WATER REUSE IMPLEMENTATION IN THE KINGDOM OF JORDAN

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I Introduction

When asked by the media if he would drink the effluent from an advanced tertiary wastewater treatment plant that he had designed, a well known engineer responded "Scientifically yes, aesthetically, no". Even if all the scientific data supports water reuse, there is still the aesthetics issue. But water reuse is becoming accepted in Jordan even by the public at large and the religious community. Realizing the critical need for renewable water resources for Jordan, the Ministry of Water and Irrigation (MWI) and the U.S. Agency for International Development (USAID) have collaborated in implementation of a major project to demonstrate that recycled water can be used for multiple purposes safely, cost effectively and in an environmentally friendly manner. Freshwater resources in Jordan, as in most of the Middle East, are scarce, and diminishing and action must be taken now to ensure that future generations will have an adequate supply. Heavy exploitation of available water resources has lead to increasingly decreasing levels of ground water aquifers and in the level of the Dead Sea. The time has come to reuse it to the maximum extent possible or lose it for future generations.

Water has been reused by humans for centuries, but with the recurring drought conditions in Jordan and with the shifting populations in the region, recycling and reuse continues to be an important resource, but it is becoming ever more important to reuse it effectively and safely. The government of Jordan through the MWI has made the decision to institutionalize water reuse, to monitor it and control it in a manner that does not pollute the environment. Reused water is not appropriate for all crops and careful selection and monitoring is critical to ensure that public health and safety concerns are properly addressed.

The overall goal of the Jordan program as contained in the project Scope of Work is to implement direct water reuse in Jordan that is reliable, commercially viable, environmentally sustainable and safe. The project must demonstrate to decision makers and to the public at large that water reuse is an effective, viable and safe component for managing Jordan's water resources. Also, institutional capacity to develop water reuse and implement relevant supporting actions must be enhanced through practical application. In addition, this activity must develop the capacity to plan, manage and monitor practical and sustainable direct water reuse projects associated with other medium and small-scale wastewater treatment plants in the Kingdom. Demonstration of the practical application of water reuse principles is being achieved through the implementation of pilot demonstration farms in three areas of the country.

The Water Reuse Implementation Activity is a USAID funded project in Jordan that includes pilot demonstration farms to show it can be done, documentation and public information to let people know what we are doing and institutional enhancement to provide long-term sustainability. The project is currently nearing the end of a 16-month Phase one and a second phase is in the planning stage. Pilot demonstration farms have been established at Wadi

Musa, Aqaba and Irbid, Jordan using well-treated wastewater for crop irrigation. PA Government Services is providing the technical services for this project through the use of world-renowned water reuse experts and through limited term subcontracts with local agencies. USAID is providing technical guidance and oversight of the project in a collaborative approach, and MWI through the Water Authority of Jordan (WAJ) and the newly reconstituted Water Reuse Unit is providing technical support and guidance.

At Wadi Musa (near Petra), a new demonstration farm has been established on an area of 70 dunums (7 hectares) and an additional 1000 dunums (100 hectare) area is being readied for farming by local tribal communities. On the campus of the Jordan University of Science and Technology (JUST) near Irbid in the north of Jordan, a new farm site of 100 dunums (10 hectares.) has been established and an additional 620 dunums (62 hectares) is being developed for agriculture. At Aqaba, in the south of Jordan, a new demonstration farm of 100 dunums (10 hectares) has been developed and an additional 1000 dunums (100 hectares) is being prepared for additional agricultural development.

At all three pilot Demonstration Projects:

- Dynamic and varied cropping schedules have been developed and tested along with various applications and irrigation methods.

- Performance data has been collected, evaluated and reported, including soil and tissue characteristics, growth rates, water quality and meteorological data.

- Groundwater quality has been monitored and sampling wells have been drilled as necessary.

- Extended farming areas have been evaluated for additional agricultural development as the water supply permits.

- A color-coding system has been implemented by MWI using the international standard of purple piping for all distribution network piping.

- Qualified staffing has been arranged and maintained throughout the project. Subcontractor staff includes representatives of Jordanian Universities with strong agricultural backgrounds.

- A variety of additional technical specialists have been utilized in areas such as agronomy, soil hydrology, environmental health, marketing specialists, Agro Economists, Horticulturalists, Flora and Fauna Specialists and many others.

- Wastewater Treatment plant effluent quality has been carefully monitored and crops selected based on a number of factors including health and safety, marketability, and innovation.

- Equipment procurement has been completed that includes, irrigation networks, pump stations, farm equipment, trees, shrubs and seeds.

- Diversifications of cropping patterns have been practiced and innovative methods have been implemented to enhance income-generating opportunities.

