients. While wastewater will bring nutrients to the soil, wastewater cannot replenish or restore soil nutrient reserves without adequate soil management practices. As stated by the Ministry of Agriculture and Land Reclamation: improving soil fertility in reclaimed lands in Egypt requires a battery of soil conditioners including:<sup>2</sup>

- Manure: about 20 m<sup>3</sup> 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

Table 7 shows the full results of the soil tests.

<sup>2</sup> Translated and adapted from the MARL test report (Regional Lab for Soil Fertility)

**Table 7 Complete Soil Tests Results**

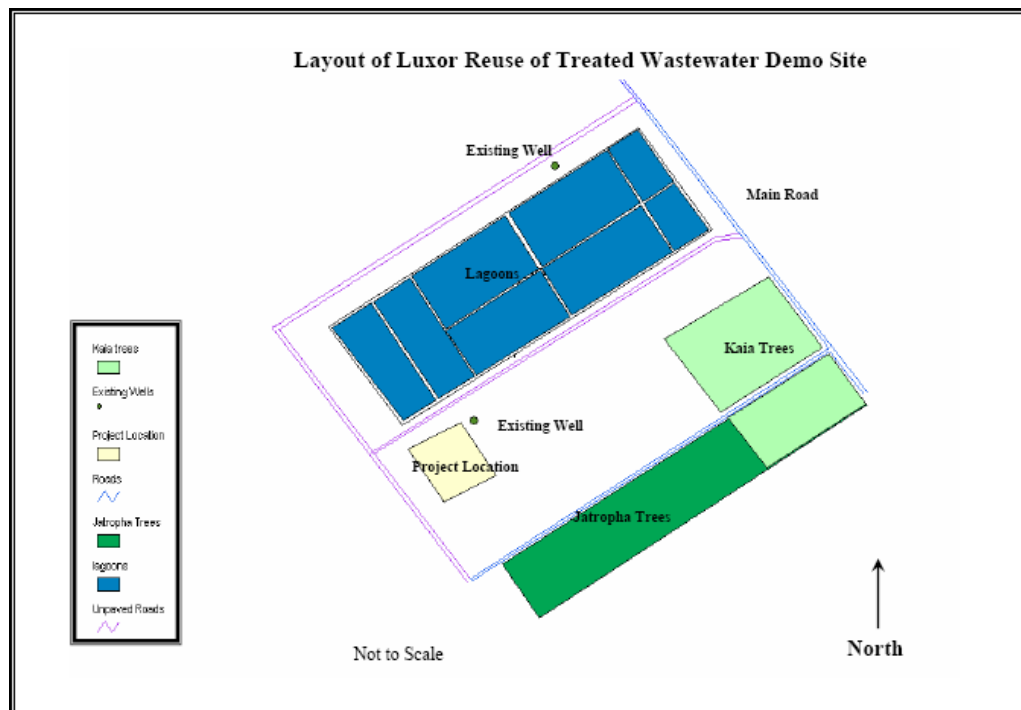
Plot	Depth (cm)	pH	TDS (%)	CaCO <sub>3</sub>	K	Na	Mg	CA	So4	Ci	Hco3
A	0-30	8.3	0.08	14.4	0.3	1.6	0.4	1.5	2.7	0.44	0.66
	30-60	8.2	0.1	18.5	0.2	2.04	0.6	2.2	3.94	0.44	0.66
	60-90	8.6	0.2	10.3	0.2	3.4	1.7	3.7	7.9	0.44	0.66
B	0-30	8.4	0.1	11.9	0.2	1.8	1.4	2.2	4.5	0.44	0.66
	30-60	8.9	0.1	13.2	0.2	2.5	1.4	2.2	4.98	0.44	0.88
	60-90	8.4	0.1	22.2	0.2	2.8	0.4	3.5	5.36	0.66	0.88
C	0-30	8.2	0.05	18.5	0.3	0.9	0.5	1.3	5.58	0.66	0.66
	30-60	8.8	0.03	20.6	0.2	0.8	0.3	1.3	1.28	0.44	0.88
	60-90	8.8	0.03	17.7	0.2	0.7	0.3	1.3	0.96	0.88	0.66
	Composite	8.3	0.1	15.6	0.5	2.5	0.4	3.3	4.94	1.1	0.66

**2.4. Group 3: Groundwater**

*2.4.1. Baseline*

In February 2005, the Project collected a groundwater sample from a 20-meter deep (production) well located 1 km west of the demo site, near the forested area. The sample was analyzed at CLEQM (MWRI). Test results indicated no fecal contamination. According to Mr. Salah Eldine Ramadan, Director of the Soil Fertility Lab in Luxor (MARL), “groundwater in Luxor in the area of the demo site [area also known as “Hbail”] is moderately to highly saline.” TDS values from neighboring farms ranged from 900 - 4,000 (1.4 to 6.25 dS/m). Figure 3 shows the demo site and surrounding wells.

