International Journal of Water Resources and Arid Environments 5(1): 29-34, 2016
ISSN 2079-7079


# Socio-Economic Studies on Treated Wastewater Reuse in Western Desert, Egypt: An Integrated Approach

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**Abstract:** This work is a part of "Alexandria Effluent and Sludge Reuse Study" which has been commissioned to establish the appropriate approaches to be adopted by Alexandria General Organization for Sanitary Drainage (AGOSD) to secure efficient and beneficial disposal of treated wastewater and sludge. The Study is being funded by the European Investment Bank and is being carried out on behalf of AGOSD by Wrc. The objective of this study was to find alternative and additional water resources to develop marginal desert lands of west delta of Egypt and to allow safe and economically responsible reuse of treated wastewater from the city of Alexandria through agriculture. In order to achieve these goals a detailed survey for 74000 feddans (30800 ha) in Alexandria catchments was studied. During the study the area was classified into three categories according to the farm size to represent the range of farm types in the development area (small, medium and large farms). The overall cropping pattern for the command area and the cost of the tertiary and on-farm irrigation systems (surface and drip), other infrastructure and equipment and all operating and maintenance costs were calculated. Agro and socio-economic evaluations were undertaken. Social studies indicated that adoption of the scheme would have considerable social and socio-economic benefits derived from the resettlement of landless people from the overcrowded delta lands and the urban fringes. More than 2000 farmers and their families would benefit from increased incomes, employment and enhanced land values. The scheme itself, in economic and financial terms, is only marginally attractive for smallholders and the inclusion of tree production enhances the viability and provides employment. The production of forage would have a positive impact upon the livestock of the semi-nomadic Bedu and result in considerable expansion of sheep production, many of whom would be destined for export. The production of grains and wood would go some way to reduce imports of these commodities. Overall employment opportunities and incomes of settlers and nomads would improve. The results showed that the total capital costs of the treated wastewater conveyance system scheme are estimated at USS 394 million and the average annual net return per feddan was much lower on the small farm than the other models because of the less capital-intensive semi-commercial farming system adopted. Overall, the project would have an EIRR of 7.6%. Despite the relatively high capital cost of the project the economic performance is reasonable. The major contribution to the benefits is obtained from the industrial tree crops to produce high quality tropical hardwood and/or wood for fuel or pulp and they make up over half of the predicted irrigated command area and produce over 70% of the benefits. Without forestry, the scheme would be uneconomic. In conclusion, the study showed that treated wastewater re-use can significantly contribute to national development schemes.

**Key words:** Socio-economic · Treated wastewater · Egypt · Agricultural production

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## INTRODUCTION

The current water budget in Egypt show that the annual water demand exceeds the available fresh water by 6 billion $m^3$/year [1]. Therefore, it is essential to develop water resources through untraditional ones.

Wastewater has been used to support the agricultural production in many countries such as USA, Germany, India, Kuwait, Saudi Arabia, Oman, Jordan and Tunisia [2].. Several investigators indicated the beneficial role of wastewater in increasing crop yields without or with minimal risks to the plant, soil, groundwater and health [3-8].

Alexandria is the second largest city in Egypt with about three million inhabitants and it also has about 40% of the Egyptian industry. It has two large WWTPs and a third is planned.The provision of sewage treatment in Alexandria has resulted in the production of substantial quantities of treated wastewater and sludge. In an arid country such as Egypt, these materials should be regarded as valuable resources for agricultural irrigation and soil fertilization, particularly as water resources are limited and there is an urgent need for continued horizontal expansion of agriculture into the desert areas as the population expands. However, treated wastewater need to be treated and managed appropriately to avoid potentially adverse impacts on the environment and human health. The use of treated wastewater and sludge must also be practicable and economic, to ensure operational sustainability [9-11]. The principal objective of this study is to allow safe and economically responsible reuse of treated wastewater in warm climates with special reference to Egypt from the city of Alexandria in order to make best use of existing resources and to protect the environment and human health.

## MATERIALS AND METHODS

The Alexandria Effluent and Sludge Reuse Study has been commissioned to establish the appropriate approaches to be adopted by Alexandria General Organization for Sanitary Drainage (AGOSD) to secure efficient and beneficial disposal of treated wastewater and sludge. The Study is being funded by the European Investment Bank and is being carried out on behalf of AGOSD by WRc. In order to support the development of a full-scale scheme for the reuse of about 1.5 million $m^3$ per day, the main components of the study were to characterize treated wastewater quality and to assess its suitability for reuse in the agricultural purposes and to demonstrate the use of treated wastewater in agriculture through monitoring of the field trials, to show the potential agronomic and environmental benefits and impacts. In addition to propose treated wastewater reuse scheme and outline design prepared by the study as well as the financial and economic analyses of the proposed project.

