

Demonstrating the Suitability of Using Engineered Wetlands as a Low-cost Alternative for Treating Sanitary Sewage



Abstract: The Lake Manzala Engineered Wetlands Project (LMEWP) is a successful demonstration of the use of engineered wetlands to treat and reuse wastewater. The demonstration project has shown that engineered wetland treatment facilities constitute an effective, low-cost, low maintenance option and are well-suited for the climatic and operational conditions present in the Nile Delta of Egypt. Reduction rates of 61 % of BOD, 51% of Total Nitrogen and 99.7 % total Coliform bacteria have been collected at the project site, demonstrating a highly efficient technology. Treated water from the LMEWP can be safely and effectively used as a water source for fish farming and for safe disposal into Lake Manzala. These successes, if replicated in the area, will have a significant impact on the quality of local fish for human consumption, and will help to improve the water quality in Lake Manzala. LMEWP is contributing to an increasing interest across the Egyptian national government and several governorates to use low cost innovative treatment technologies (approximately 1/4 of the price of conventional treatment systems) to cope with the significant sewage treatment demands in Egypt.

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PROJECT DESCRIPTION

The Lake Manzala Engineered Wetland Project (LMEWP) is an experimental wastewater treatment plant located in the north-eastern corner of Egypt. Lake Manzala is located on the northeastern edge of the Nile Delta, between the two port cities of Domietta and Port Said. The project area is located at the tail end of the Bahr El Baqar drain, on the boundaries of Lake Manzala. This project, funded by the Global Environment Facility through UNDP as implementing agency, was designed as a prototype and learning project. It therefore emphasized issues of international collaboration – through for instance the involvement of the Tennessee Valley Authority (TVA) responsible for the conceptual design, and a Danish team from NIRAS assisting with facility planning and monitoring. All partners worked closely with both the Egyptian private and public sectors to build national capacities and ensure that a critical mass of Egyptian experts was trained to operate and replicate the experience after the end of the project.

THE EXPERIENCE

Issues and Challenges

Egypt is facing a pressing need to both treat the sewage wastewater of its increasing population, and to treat the agricultural drainage discharges, much of which eventually flows into the Mediterranean Sea – a shared water body all riparians have committed to protect through the Barcelona convention. As an arid, water scarce nation, Egypt is also keenly interested to safely and effectively treat and reuse wastewater.

Currently, Egypt produces around 5 bcm of untreated sanitary wastewater per year, and 12-13 bcm of its drainage water enters the Mediterranean annually. The already burdened Egyptian budget cannot afford the high cost of implementing conventional sanitary systems on a grand enough scale to solve these challenges. As such, low-cost technology is needed.

In a large number of towns and villages, the Egyptian government has provided local residents with clean, potable tap water, but no proper sanitary waste systems. The most commonly adopted solution is septic tanks, dug into the ground, some without proper flooring. However, septic tanks only work in certain environments. High tap water consumption, when coupled with the heavy clay soil of the Nile Delta and the low rate of infiltration and permeability of the Nile Valley, prevents the septic tanks from emptying naturally. This causes a water logging situation – creating health hazards and agricultural damage both inside residential areas and in the surrounding agricultural fields. The potentially hazardous situation is further aggravated by residents manually emptying their septic tanks into nearby agricultural drains and irrigation canals, often in close proximity to their houses.

Egypt also faces a severe challenge from agricultural drainage discharges, which flow untreated from farmers' fields into the Nile river and then into the Mediterranean Sea. Most agricultural fields in Egypt are treated with chemical fertilizers, pesticides and face increasing salinity. The Nile is Egypt's main water source, and a drop entering the Mediterranean might have been used several times as it flows from the High Aswan Dam to the Mediterranean. Water quality continually deteriorates as it flows northwards, moving from farm field to drainage canal to industrial plant, and so on.

Given Egypt's water scarcity, its vast amount of untreated wastewater, the availability of empty land, and the need for low-cost technology, engineered wastelands have been suggested as a viable alternative

with which to treat and re-use wastewater and ensure proper quality of water flowing into shared water bodies.