II Demonstration Documentation, Training and On-Site Training

The Jordanian public is uncomfortable with treated wastewater reuse due to the implications of its usage, although it is being reused informally and sometimes in an uncontrolled manner. The project is finding ways for changing the negative public perception on wastewater through the demonstration sites, and is showing that reclaimed water has a benefit and is an asset to the farming and industrial communities. Reclaimed water must be shown to be a reliable source for these communities.

Other benefits that are being demonstrated include the freeing up of fresh water, wastewater discharge reduction and the resultant environmental enhancement, public health and safety when control measures are implemented for the reuse and, last but not the least, income generation.

In order to change the negative image of using recycled water for irrigation of crops, a comprehensive public awareness program has been initiated to demonstrate the positive aspects of water reuse. The program includes:

- Six Stakeholder Workshops with presentations on water reuse for various special interest groups, including farmers, utility managers, religious leaders, and the public at large.

- Two technical papers presentation to international conferences, this being one of those and another planned for 2004 at the Water Environment Federation conference.

- A well stocked reference library to make technical reports and publications available to water resources personnel and the public.

- A strategy regarding the appropriate levels of treatment and on the appropriate types of crops that will be effluent tolerant, suitable for export and cost effective. The first step in the development of this strategy, a survey of all wastewater plants in the kingdom and an assessment of their condition, has been completed

- Two Study Tours to successful water reuse projects in other countries, for water reuse managers and counterparts from Jordan. The study tours included site visits to water reuse projects in the U.S., Tunisia and Morocco.

- Meetings with community and religious leaders in an attempt to obtain socio-cultural acceptance of water reuse.

- Training for field workers and farmers regarding safety measures, hygiene and control measures when working with reclaimed water.

A media campaign has also been initiated that includes press releases for all project achievements and milestones. As an example, one of the demonstration projects recently harvested a crop of barley and vetch that was tested, found to be safe and was sold for animal fodder. The proceeds were donated to the Needy Student Fund at the Jordan University of Science and Technology and this donation was reported in the press. We have also established a logo for the Water Reuse Unit of the Water Authority of Jordan and have instituted a broad media campaign in preparation for the first National Water Reuse Conference scheduled for December. At all stakeholder meetings, USAID and MWI play a vital role.

III Institutional Enhancement

Identification of the institutional overlaps and gaps in the areas of responsibility for managing water reuse activities, plans, and projects are being addressed. A detailed plan for collaboration among Jordan's implementing agencies towards affecting planned reuse projects around the kingdom is under development.

A primary institutional issue that is being resolved through this treated wastewater reuse activity is the overlap of roles among implementing agencies of the Government of Jordan particularly regarding the permitting and approval process. Outreach programs with incentives have been devised for dealing with clarification of these issues and resolving them while devising incentives for farmers and other users and to assist them through the identification of marketing strategies.

In order to strengthen Jordan's institutional capability and to provide sustainability for the project activities, the water reuse project has played a major role in the following:

- An existing Water Reuse and Environment Unit within the Water Authority of Jordan has been revitalized, equipped and provided with an operating mandate and organization chart. The Water Reuse Unit has been designated as the permitting, monitoring and standard setting Authority in Jordan for both municipal and industrial reuse programs. They also have played a strong role in the Water Reuse Project.

- A Water Reuse Coordination Committee has been formed and has been holding regular meetings to coordinate all water reuse activities in Jordan. The Committee is composed of representatives of the Ministries of Agriculture, the Environment, Industry, Health and Water and Irrigation.

- A plan has been developed for the establishment of a Water Reuse Regulatory Agency within the Ministry of the Environment. The Agency will be responsible for enforcement and mitigation action against violators of permit conditions. The new regulatory function will be established within the Ministry of the Environment.

- A National Workshop on Water Reuse will take place in Amman in December of this year. The workshop will take place under the purview of the Water Reuse Coordination Committee and will include speakers from Jordan and other nearby countries.

- New Industrial Waste Reuse standards have been developed and are being implemented in Jordan with provision for permitting, monitoring, enforcement and with some specific prohibitions.

- A strategy has been developed to encourage and induce industries to recycle and reuse product water to the maximum extent possible. Incentives have been identified for those industries that are successful in their recycling programs. As part of this activity, many industries are being evaluated and recycling programs developed.