In order to achieve such goals samples of treated wastewater were taken to assess the quality of the treated wastewater The standard procedures for these analysis were applied [12]. Field trials were established to evaluate and demonstrate the reuse of treated wastewater to arable crops and trees in a typical soil similar to the reclaimed land in the targeted area of reuse. The proposed treated wastewater convenience system and the outline design was prepared by the Study. Financial, social and economic analyses of the proposed project were prepared.

## RESULTS

The detailed chemical and microbiological analyses of the treated wastewater were carried (Table1) showed that the treated wastewater complied with the adopted limit values of the Egyptian code of practice of reuse (Decree 44/2000).

The crop yield results demonstrated that crops irrigated with secondary treated wastewater perform equally as well as, or significantly better than, with canal water. It is worthy to note that the treated wastewater potentially contributes a significant portion of the nutritional requirements of crops (Table 2).

Generally, yields were raised to a similar extent by the full rate of fertilizer application compared to the half rate for both sources of irrigation water (Fig. 1).

The tree trial data showed that Casuarina had the highest survival rate (97%) and Ficus 84%, as may be expected being locally adapted. Eucalyptus and Bombax achieved 53%, but other fruit trees did not establish (Table 3). Samples of leaves were taken from each species and treatment and analyzed for trace element composition and these showed no differences between the treatments, having low concentrations of trace elements and heavy metals.

**The Proposed Treated Wastewater Reuse Scheme:** A route has been proposed and costs estimates prepared for a dedicated treated wastewater Conveyance System (ECS) to transfer the future treated wastewater from the

Table 1: Analysis of effluent applied to field trials (mean values) and compared with maximum limit values in Decree 44/2000.

| Parameter[(1)] | Biotower | Limit values for secondary treated effluent |
|---|---|---|
| pH | 8.3 | 6 to 9 |
| Dissolved oxygen | 7.8 | - |
| Total suspended solids[(2)] | 67 | 40 |
| Biological oxygen demand[(2)] | 59.6 | 40 |
| Chemical oxygen demand | 158 | 80 |
| Oil and grease | 7 | 10 |
| Total dissolved solids | 1164 | 2000 |
| Alkalinity | 352 | - |
| Sodium adsorption ratio | 6.2 | 20 |
| Nitrogen (TKN) | 18.6 | - |
| Nitrate ($NO_3$) | 0.094 | - |
| Ammonia ($NH_3$) | 13 | - |
| Chloride ($Cl^-$) | 444 | 300 |
| Phosphate ($PO_4$) | 3.1 | - |
| Sodium (Na) | 584 | - |
| Calcium (Ca) | 396 | - |
| Magnesium (Mg) | 170 | - |
| Potassium (K) | 40 | - |
| Cadmium (Cd) | 0.0015 | 0.01 |
| Chromium (Cr) | 0.0074 | 0.01 |
| Copper (Cu) | 0.003 | 0.2 |
| Lead (Pb) | 0.0414 | 5 |
| Nickel (Ni) | 0.0124 | 0.2 |
| Zinc (Zn) | 0.041 | 2 |
| Boron (B) | not determined | 3 |
| Molybdenum (Mo) | not determined | 0.01 |
| Manganese (Mn) | not determined | 0.2 |
| Iron (Fe) | not determined | 5 |
| Cobalt (Co) | not determined | 0.05 |
| Parasite eggs (No. ova/l) | mean: 283; median: 0 | 1 |
| Faecal coliform (MPN/100 ml) | median: $7.3 \times 10^7$ | 1,000 |

Note: [(1)] Units as mg/l or as indicated and [(2)] Elevated values due to the presence of algal growth in effluent storage tank. Mean values for freshly treated effluent: pH 7.7; TSS 37 mg/l; BOD 41 mg/l.

