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Agro-Economic Studies on Wastewater Reuse in Developing Marginal Areas in West Delta, Egypt

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Abstract: The objective of the 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(one feddan=4200 m^2) in Alexandria catchments was studied. During the study the area was classified to 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. The results showed that the total capital costs of the treated wastewater conveyance system scheme are estimated at USS 394 million, with annual operating and maintenance costs of USS 40 million. 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. Nevertheless, perennial crops (fruit trees and fuel wood) represented an important contribution to profitability and if these perennial crops are excluded from the cropping pattern then the FIRR(Financial Internal Rate of Return)falls to less than 0 %. Overall, the project would have an EIRR (Economic Internal Rate of Return) of 7.6%. 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 water several times during its conveyance to the project area and the predominant use of expensive trickle irrigation systems, 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: Egypt • Marginal lands • Treated wastewater

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 [3-9].

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

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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. The principal objective of the 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 [10]. 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 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 (Table2)

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(Table3). 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 East, West and Agamy-Mex-Dekhila WWTP to treated wastewater discharge points into the ECS (Fig.2). 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 (Table4).

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 lowest 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

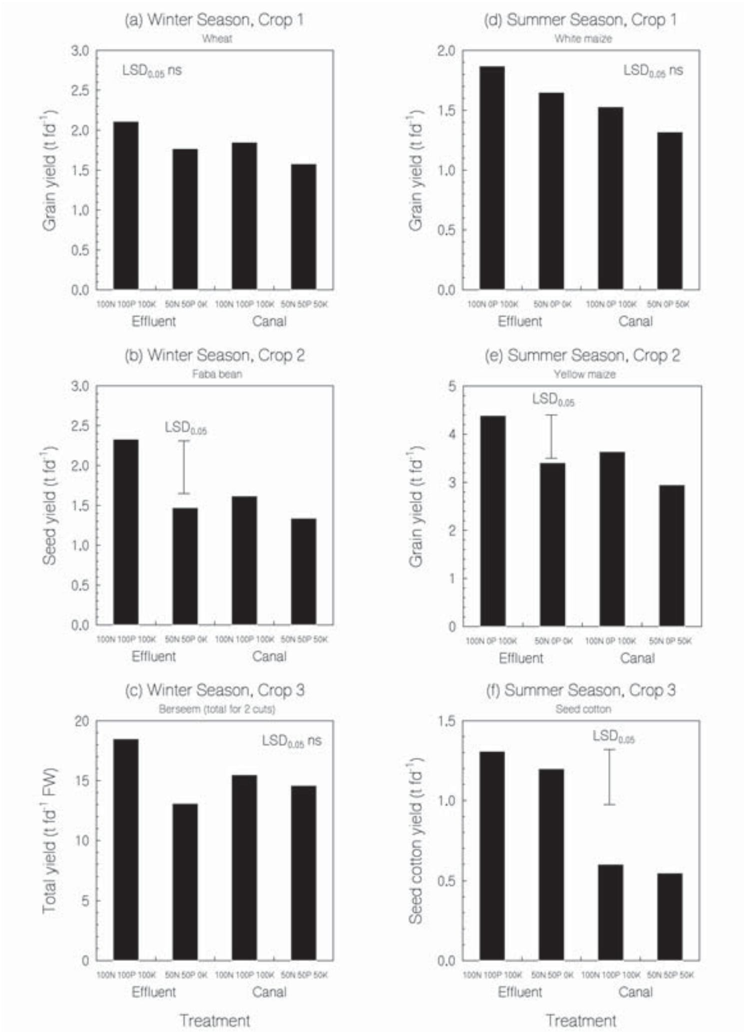

Fig. 1: Economic yield parameters of three winter season and three summer season crops irrigated with treated effluent and canal water and receiving adjusted rates of inorganic fertilizer

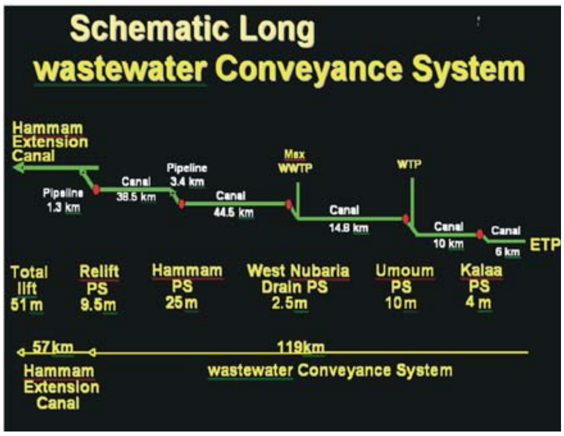

Fig. 2: Schematic long section for the proposed conveyance system for the treated wastewater

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: 7.3×10^7	1,000

Note: (1) Units as mg/l or as indicated

(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 fertilizer 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

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

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 and 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

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.

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.

CONCLUSION

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 re-use can 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.

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