IV Pilot Demonstration Farms

1. Jordan University for Science and Technology (JUST)

The JUST Pilot Demonstration Project is being managed through a subcontract between PA and the University that was signed on March 20, 2003. The project is located on the campus of the university and includes five sites where treated wastewater is applied to a variety of agricultural crops utilizing several different irrigation methodologies. The five sites encompass a total of 720 dunums (72 hectares) of land that was not previously cultivated. The project manager for the subcontract is a university professor who is taking time off from his normal teaching duties. In addition, PA provides a Site Manager and a site engineer who spend full time on the project. Agricultural specialists of various specialties are provided on an as needed basis through PA or through the subcontractor. USAID provides active technical support and guidance and MWI is a full partner in the program.

The crops grown on the JUST Demonstration Project include field crops such as vetch and barley, tree crops including pistachio, almond, carob, fruited and non-fruited pine, cactus and washingtonia (ornamentals) and olives. The mortality rate of the crops has been very low and well within normally expected ranges. The crops are planted according to the Jordanian agricultural seasons and one field of barley and vetch has been harvested and the crops sold to provide feed for the livestock of the university's herd. A control area was established using conventional irrigation techniques and fresh water. Plant height for the barley and vetch was 25 to 28 percent higher in the fields irrigated with reused water than in the control area. Approximately 2400 trees of various types have been planted to date at the JUST site.

Tables 1,2 and 3 show the crop diversification at JUST:

Table 1 ***Field Crops Planted at JUST Demonstration Site***

JUST Demonstration Site	**Area Cultivated with Reclaimed Water**	**Yield Total Biomass/ha**	**Area Cultivated without Reclaimed Water**	**Yield Total Biomass/ha**	**Percentage Increase with TWW (per ha.)**
Vetch	0.35 ha.	2,357 kg.	0.15 ha.	1,466 kg.	
Barley	0.35 ha.	2,400 kg.	0.15 ha.	1,733 kg.	
Vetch & Barley	0.35 ha.	2,228 kg.	0.15 ha.	1,600 kg.	

Data Source: JUST Pilot Project (2003)
Note: At JUST, plant height for barley and vetch was 25-28% greater in the crops irrigated with TWW than in the control crops.

Table 2 ***Tree Crops Planted at JUST Site (Site 1)***

Tree Variety	*Number Planted*	*Percentage Growth*
Pistachio	33	10%
Almond	39	22%
Carob	39	25%
Pine (fruited)	35	20%
Pine (non-fruited) *	840	24%
Cactus	149	30%
Washingtonia (ornamental)	35	* N/A

Data Source: JUST Pilot Project (2003)

Note: Saplings were planted March 2003, and all irrigated with TWW. Growth results represent total rates from March to August 2003. *Washingtonia* was planted in August 2003, hence no growth data is reported.

Table 3 ***Tree Crops Planted at JUST Site (Wadi Hassan Site)***

Tree Variety	**Number Planted**	**Percentage Growth**
Almonds	482	22 %
Olives (3 cultivars)		55 %
Olive Baladi	103	
Olive K-18	105	
Olive Nabali	105	
Carob	130	30 %
Pine (fruited)	66	20 %
Pistachio	241	10 %

Data Source: JUST Pilot Project (2003)
Note: Saplings were planted April 2003, & all were irrigated with TWW. Growth results represent total rates from April to August 2003.

Two interesting aspects of the operation concern the cactus and the fodder crops. The flowers from the cactus are used for animal feed and are high in essential nutrients required by the animals. They are low water consumers and produce two harvests per year. The cactus increased in size by more than 100 percent since they were first planted, in the first four months of the project. Another significant story regarding the barley and vetch concerns the baling and sale of the crop. The portion of site one that was used for this crop was approximately 20 dunums (5 acres), and the first harvest yielded approximately 1700 kilograms that was sold for $1200.00. The proceeds from the sale went to the Needy Student Fund on campus.

Strict monitoring is being maintained throughout the project and the harvested crops were tested for tissue uptake prior to the sale and found to be safe for use as animal feed. Among the parameters monitored through the project are the following:

- Baseline soil properties
- Soil bulk density
- Long term infiltration rates
- Soil moisture relationships
- Soil Chemical properties
- Plant tissue chemistry and tissue uptake rates
- Application water quality from the treatment plant
- Ground water quality from downstream wells

The JUST campus is contained on 11 square kilometers and serves a campus community of 13,000 students and 600 professors. The wastewater treatment plant that provides the water for reuse is on campus and serves the university buildings and the campus hospital. It is a mechanical plant utilizing rotating biological contactors (RBC) technology and has a design capacity of 1200 M^3/day. The current flow through the plant is approximately 300 m^3/day and only half of the treatment units are in service. All of the plant effluent is used for agricultural irrigation at the demonstration site. The plant effluent is disinfected and pumped to a small holding pond to store treated wastewater until it is needed. Sand filtration is provided prior to distribution to the fields. The effluent quality is shown in Table 1.