Table 2: Percentage of recommended amounts of fertiliser supplied by effluent to winter and summer crops, Effluent Irrigation Trial, Baghdad.

| Parameter | Wheat | Faba bean | Berseem | White maize | Yellow maize | Cotton |
|---|---|---|---|---|---|---|
| Nitrogen | 32 | 27 | 68 | 9 | 14 | 17 |
| Phosphorus | 81 | 21 | 52 | - | - | 18 |
| Potassium | 359 | 90 | 455 | 53 | 85 | 116 |

East, West and Agamy-Mex-Dekhila WWTP to treated wastewater discharge points into the ECS. The costs and benefits determination of the treated wastewater reuse scheme indicated that the total capital costs of the scheme are estimated at US$ 394 million, with annual operating and maintenance costs of US$ 40 million (Table 4).

The economic study showed that the small farm model showed the largest FIRR of 19 %, compared with a FIRR of 10% for both the medium and large farm models (Table5). This is a reflection of the lower costs and immediate returns from annual cropping on the small farms, whereas the larger farms are more capital intensive and take longer to achieve positive cash flow due to the predominance of tree crops. However, the average annual net return per acre is much lower on the small farm than the other models because of the less capital-intensive semi-commercial farming system adopted. Nevertheless, perennial crops (fruit trees and fuel wood) still make an important contribution to profitability. If these perennial crops are excluded then the FIRR falls to less than 0%.

Overall, the project would have an EIRR of 7.6% (Table 6). Despite the relatively high capital cost of the project and the high operating and maintenance costs necessitated by the need to lift pump the treated wastewater water several times during its conveyance to the project area and the predominant use of expensive trickle irrigation systems, the economic performance is reasonable.

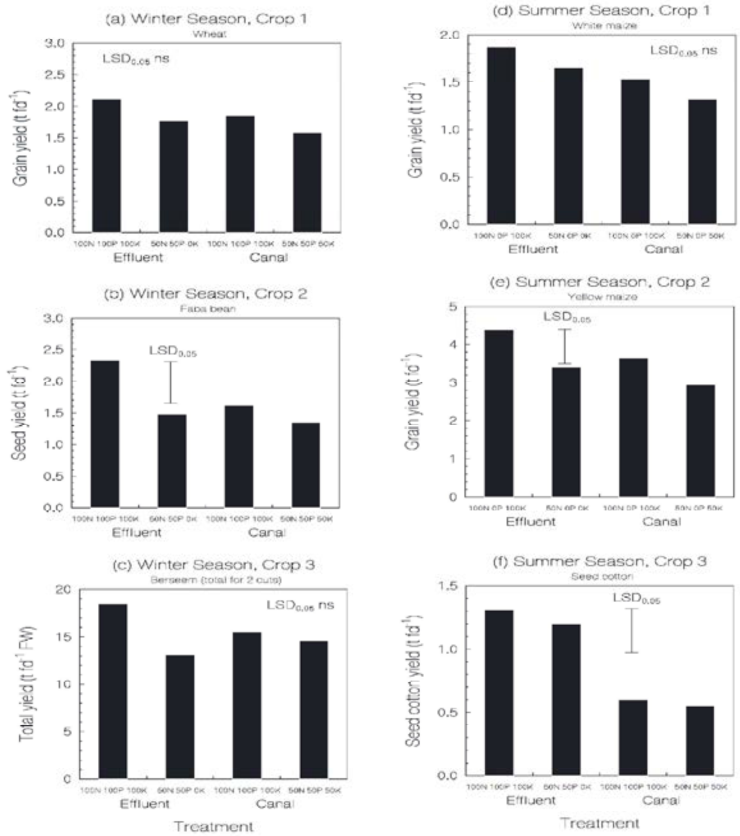


Fig 1: Economic yield parameters of 3 winter season and 3 summer season crops irrigated with treated effluent and canal water and receiving adjusted rates of inorganic fertiliser.

Table 3: Survival of trees and shrubs after two seasons (number planted and percent survival).

