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AGRICULTURAL DRAINAGE WATER REUSE IN EGYPT: STRATEGIC ISSUES AND MITIGATION MEASURES

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ABSTRACT – Agricultural drainage water reuse is well developed in Egypt, particularly in the Nile Delta region. However, the drainage reuse practices has been threatened by the deteriorating drain water quality due to municipal and industrial wastewater pollution. The government is implementing different programmes for improving the irrigation system and changing water allocation among the regions and water use sectors, which will alter the patterns of drainage availability and the drainage water management perspective. Such programmes are the irrigation improvement programme and the government strategy to reduce size of the cultivated area with the high water requirement crops. This paper investigates the potential impacts of these programmes on drainage water availability and on its suitability for reuse. It highlights several strategic drainage reuse issues such as the minimum drainage outflow requirements to maintain the ecological life features in the northern lakes and to help controlling the seawater intrusion, and pollution control.

Key words: agricultural drainage water reuse, water pollution, water allocation and water conservation

INTRODUCTION

Operation of the Nile system is presently successful in meeting the current water demands. However, Egypt must do more with less water to cope with future development plans for the country and with projected future increase in population. The government of Egypt has introduced different innovations to the existing system in order to save water from old lands to be diverted to the targeted new lands. These innovations included projects and water reuse programmes. Drainage water is one of the valuable water resources in Egypt created by the intensive and large irrigation/drainage systems. Drainage water reuse is also viewed as relatively less-infrastructure requirements to be constructed and cheaper option. However, environmental impacts are very important to be considered in the implementation of drainage reuse.

Drainage reuse was practiced since 1970 in the Lower Egypt. With the expansion of drainage reuse activities, the government developed, in 1975, a national policy for drainage reuse in an attempt to raise the Nile water use efficiency and hence to expand the cultivated area. At present, drainage reuse is widely practiced in Delta region through 23 locations defined as central drainage reuse system. This system provides about 4.0 BCM/year of drainage water to be mixed with the fresh water of main canals. The government has an ambitious plan to expand drainage reuse to reach 8.0 BCM/year leaving a quantity not less than 8.0 BCM/year to be discharged to the sea which, is thought to be the minimum amount to keep the salt balance for Delta region. As water resources became scarcer in recent years, due to expanding the cultivated area and then spreading water out of Delta and the expansion of rice cultivation, water deficit at canal tails was recorded. Therefore, farmers found that the only way to compensate their irrigation is the nearby drains. They started to lift drainage water to their fields violating the irrigation and the drainage laws and regulations, and neglecting the side effects of the polluted drainage water. The objective of this paper is to highlight on drainage availability, potential of expanding drainage reuse, and strategic issues to be considered in drainage reuse policies and practices.

DRAINAGE REUSE FOR IMPROVING WATER USE EFFICIENCY

The agricultural drainage reuse is defined as the excess of crop evapotranspiration in addition to canal tail losses. The drainage flow is carried by the drainage system to be disposed out of the irrigation system. The philosophy of drainage reuse is to lift out a portion of this drainage water to be mixed with canal water. Hence, the canal will be able to irrigate more land. This means that for the same canal flow, crop evapotranspiration increases which means increasing water use efficiency. Fig. 1 explains this phenomenon.

It can be concluded from the figure that the irrigated area can be increased from “A” to “A+ΔA” through applying a reuse system which adds an amount of water of ΔD to the inflow Q. Consequently, the crop evapotranspiration can increase from “ET” to “ET + ΔET”. Using the classic definition of water use efficiency (η) which is written as follows:

$$\eta = \text{crop evapotrnspiration / inflow}$$

Then,

$\eta_1 = ET / Q$ (without reuse)

$\eta_2 = (ET + \Delta ET) / Q$ (with reuse)

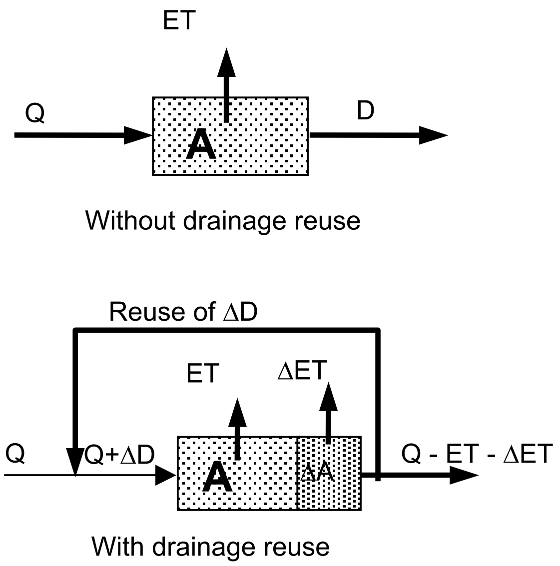

Figure 1. Drainage water reuse and water use efficiency

This shows the increase in water use efficiency through introducing drainage water reuse into the irrigation system.