Addressing the Issue

The Lake Manzala Engineered Wetland Project investigated the suitability of using engineered wetlands as a low-cost alternative for treating agriculture drainage water prior to reaching Lake Manzala and on the Mediterranean Sea. The project's goals included:

- i. Improvement of the quality of the water of the northern lakes, which provide the country with a substantial quantity of fish and aquatic products and provide a living for thousands of inhabitants in the area
- ii. Improvement of the water quality in the Mediterranean Sea, thereby confirming Egypt's commitment to protecting the Mediterranean
- iii. Demonstrating to the local community the benefits of using treated water for the safe production of fish and agricultural commodities
- iv. Disseminating information on the benefits of engineered wetlands technology as a low-cost option for wastewater treatment.
- v. Generating employment for the local inhabitants, many of whom live at a lower quality of life than most Egyptians.
- vi. Developing national expertise on engineered wetland technology and raising national awareness of the importance of dealing with low quality water.
- vii. Utilizing the LMEWP prototype to further the understanding and operations of engineered wetlands, and to broaden support for its use in Egypt and other nations

The LMEWP was allocated 245 acres by the Egyptian government, and the engineered wetland currently occupies 60 acres. LMEWP was designed to treat 25,000m³/day of water lifted from Bahr El Baqar, which discharges 3.0 mcm/day to Lake Manzala. Two other drainage canals – Bahr Hadous and El Serw – also discharge water into Lake Manzala.

Engineered wetlands are an imitation of natural wetlands. Natural wetlands are open areas of land occupied by natural vegetation and shallow waters. Natural wetlands are known for their ability to improve water quality and regulate floods and droughts. When water enters at one end of the natural wetland loaded with a high concentration of suspended matter, heavy substances and toxins, it leaves the other end with reduced loads of these contaminants and pollutants most of which are taken up by the wetland plants.

Engineered wetlands are typically shallow basins filled with a relatively impermeable substrate, usually soil or gravel, and planted with vegetation tolerant of saturated conditions. Water is introduced at one end and flows over the surface, and is discharged at the other end through a structure which controls the depth of water in the wetland. The selection of aquatic plants – such as cattail, papyrus, and other reeds – along with the slope of the substrate determine the speed at which the water flows through the engineered wetland and consequently the extent to which it is cleansed through its passage.

The first step in the wastewater treatment process after pumping to the facility is to hold the wastewater briefly in sediment ponds. LMEWP works with two sedimentation ponds, into which two screw pumps lift water from Bahr El Baqar. The depth of water in these ponds is 1.5m. After water is allowed to settle for 48 hours, 80% of the suspended solids are removed. Two drying beds, located near the sediment ponds, receive sediments for drying.

Following sedimentation, and given the experimental nature of the LMEWP, two different techniques were tested for step two. The first technique uses wetland cells with aquatic reeds. The water from the sedimentation ponds flows by gravity through a distribution channel into cells planted with both emergent and floating plants. Different types of emergent reeds (e.g. Bulrush, Cattail, Papyrus) and different types of floating weeds (e.g. Water Hyacinth, Duck Weed); have been studied. In addition, testing has been done on supply rates and flow speeds through the cells.

The second technique uses a reciprocating treatment system. The water is moved from a surface flow to a sub-surface flow, through perforated pipes imbedded in a graded gravel media. Two separate cells pump the water back and forth. This type of aeration/de-aeration process causes the water quality to improve by enhancing oxygen content and releasing nutrients.

RESULTS AND LEARNING

Monitoring data indicates that the treatment system is effective in reducing pollutants (as measured by turbidity, BOD, nitrogen and phosphorus removal) from moderately polluted agricultural drainage water. The final product is water of a similarly high quality as that from water treated by conventional sewage systems. The facility has not been tested on highly polluted municipal and industrial wastewaters, however the literature on engineered wetlands shows considerable success in treating also heavily polluted waters.

The analysis from the collected field data, since August 2006, indicate the following removal efficiencies of the facility:

Constituent	Removal Efficiency
Biological Oxygen Demand	61.2%
Total Suspended Solids	80.0%
Total Phosphorous	15.2%
Total Nitrogen	51.4%
Organic Nitrogen	25.9%
Total Coliform	99.7%

(The table above indicates an overall efficiency of the facility based on the ratio between the influent wastewater and effluent water concentrations).

During the LMEWP, studies have been made on reuse opportunities for the treated water, both for field crops and fish farming. The poor, salty soil conditions in the area make it difficult to plant crops, however the lower Nile delta area is used extensively for fish farming. Results from the LMEWP indicate that fish raised in ponds using the treated water are healthy for human consumption, and for re-stocking Lake Manzala. The project has included the construction of 60 (feddans = acres) of fish ponds, recently completed. It is anticipated that by 2010, with the fish farm at full production, operating costs for the entire facility can be offset by the fish farm income.

The total budget of the project is US\$4.8 million, \$4.5 million as a contribution from GEF and \$0.3 million as a contribution from the Egyptian Environmental Affair Agency and Ministry of State for Environmental Affairs, in addition to the 245 acres of land as an in-kind contribution. This total figure is on the high side of what future project developers can expect when developing engineered wetland facilities in Egypt. The LMEWP was a demonstration project, utilizing international consultants and proprietary designs, and was situated at a difficult site to develop. Future facilities developed locally in Egypt should be able to reduce development costs by 30 – 40%.