**Figure 3: General Map of the Demo Site and Surrounding Wells**



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### 2.4.2. Monitoring results

An observation well was constructed inside the demo site. Groundwater samples were collected on three different dates. Table 8 presents an overview of groundwater samples collected onsite and the date of sampling.

**Table 8 Summary of Groundwater Tests**

Location	Date	Chloride (mg/l)	Alkalinity (mg/l)	Ph	Conduct. EC (Ds/m)	Tss (mg/l)	Ts (mg/l)	Total Coliform (CFU/ml)
On-site	July 14, 2007	340	140	6.9	4651	88	4192	700
Man-made forest		80	810	7.4	1864	61	1678	0
On-site	August 6, 2007	312	200	7.5	6750	136	4455	600
Man-made forest		80	1220	8.02	1840	50	1376	0
On-site	September 15, 2007	360	160	6.8	4670	90	4200	800
Man-made forest		72	780	7.3	1856	60	1670	0
On-site	October 14, 2007	350	135	6.8	4563	85	4165	700
Man-made forest		75	800	7.4	1855	58	1668	0
On-site	November 25, 2007	180	140	8.18	5200	46	3458	0
Man-made forest		80	240	8.17	1750	40	794	0
On-site	December 17, 2007	355	155	6.9	4520	90	4100	800
Man-made forest		65	420	7.2	1740	55	1570	0
On-site	January 20, 2008	320	220	7.6	6720	140	4460	0
Man-made forest		76	1180	8.03	1780	48	1380	0

**Groundwater salinity** as expected is high. This however *cannot* be attributed to the demo site because salinity was high before planting and TDS (total dissolved salts) values in treated wastewater were generally low to moderate.

**Coliform** were present in some of the samples taken at the on-site well during several of the tests. The reasons are not know.

## 2.5. Group 4: Crops

### 2.5.1. Baseline

The Project Committee selected five demonstration crops from Grade B & C of the Egyptian Water Reuse Code) for the demo site: flowers and ornamentals, flax, Jojoba, sorghum, and Jatropha, Crop selection was based on a number of factors:

## Task 6. Environmental Evaluation of Using Treated Wastewater in Agriculture

- Water quality of the treated waste water
- Climate and soil conditions
- EEAA and MALR interests
- Marketing and economic considerations.

**Table 9 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)

The demonstration site was divided into 18 plots of equal size (0.5 feddan each). The Project also planted a green fence to mark the perimeter and to serve as windbreak. Figure 4 shows the distribution of the crops in the demo site.

### 2.5.2. Monitoring Results

Details on Luxor Demo Cropping dates and other relevant information are summarized in Table 10.

**Table 10 Luxor Demo Crops**

Crop	Growth Period (days)	Planting Date	Harvest Date	Cultivated Area	Yields	Unit	Yield/unit
Roses	All year	Jan-06	Weekly cuts	9 Karat	From January 07 To December 07 (25,723 Roses)	Cut Roses/Karat In Year	2858
Ornamentals	All Year	Jan-06	Feb, Mar, Apr 07	Bird of Paradise 11 K	71	Flowers/ Karat	6
			N/A	Indian Fig 1.5 K Golden Dewdrop 2 K	N/A	Trees sold/fd	N/A
Flax	5 months	Winter 2005	May-06	1.8Fd	1.3 Ton	Ton/Fd	0.72
		Winter 2006	May-07	2.5 Fd	6.47 Ton		2.59
Jojoba	Perennial	Dec 2005	N/A	2 Fd	N/A	Kg/tree	N/A
Jatropha	Perennial	Nov-05	Summer 2007	1 Fd (496 Tree)	245 Kg	Kg/tree	0.5
Sorghum	3-4 months	Summer2006	Cut 1: June 06	2 Fd	Cut1: 10.19 Ton	Tons/fd	5.10
			Cut 2: August 06		Cut 2: 6.87 Ton		3.44
			Cut 3 : September 06		Cut 3 : no yield		No yield
Olives	Perennial	Dec 2008	Summer2007	12 Karat	Cut 1: 2.4 Ton	Kg/tree	4.7
			N/A	3 Fd	N/A		N/A

Crop samples were collected from all the plots except Jatropha (see summary in Table 11). Jatropha trees need at least 3-5 years to produce its first mature fruits.