DRAINAGE REUSE PRACTICES IN EGYPT

Three levels of drainage reuse are practiced in Egypt. The first is called “main drainage reuse level” which is implemented through the government programmes. The second is called” unofficial drainage reuse level” which is practiced by the individual water users according to the water deficit. The third type of reuse can be defined as”intermediate drainage reuse level”; it is implemented by the local irrigation directorates in their respective province jurisdiction. These levels of reuse differ from one region to another in terms of reuse pattern, quantity, and quality.

Main Drainage Reuse

Main drainage reuse means mixing drainage water of main drain with main canal. This type of reuse started in the early of 1970's to raise water use efficiency and then saving water to reclaimed areas. There are 23 main reuse locations in Delta region and 9 locations along Bahr Yousef canal in Middle Egypt. Reuse locations in Delta include 21 pump stations and 2 drains flow by gravity to Rosetta branch. Three other drainage reuse pump stations discharge their drainage water to Damaietta branch. Fig. 2 shows the existing and planned drainage reuse locations in Delta region. Table 1 summarizes annual drainage reuse quantity and quality since 1984, while Table 2 shows the drainage outflow during the period 1984/85 to 1995/96. Years after 1996 were not considered in the analysis since Aswan releases were higher than normal due to high floods during these years. The drainage reuse increased from 2.8 BCM/year in the 1980s to about 4.0 BCM/year in the 1990's, while drainage outflow to the sea looks to be constant and on the order of 12.5 BCM/year. Increase in drainage water reuse was a result of constructing four new drainage reuse pump stations.