There were unforeseen difficulties and delays in construction of the facility, relating in particular to its location. The project also suffered the unexpected withdrawal of TVA involvement due to US government security concerns in 2003. The RGS (sub-system), has yet to function as planned, its completion, testing and operation having suffered significantly from the TVA withdrawal. The monitoring of results was also delayed, as monitoring plans took time to draw up and for the parties to reach agreement. As a result, the facility has just completed its first full year of operation under approved monitoring protocols (since August, 2006). Facility operations have been further hampered in 2007 as a result of the prolonged changeover from EEAA to NWRC responsibility.

A primary set of project stakeholders are the local community where the facility is located. Benefits to local residents were prioritized in the project from the onset. Achievements include the improvement of the access road to the project site, the creation of job opportunities in construction and facility

maintenance, and providing training on improving fish production using reclaimed water. In addition, an agreement was reached with animal herders in the vicinity to periodically harvest the wetland reeds, which they use for animal fodder, also enabling the wetland system to operate effectively.

GEF support is ending prior to the fish farm being put into operation, prior to successful demonstration of any other revenue-enhancing options – for instance harvesting papyrus reeds: and prior to an approved plan (and budget) in place for future operations. There are therefore some risks and challenges with respect to sustainability. The Egyptian Government (MWRI and NWRC) have clearly indicated their keen interest to continue operating the facility, and to use it as a centre for regional training on operating engineered wetlands facilities.

Lessons Learned

- A rough comparison between the Capital Cost of the Lake Manzala Engineered Wetland Facility and Conventional Methods suggests that the capital cost of engineered wetlands can be 1/4 of the capital cost of conventional treatment methods. Also, an important advantage of engineered wetlands systems are their low operation and maintenance costs as shown below.

Method of Treatment	Capital Cost (L.E/m3)	Running Cost (L.E/m3)
Extended Aeration	3500	140
Oxidation Ditch	1700	105
Aerated Lagoon	1800	70
Oxidation Pond	1300	20
Engineered Wetland	400	Less than 1

- The direct involvement of the national institutions in design, construction, operation and maintenance – under the supervision of the international consulting firm – resulted in technology transfer to the project staff, national consultants, national contractors and research students. In terms of capacity building, it is important to maintain the balance of specialists from both governmental institutions and private sector firms. This will help to ensure the sustainability of the project after the phase-out of GEF funds.
- The open advocacy approach used by the project, which sought to maximize the involvement of relevant organizations and push for the merits of the technology, has been beneficial, contributing to a strengthening of national interest in the engineered wetlands. The project managers are continuing to maintain an open dialogue with interested groups and funding agencies, and their efforts are attracting additional international support. An agreement with a Canadian-funded project has been reached to test the reuse of LMEWP treated effluent for irrigated agriculture.
- Preliminary results show that the dimensions of the LMEWP facility can accommodate a treatment flow of up to 40,000 cubic meters per day, instead of the planned 25,000, due to the better than expected influent quality coming from the Bahr El Baqar drain, and taking into consideration the climatic conditions (hot, sunny) of the region. Future project designers should take into account these findings, enabling a larger volume of water to be treated, or, alternatively they can plan for facilities that occupy up to 40% less space.
- The project was initially viewed with suspicion by the local community, in part due to issues of land ownership and squatters rights. These have long been issues in the Nile Delta and were a leading cause for the initial project concept, developed with Denmark in 1994, to fall through. While the larger issue of how to handle land ownership and squatter rights in the Nile Delta area remains unresolved, the constructive and cooperative approach taken by project management has meant increased site safety, and the building of local interest and support. Future projects in Egypt and elsewhere will surely encounter land ownership rights issues and need to include strategies for local buy-in. Local fish farmers should especially benefit from the project. Local fish farmers have visited the site and a few have started to establish small-scale replicas using the LMEWP wetland design. They recognize that this type of treatment can improve fish health and size, enabling them to increase productivity and profit.
- During the course of facility construction, the LMEWP was sometimes subject to criticism from conservationists and ecologists due to confusion as to the purpose of the wetlands. When planning or initiating such an undertaking, it is crucial to communicate properly its intent. The purpose of the

facility was to treat wastewater, not to create wetland habitats for species conservation. Ironically, several species of birds now nest in the engineered wetlands, proving through their presence the effectiveness of water treatment.