Table 4 – WWTP Effluent Quality JUST

Test	Units	Jordanian Standard 893/2002 Cash Crops/Field Crops	Effluent Value
pH	SU	6.0 – 9.0/ 6.0 – 9.0	7.24
BOD_5	mg/L	200/300	5
COD	mg/L	500/500	35
EC	ds/m		1.06
TSS	mg/L	159/150	19
NO2-N	mg/L		<0.003
NO3-N	mg/L	10/10	21
T-N	mg/L		
T-P	mg/L		4.17
Cl	mg/L	400/400	165
SO_4-S	mg/L	170/170	24
Na	mg/L	230/230	100
Mg	mg/L	100/100	22
Ca	mg/L	230/230	77
E-coli	MPN/100 ml	1000/	2

2. Wadi Musa/BADIA Research and Development Program

The Wadi Musa Pilot Demonstration Project is being managed through a subcontract between PA and the BADIA Research and Development Program (BRDP) that was signed in January 2003. The project is located in Wadi Musa which is near the Petra Nature Reserve and adjacent to the Petra Regional Wastewater Treatment plant. The project includes a 70 dunum (7 hectare) demonstration area where treated wastewater is being applied to a variety of agricultural crops utilizing several different irrigation methods and a 1000 dunum (100 hectare) farming area currently under development. The demonstration area has been fully planted and a fully functioning drip irrigation system installed. The farming site irrigation system is currently under design and planting is anticipated in time for the winter growing season. The farming site has been planted in previous years using rainwater for irrigation only. The project manager for the subcontract is the Director of BRDP, with support from the agricultural staff of the University of Jordan. In addition, PA provides a Site Manager and a site engineer who spend full time on the project. Agricultural specialists of various specialties are provided on an as needed basis through PA or through the subcontractor. USAID reviews project activity and advises on technical issues and MWI provides constant support and encouragement.

The crops grown on the Wadi Musa Demonstration Project include field crops such as alfalfa, maize, sunflowers and Sudan Grass, tree crops including pistachio, almond, olives, date palms, lemons, poplars, spruce and junipers and many varieties of ornamental flowers including iris, geraniums, petunias and daisies. The yield of maize is approximately 25 percent higher than for maize grown with fresh water, and the yield for sunflowers is approximately 30 percent higher. Approximately 2020 trees of various types and 400 shrubs and flowers have been planted to date at the Wadi Musa site.

Tables 5 and 6 illustrate the crop diversification at the Wadi Musa Site:

Table 5 ***Tree Crops Planted at Wadi Musa Site***

Tree Variety	*Number Planted*	*Percentage Rate*
Pistachio	150	10 %
Almond	189	20 %
Date Palms	52	30 %
Lemon	50	25 %
Poplar	580	60 %
Spruce	400	60 %
Juniper	500	40 %
Ornamental shrubs & flowers	400	75 %

.Data Source: BRDP Pilot Project (2003).

Note: All saplings and stock were planted in April 2003. Average growth is reported to be approx. 25% higher than plants irrigated with fresh water in the Wadi Musa area (Source: NCARTT, 2002).

Table 6 **Field Crops Planted at Wadi Musa Site**

WADI MUSA Demonstration Site	**Area Cultivated with Reclaimed Water**	**Yield / ha.**	**Area Cultivated without Reclaimed Water**	**Yield / ha. ***	**Percentage Increase with TWW (per ha.)**
Maize	0.4 ha.	Total Biomass: 6,875 kg./ha Total Seed: 1,837 kg.	N/A	Total Biomass: 4,680 kg./ha Total Seed: 1,268 kg/ha	**32 %**
Sunflower	0.4 ha.	Total Biomass: 4,637 kg/ha Total Seed: 1,442 kg/ha	N/A	Total Biomass: 3,478 kg/ha Total Seed: 1,082 kg/ha	**24%**

Data Source: BRDP Pilot Project (2003) and NCARTT (2002).
Note: Data for average yields for fresh water growth provided by NCARRT, for the Wadi Musa/Shobak districts.

The poplar trees have demonstrated impressive growth. They have approximately doubled in size in the first three months since planting. The sunflowers are also growing well and cut flowers have been provided free to several tourist hotels in the Petra area. The hotel managers have indicated that they would like to purchase all the flowers that can be produced at the site. The proceeds from the sale of the crops grown in the demonstration site are planned to be used to establish a revolving fund for the farmers who will plant the 1000

dunum (100 Hectare) farming site. Many of the farmers who will obtain leases to farm the land from the Petra Regional Authority (PRA) are members of local Bedouin tribes who will be provided with loans from the revolving fund to establish and plant their lease holdings. USAID has also indicated that it would consider providing additional funds for the revolving fund.