Figure 4 Crop layout

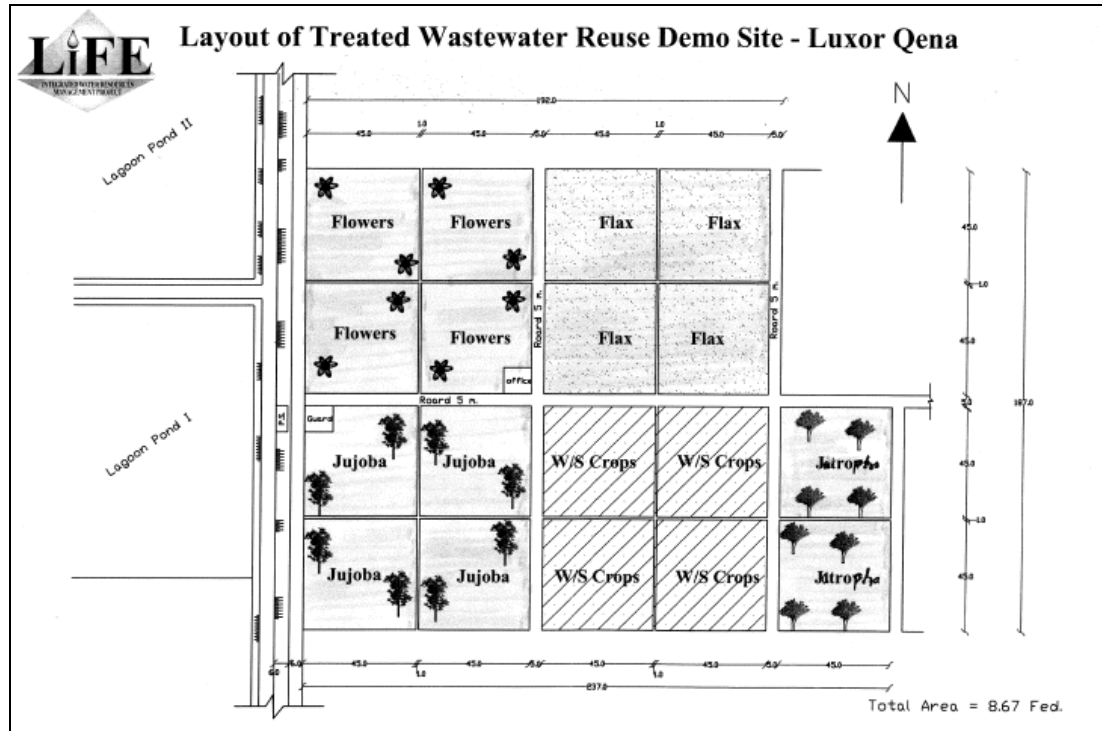


Table II Summary of Crop Tests

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 durenta), 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 TWVW without further investigations.

## 2.6. Group 5: 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. This way, LIFE would be able to ensure a gradual transfer of the demo site to the Ministry of Agriculture and Land Reclamation at the end of the Project.

### 2.6.1. Baseline

All the five graduates of the first group were sent for a medical check up in February 2006 (about one month after starting to work in the demo site). The check-up was conducted at two facilities:

1. El Amal Medical Lab in Luxor for Hepatitis A and B tests, and
2. Luxor International Hospital for parasites and microbiological tests

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.

In June 2007, 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.

### 2.6.2. Monitoring Results

A second medical check-up of the graduates was conducted in February 2007 (by that time, there were only four graduates). All four graduates tested negative for parasites (*Ancylostoma*, *Ascaris* and *Amoeba*), infectious diseases (Typhoid and para-Typhoid), as well as Hepatitis A (HAV-IgG) and B (HAV-IgM).

Risk reduction measures implemented at the demo site are presented in Table 12.

**Table 12 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 & gloves	Provide workers with adequate protective boots and gloves, as well as first aid kit and a dedicated wash room.
Medical Check-up	Conduct regular medical checkup 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)

### 3. CONCLUSIONS AND RECOMMENDATIONS

#### 3.1. Conclusions

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

- 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.

#### 3.2. Recommendations

Several recommendations were formulated based on the Luxor demo site. These recommendations were divided into two groups: recommendations for (i) end-users and (ii) the Government of Egypt.

##### 3.2.1. End-Users

- **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 NPK 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.

##### 3.2.2. Government of Egypt

- **More graduate training.** Egypt should increase the number of farmers/students who receive training in wastewater reuse for irrigation. The Luxor demo site trained 5 graduates the first year and started training another 7 new graduates the second year. Establishing demo sites at existing waste water treatment facilities provides an excellent environment for on-the-job training. Such training could be facilitated by MALR and EEAA.
- **Disseminate pertinent findings on treated wastewater reuse** (EEAA newsletter, TV, journals). It is important to explain the pros and cons of water reuse to farmers and potential investors through a national information campaign. Important messages related to

the opportunities and risks of water reuse can be communicated through newspapers, subject magazines and TV.

- **Monitor the long-term effects of water reuse on biodiversity** (especially birds, mammals, and reptiles). Although plant cover is scarce in open deserts, desert ecosystems harbor important biodiversity in the form of reptiles and xeric plants. The demo site in question is part of a larger area that has already been significantly altered from years of water reuse and forest cultivation. Egypt must begin to assess the long-term effects of water reuse on biodiversity if it decides to implement large-scale irrigation projects using treated wastewater.