- The initial project concept envisioned a major wetland facility, providing a demonstrable and significant improvement in the Bahr El Baqar drain water, prior to discharge into Lake Manzala. The GEF project that was eventually funded treats just 1% of the drain volume, so the intent shifted from one of direct environmental benefit, to indirect benefit – through demonstrating the viability of this low cost technology for water reuse as well as discharge. Other objectives of the project included to assist with sustainable economic development in the community where the facility was developed. For future wetland facilities, it is important to ensure that the objectives are clear, achievable, and prioritized, and that site selection is carefully done in support of the main objectives. The LMEWP was situated in a site that may be well- suited for environmental benefit, and community support, but is less ideal as a site for research and training.
- At the end of GEF support, the LMEWP is in the midst of a changeover in responsibility with the Egyptian Environmental Affairs Agency (EEAA) ceding ownership and reasonability to the national Water Research Centre (NWRC) under the Ministry of Water and Irrigation (MWRI). The changeover makes sense, as the NWRC is the agency best able to manage the facility and benefit from its use, yet the late date of the changeover, coming only as the GEF funding concludes, poses a risk to the sustainable operation of the facility.
- The development of a Business Plan for the facility only at project end creates difficulties for agencies to set their budgets and staffing effectively. The LMEWP would have benefited from an “Exit Strategy” being developed soon after the project midpoint, to assist the Egyptian Ministries in planning for the facility post-GEF support, to include a business plan drafted at least 18 months prior to project conclusion. The Business Plan would also benefit from a clear distinction between the treatment facility operations and the fish farming operations. These are in fact two separate activities, and the fish farm may be suitable to open to concession contract for private management.

REPLICATION

LMEWP is contributing to an increasing interest across the Egyptian national government and several governorates to use low cost innovative treatment technologies to cope with the significant sewage treatment demands in Egypt. Already, the Governorate of Port Said has utilized the LMEWP design for a new treatment facility in a nearby village, to treat municipal sewage, and other facilities are at the design stage. In-stream wetland systems are being tested for cleaning effluent within the agriculture drainage canals, and designs are being developed for expanding wetland systems at the mouth of several of the agriculture drains prior to emptying into the delta.

Egypt has recently revised its effluent reuse code, and there is great interest in the use of engineered wetlands for treating and then reusing agriculture drainage water for fish farming, cultivation of trees and other irrigation purposes. The LMEWP success in rendering drainage waters fit for fish farming, should provide a strong impetus for further replication of the technology elsewhere in the Lake Manzala area and across the Delta.

The business plan now being developed for the LMEWP should help the Egyptian Government manage this facility and serve as a model for other facilities. It can help to convince local authorities of the economic viability of such facilities, and highlight their low operation and maintenance costs, and income generation potential.

In trying to achieve the MDGs in relation to water sanitation, many countries are now preparing water sanitation plans. The high cost of achieving improved sanitation requires that innovative low-cost technologies are utilized. The sanitation plans under development offer excellent opportunities for the promotion of engineered wetlands and provide a framework for the replication of such plants.

SIGNIFICANCE

Treated water from the LMEWP can be safely and effectively used as a source water for fish farming and for safe disposal into Lake Manzala. These successes, if replicated in the area, will have a significant impact on the quality of local fish for human consumption, and will help to improve the water quality in

Lake Manzala. The area of natural wetlands in Lake Manzala has shrunk from 700,000 feddan to 200,000 feddan over the past seventy years. The LMEWP demonstrates the benefits of wetlands in reducing pollution, and should spur the Egyptian government towards replenishing and protecting the natural wetland systems in the delta.

The draft Business Plan for the LMEWP proposes a vision for LMEWP and set of important immediate objectives:

Vision: A focal centre for engineered wetlands capacity building, technology transfer, adaptation and awareness creation

Immediate Objectives

1: Establish feasibility of improving the water quality of Lake Manzala through engineered wetland technology

2: Potential for local economic activities enabled by engineered wetland technology established

3: Low cost solutions for village level waste water treatment identified and design foundation specified

4: Cost – effective affordable, competitive means of water production for economic activities developed

5: Steady state conditions, long term sustainability, lifespan forecasting and life cycle economics established

The project has contributed to the expansion of knowledge and expertise within Egypt on the design, construction and operation of engineered wetland facilities. There is now an opportunity for Egypt to continue to refine this expertise, becoming a recognized leader in the development of innovative low cost treatment technologies. The articulation of the long-term objectives for the site in terms of its use and sustainability can ensure that Lake Manzala provides cutting edge experience in a region with growing water shortages. Learning from the LMEWP experience, other countries with similar climatic conditions can rapidly adapt the process, and streamline initial testing and start up procedures

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See a description of the project and activity at: <http://www.waterfair.org/content.spring?contentItem=472> and <http://www.undp.org.eg/Default.aspx?grm2catid=15&tabid=148>.

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