As in all the demonstration farms, strict monitoring is being maintained throughout the project and the crops are being tested for tissue. Among the parameters monitored through the project are the following:

- Baseline soil properties
- Tissue analysis
- Climatological Data
- Long term steady state infiltration testing
- Treated wastewater quality as applied

The data collected have been used in the development of an Irrigation and Crop Management Plan to document the infrastructure requirements and the vegetative plant growth achieved through the project.

The USAID funded wastewater treatment plant that provides the water for reuse serves the Petra community with its large, seasonal tourist population. It is an extended aeration activated sludge plant that includes nitrogen reduction capability and has a design capacity of 3400 m^3/day. The current flow through the plant is approximately 1000 m^3/day and only half of the treatment units are in service. Most of the plant effluent is used for agricultural irrigation at the demonstration site and the remainder will be utilized for the farming area. The plant effluent is disinfected and pumped to a large polishing/holding pond to store treated wastewater until it is needed. The effluent quality is shown in Table 7.

Table 7 – WWTP Effluent Quality Wadi Musa

Test	Units	Jordanian Standard 893/2002 Cash Crops/Field Crops	Effluent Value
BOD_5	mg/L	200/300	3
COD	mg/L	500/500	31
TSS	mg/L	150/150	9
Turbidity	units		4
Cl_2 Res	mg/L		0.5
Ammonia	mg/L		5

3. Aqaba/ECODIT Inc.

The Aqaba Demonstration Project is being managed through a subcontract between PA and ECODIT, Inc., an American consulting firm, that was signed on May 5, 2003. The project is located in the southern coastal city of Aqaba and is managed in close association with the Aqaba Special Economic Zone Authority (ASEZA). While ASEZA is not a party to the subcontract, they are nevertheless a full and active member of the project team. The Aqaba project got a delayed start because of the current political situation in the area. The project includes a 100 dunum (10 hectare) demonstration area where treated wastewater will be applied to a variety of agricultural crops utilizing different irrigation methodologies. The site has not yet been planted because the project was late getting started and missed the Spring planting season. The subcontractor has prepared a cropping plan and the land is being prepared in preparation for cultivation and Fall planting. PA provides a Site Manager and a

site engineer who spend full time on the project and receive their work assignments from the subcontractor. Agricultural specialists of various specialties are provided on an as needed basis through PA or through the subcontractor. USAID and MWI provide active technical support and advice.

The activities to-date at the Aqaba pilot demonstration site have been limited to preparatory events leading up to site development and planting. Comprehensive bio-diversity surveys have been undertaken in recognition of Aqaba's unique coastal environment, and the presence of the international boundary near the demonstration site. These studies include avifauna survey, groundwater testing, flora and fauna surveys, and soil infiltration. (Wastewater treatment plant effluent quality is monitored by the MWI; the effluent quality at this present time is regarded as very low due to the over-capacity use of the treatment plant.)

The major stakeholders of the project meet regularly to set project policy and future directions. These comprise the local government authority (ASEZA), local major farms, the Aqaba Industrial Estate, and representatives from MWI. At the most recent meeting in September 2003 a cropping plan was developed for the 100 dunum (10 ha.) site and will be comprised of the following: 20 dunums (2 ha.) of ornamental shrubs and bushes and 2 plant nurseries, 40 dunums (4 ha.) of fruit trees including citrus, date palms, guava, mango, and papaya, and 20 dunums (2 ha.) of fodder/forage crops, including vetch, maize, barley and alfalfa. An additional site belonging to the Civil Aviation Authority will be planted with 6 rows of acacia trees on either side of the main airport road, covering an area of approximately 50 dunums (5 ha.) This latter area may be expanded in future as the volume of effluent from the treatment plan increases. A cropping plan has been developed for the 100 dunum (10 ha.) site and will be comprised of the following: 20 dunums (2 ha.) of ornamental shrubs and bushes and 2 plant nurseries, 40 dunums (4 ha.) of fruit trees including citrus, date palms, guava, mango, and papaya, and 20 dunums (2 ha.) of fodder/forage crops, including vetch, maize, barley and alfalfa. An additional site belonging to the Civil Aviation Authority will be planted with 6 rows of acacia trees on either side of the main airport road, covering an area of approximately 50 dunums (5 ha.) This latter area may be expanded in future as the volume of effluent from the treatment plan increases.

Summary

Phase I of the Water Reuse Implementation Activity is nearing its conclusion, but water reuse is such an important concept in Jordan that USAID and MWI are fully committed to carrying on the work in Phase II.