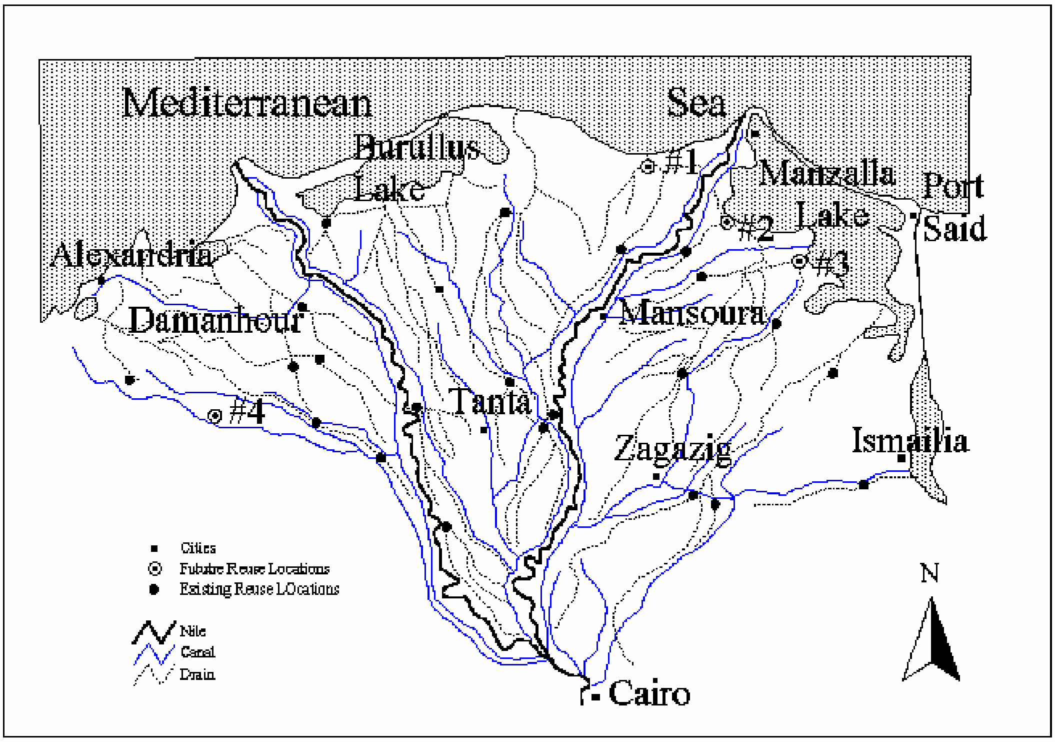

Figure 2. Existing and future drainage reuse locations in Delta

Table 1. Drainage water reuse in Delta

Year	East Delta		Middle Delta		West Delta		Whole Delta	
	Quantity m.m^3/y	Salinity ppm	Quantity m.m^3/y	Salinity ppm	Quantity m.m^3/y	Salinity ppm	Quantity m.m^3/y	Salinity ppm
1984/85	1301	819	763	826	814	915	2878	864
1985/86	1263	832	748	774	788	966	2799	858
1986/87	1420	858	766	794	807	979	2993	877
1987/88	1381	922	693	902	629	1216	2703	986
1988/89	1400	979	704	934	555	1037	2659	979
1989/90	1504	1005	1506	1434	626	954	3636	1171
1990/91	1585	1018	1999	1088	639	1005	4223	1050
1991/92	1445	934	2058	1152	617	934	4120	1043
1992/93	1460	902	1841	1082	561	819	3862	973
1993/94	1120	1011	1691	1126	619	717	3430	1018
1994/95	1390	1050	1843	1190	685	794	3918	1069
1995/96	1746	1210	1815	1146	706	768	4267	1107
Average for 84/85-88/89	1353	882	735	846	719	1023	2806	913
Average for 90/91-92/93	1499	965	1851	1189	611	928	3960	1059
Average for 93/94-95/96	1419	1090	1783	1154	670	759	3872	1065

Table 2. Annual drainage outflow to Sea and lakes

Year	East Delta		Middle Delta		West Delta		Whole Delta	
	Quantity $m.m^3/y$	Salinity ppm	Quantity $m.m^3/y$	Salinity ppm	Quantity $m.m^3/y$	Salinity ppm	Quantity $m.m^3/y$	Salinity ppm
84/85	4391	1357	5013	2144	4321	3686	13725	2381
85/86	4219	1498	4883	2374	4339	3213	13441	2374
86/87	3815	1555	4900	2381	3955	3021	12670	2330
87/88	3514	1690	4291	2534	4030	3616	11835	2650
88/89	3181	1766	4142	2483	4168	3840	11491	2778
89/90	3651	1824	4159	2554	4573	3680	12383	2752
90/91	3726	1741	3674	2598	5116	3994	12516	2912
91/92	3795	1536	4092	2701	5118	3494	13005	2675
92/93	4094	1568	3740	2618	4312	3821	12146	2688
93/94	4219	1734	3569	2765	4613	3520	12401	2694
94/95	4256	1907	3966	2675	4252	3635	12474	2739
95/96	3790	2048	4127	2662	4469	3629	12386	2822
Average for 84/85-88/89	3824	1573	4646	2383	4163	3475	12632	2502
Average for 90/91-92/93	3817	1667	3916	2618	4780	3747	12513	2757
Average for 93/94-95/96	4088	1897	3887	2701	4445	3595	12420	2752

Fig. 3 shows the trend of drainage reuse in Delta during the period 84/85 – 95/96. The figure shows that drainage water reuse started to increase by the end of the 1980's till it reached a level of about 4.2 BCM/year in 90/91, then it declined again to a level of about 3.4 BCM/year due to shutting down some reuse locations. After that, the drainage water reuse started to increase to reach a level of about 4.0 BCM/year in 95/96. The trend of salinity in reused drainage water seems to increase with the increase in reuse and declines also as the reuse declines.