| | Compost+Canal | | Compost+Effluent | | Effluent | | Overall |
|---|---|---|---|---|---|---|---|
| Species | No. planted | % survival | No. planted | % survival | No. planted | % survival | % survival |
| Original plantings that survived initially | | | | | | | |
| *Bombax* | 5 | 20 | 5 | 60 | 5 | 80 | 53 |
| *Casuarina* | 22 | 100 | 22 | 95 | 22 | 95 | 97 |
| *Eucalyptus* | | | | | | | 53 |
| *Populus* | 5 | 0 | 5 | 0 | 5 | 0 | 0 |
| *Rosa* | 18 | 0 | 18 | 0 | 18 | 0 | 0 |
| *Dodonea* | 29 | 93 | 39 | 97 | 39 | 95 | 95 |
| *Myoporum (1st row)* | 26 | 81 | 26 | 81 | 26 | 100 | 87 |
| *Myoporum (2nd row)* | 22 | 100 | 24 | 88 | 24 | 100 | 96 |
| *Duranta* | 23 | 30 | 23 | 78 | 33 | 52 | 53 |
| *Adhatoda* | 25 | 68 | 21 | 71 | 28 | 46 | 62 |
| *Hibiscus* | 26 | 73 | 22 | 67 | 24 | 86 | 75 |
| *Nerium* | 30 | 100 | 26 | 77 | 29 | 66 | 81 |
| Replacement species | | | | | | | |
| Ficus | 5 | 80 | 5 | 100 | 7 | 71 | 84 |
| Tichoma | 23 | 83 | 15 | 93 | 30 | 50 | 75 |
| *Ponsiana* | 5 | 100 | 5 | 80 | 5 | 60 | 80 |
| *Olivea (2 rows)* | 5 | 0 | 5 | 0 | 5 | 0 | 0 |
| *Pican* | | 0 | | 0 | | 0 | 0 |
| *Eryobotia* | 5 | 0 | 5 | 0 | 5 | 0 | 0 |
| Mean survival | | 58 | | 62 | | 56 | 58 |

Table 4:Capital and operating costs of proposed effluent reuse scheme.

| Item | Amount (US$ million) |
|---|---|
| Capital costs | |
| Conveyance system (canals, pumping stations, structures, etc.) | 210.8 |
| Distribution systems within the Hammam Extension Area | 126.2 |
| Detail design and construction supervision (assumes done locally) | 5.3 |
| Contingencies | 51.3 |
| Total | 393.6 |
| Operating and maintenance costs | |
| Pumping stations | 4.5 |
| Secondary and tertiary service units and trickle irrigation | 35.7 |
| Total | 40.2 |

Table 5:Farm model financial analysis (LE).

| Item | Small Farm Model | Medium Farm Model | Large Farm Model |
|---|---|---|---|
| Farm size Net Command Area (NCA) feddan** | 5 | 100 | 1000 |
| Irrigation and Infrastructure Development cost per feddan NCA | 5,780 | 11,890 | 23,550 |
| Years to positive cash flow | 2 | 5 | 5 |
| Net Annual Farm Income per feddan at full development * | 2,851 | 7,364 | 11,863 |
| Financial Internal Rate of Return (FIRR) | 19 % | 10 % | 10 % |

Note: * Averaged for the period from year 10 to 20 because of the irregular cash flow from plantation forestry.
** one feddan = 0.42 ha

Table 6: Sensitivity analysis on Economic Internal Rate of Return.

| Parameter | Variation | EIRR (%) |
|---|---|---|
| Project as evaluated | | 7.6 |
| Capital costs: | +20 % | 6.8 |
| | -20 % | 8.5 |
| O&M costs: | +20 % | 7.1 |
| | -20 % | 8.1 |
| Agricultural output prices: | -20 % | 5.5 |
| | +20 % | 9.2 |
| No hardwood, all pulpwood | | <0 |
| No industrial tree crops | | 3.7 |
| All industrial tree crops | | 7.8 |

The major contribution to the benefits is obtained from the industrial tree crops to produce high quality tropical hardwood and/or wood for fuel or pulp. They make up over half of the predicted irrigated command area and produce over 70% of the benefits. Without forestry, the scheme would be uneconomic.

**Socio-Economic Issue:** The construction of the ECS and the associated effluent reuse irrigation scheme will have positive impacts upon the present generally low socio-economic status of the local population and the landless farmers who will be settled under the development. Such opportunities would include the creation of jobs for Bedouin and other local people, as well as strengthening the local economy in terms of new business opportunities. In particular, businesses would be required for processing wood (paper pulp, sawmills, construction board, etc.) from the large-scale production of trees proposed within the irrigation scheme. Some prosperity will spread off-site to the coastal zone.

**Institutional Issues:** A minor positive impact is projected for activities on the assumption that an efficient environmental co-ordination committee is assembled. The effectiveness of the relevant institutions within the Project Area should be significantly increased by the formation of the recommended co-ordination committee.

**Human Use Issues:** Cultivation would increase significantly under an assured irrigation supply within the Hammam Extension Irrigation Scheme and this is rated a major positive impact. The possible loss of some cultivated land (needed for the ECS) in the Bahig and Hammam ED are rated a minor negative. Elsewhere there is no impact.

Livestock may be subject to a minor negative impact in Lake Mareotis ED (loss of some grazing), but a major positive impact is predicted for the irrigation scheme with some minor positive effects on the coastal plain (supply of fodder).

Fisheries would be subject to a minor negative impact within Lake Maryout (loss of nutrients from effluent).

Forestry would provide a very major positive impact within the irrigation scheme.

Urban/industrial activity may suffer in Lake Mareotis ED (minor loss of land from salt pans) with moderate positive effects within the irrigation scheme (crop and wood processing) and a minor positive effect on the coastal plain. Minor negative effects would result from the ECS cutting across lines of communications, especially unmade roads and tracks, with a moderate positive effect within the irrigation scheme (road construction) and a minor improvement in navigability in the Nubaria Canal.

Energy supply would have increased demands made for the operation of the pumping stations to give a minor negative impact. Conversely the removal of effluent from Lake Maryout will result in less water to be pumped through El Mex PS and is thus a minor positive impact.

## CONCLUSIONS

The responses of a wide range of field crops to treated wastewater irrigation is consistent with international experience, Re-use can help to maximize the wastewater benefits and contribute to national development. Collaboration between users, authorities and the public is needed. Exchange of experiences is very important as well as governmental support and encouragement is needed.

## REFERENCES


1. Abu Zeid, M., 1992. Water resources assessment in Egypt. Water Resources Development, 8(2): 76-86.
2. Rowe, D.R. and I.M. Abdel-Magid, 1995. Handbook of Wastewater Reclamation and Reuse. Lewis Pub.,USA.
3. Shatanawi, M. and M. Fayyad, 1996. Effect of Khirbet As-Samra treated effluent on the quality of irrigation water in central Jordan valley. Water Research, 3(12): 2915-2920.
4. Oron, G., Y. DeMalach, Z. Hoffman and Y. Manor, (1991). Effluent reuse by trickle irrigation. Water Science and Technology, 24(9): 103-108.
5. Oron, G., Y. DeMalach, Z. Hoffman and Y. Manor, 1992. Effect of effluent quality and application method on agriculture productivity and environment of control. Water Science and Technology, 26(7-8): 1993-1601.
6. Vasquez-Montiel, O., N.J. Horan, D.D. Mara, A. Angelakis and T. Asno, 1996. Management of domestic wastewater for reuse in irrigation. Water Science and Technology, 33: 10-11, 355-362.
7. Aissi, A., R. Chouker-Allah, H. Elmomari, A. Hamdi and B. Soudi, 1997. Impact of irrigation with treated wastewater on infiltration,seepage and uptake on growth of melon (Cucumis melo L. ).CIHEAN International Conference, Valenzano, Bari, 22-26 Sept., pp: 151-170.
8. Palacios, N.P., O.A. Pard, E. Del-Nero, F. Rodriguez and L. Sulos, 2000. Legumes for Mediterranean forage crops, pastures and alternative uses. Proceeding of the $10^{th}$ meeting of the Mediterranean sub-network of the FAO-CHIEAM Inter-regional Cooprative Res. Cahiers Options Mediters, 45: 181-185.
9. Abd El Lateef, E.M., Jeremy E. Hall, Mahmoud A.A. Farrag and Aziza A. Farrag, Agro-Economic Studies on Wastewater Reuse in Developing Marginal Areas in WestDelta,. Egypt2010 International Journal of Water Resources and AridEnvironments, 1(2): 110-115.
10. Abd El Lateef, E.M., Jeremy E. Hall, 4Mohamed S. Negm, Peter C. Lawrence, 1Medhat M. Tawfik and Aziza A. Farrag 2013. Some Biohydrological Effects of Agricultural Activitieson Desert Soil and Groundwater Pollution: A Case Study. International Journal of Water Resources and Arid Environments 3(2): 78-83.
11. Mahmoud, M.J., N. Mazahreh and M. Ayadi, 1998. Reuse of treated wastewater for irrigation of forage crops under dry land conditions. Yield nutrient uptake and soil quality. Proceeding of the Intern. Conf. of Advanced Wastewater Treatment, Recycling and Reuse, Milano, 14-16 Sept.: 2: 733-740.
12. APHA (American Public Health Association, 1992. Standard methods for the examination of water and wastewater. $18^{th}$ ed,