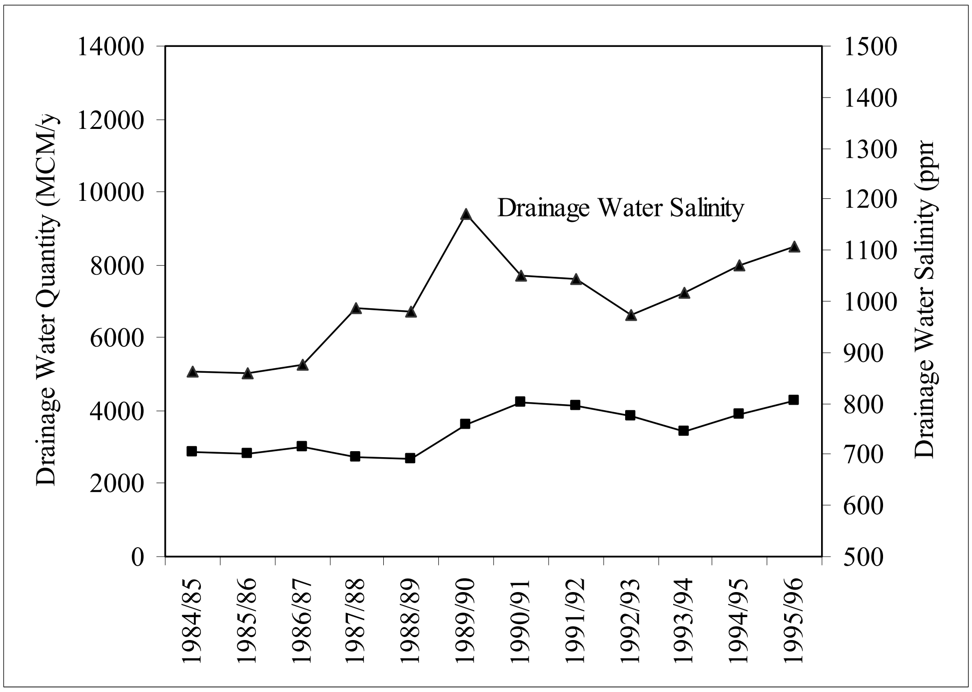

Figure 3. Evolution of drainage water reuse in Delta

Fig .4 shows the trend of drainage water outflow and the average salinity as well.

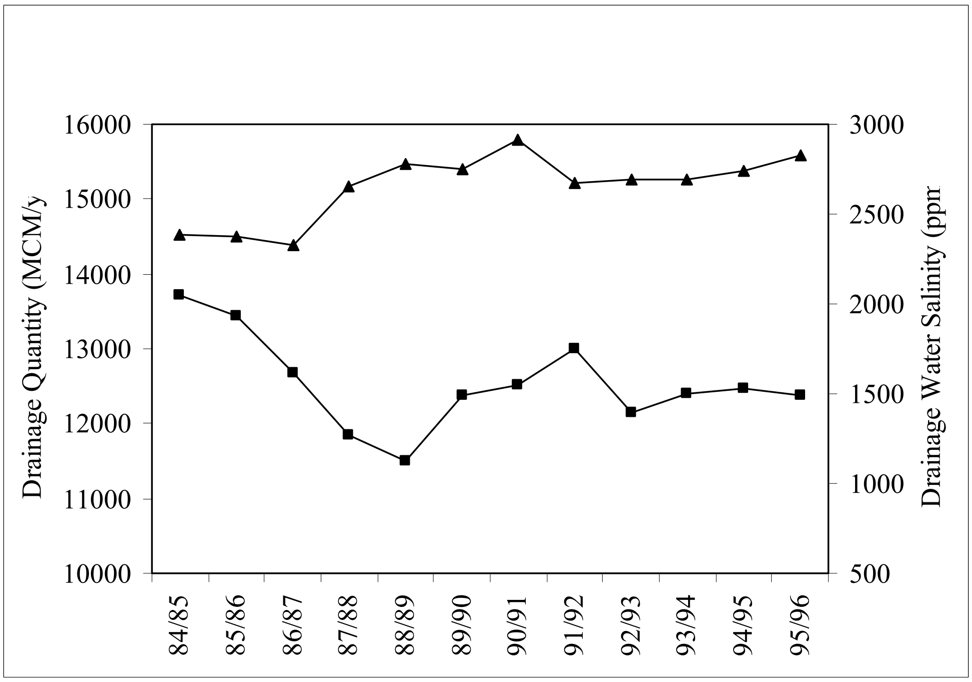

Figure 4. Evolution of drainage water outflow to the sea and lakes

Fig. 4 shows the trend of drainage water outflow and the average salinity as well.The figure shows that, the drainage water outflow declined from 13.7 BCM/year to 11.4 BCM/year during the period 84/85-88/89. This was, certainly, due to the reduction of the Nile flows entering Delta during this period that was characterized by reduction of Aswan releases due to drought conditions. Then, it increased again to be around thelevel of 12.5 BCM/year. Although the Nile flows, entering Delta, increased during the 1990's, the drainage outflow did not reach the same level as it was in 84/85. The reason would be attributed to the increase in drainage reuse either officially or non-officially. This conclusion might be interpreted by looking at the trend of salinity in the above mentioned figures. The salinity trend shows a continuous increase since 84/85. This indicates that the drainage reuse still on going and increases from year to year. The increase in reuse was due to expanding the cultivated area that reached about 8.0 million feddans by the end of 1996. As the government shifted also to the free crop policy, farmers were enthusiastic to increase their production of land and hence, crop intensification and inter-cropping were noted in the cultivated area. Increase in rice plantation was also a major factor resulted in increase in drainage reuse. Therefore, it can be concluded that horizontal and vertical expansion of the cultivated area was behind the increase in drainage reuse and hence the increased salinity and reduced quantity of drainage water outflow to the sea. In future, the drainage water outflow will decline and the salinity will increase due to reducing the Nile flows entering the Delta region particularly withthe start of Toshka project.

Unofficial Drainage Reuse

The unofficial drainage reuse is defined as farmer’s direct reuse of drainage water without pre-permission from Ministry of Water Resources and Irrigation (MWRI). It exists wherever canal water shortage is recorded, mainly at canal tail. This drainage reuse practice was recorded in the latest decade as the water demand increased versus the constant supply. Two types of unofficial reuse were observed in Egyptian irrigation system: first one is direct pumpage from drain to the field; second is in-field reuse through blocking the tile drainage system to hold the water in the field so as not to escape out. This happens in rice fields when water demand could not be met through canal water. Both types of reuse have negative impacts on irrigation system although they solve the problem of deficit irrigation. Issues associated with unofficial reuse can be listed as follows:

- Irrigation with low water quality causes deterioration of soil and crop yield.
- Irrigators are subjected to health hazards as the drainage water sometimes collects the sewage and industrial effluent.

- Installing unofficial reuse pump stations on drain banks causes collapsing these banks.
- Local reuse of tile drainage, through blocking the pipes and collectors in rice fields, causes rise of water table in the neighboring fields cultivating non-rice crops such as maize. This affects the maize which is quite vulnerable to soil, and damages the tile drainage network.
- Non-regulation of unofficial drainage reuse causes reduction of available drainage water at main reuse pump stations.
- Irrigation with direct drainage water leads to increase the number of irrigation application in order to leach out the accumulated salts, and hence increases the cost of agricultural production.

There is no an accurate survey available on the unofficial drainage reuses in Egypt. The reason is that it changes from one location to another and from time to time depending on water shortage in the canal and the need for water to meet the crop demand. A figure of about 2.8 BCM/yearwas accepted (Abdel-Azim, 2000).

Intermediate Drainage Reuse

Intermediate reuse system is mainly defined as a system to mix drainage water with fresh water of branch canals located within an irrigation directorate. On other words, it is a localized drainage reuse system that can be totally controlled by the irrigation directorate within is jurisdiction. This is different than the main drainage reuse level, which is controlled by the central water distribution and considered as a part of the national water budget. The main drainage reuse level is used to feed the main canal to help supplying enough water for downstream directorate(s). The intermediate reuse system (localized system) is viewed as a tool for compensation of the flow in canal tails and hence meeting the expected water requirements. This reuse system is constructed by irrigation directorates in order to solve the water shortage problem in branch canals. Operation of such reuse pump stations was found to be dominant in summer period for about four months. The working hours is about 10 hours per day and may increase in water deficit periods such as during rice plantation.

Abdel-Azim has investigated the suitable system for Intermediate drainage reuse (2000). He concluded that:

- Mixing reuse locations should be selected to meet some criteria such as drain is very close to canal to minimize civil works and cost, drinking plants are not existed or allowed downstream mixing, and water quality and quantity are suitable for full operation of the reuse pump over the year.
- Physical changes of drain system could be made to store water for pumping into canal. A weir of a suitable height to be constructed downstream the pump location is recommended. Stored water should not impact on the water table of nearby fields.
- Small capacity pump is preferable and number of pumps could be determined based on the drainage availability.
- This reuse system is mainly to replace the unofficial reuse practices and hence minimize the negative environmental impacts. However in some areas, this reuse system can achieve water saving at a level of 10% or even higher.
- Expansion of such reuse system is dependent on the existing main reuse programme. Increasing intermediate reuse system may cause reduction of drainage availability at some main reuse locations and consequently result in negative environmental impacts and in economical losses due to heavy cost of infrastructure. However, intermediate reuse system could replace the main reuse (part of) system that suffers from heavy pollution of main drain.

CLASSIFICATION OF DRAINAGE WATER IN THE NILE DELTA

Drainage water in the Delta region represents a major source of water, particularly for agricultural purposes. If drainage water in Delta is not reused, it will flow out to the sea. Therefore, drainage reuse schemes are vital to save water and maximize the use of limited Nile share for Egypt. However, the drainage reuse is constrained by many factors such as drainage water quantity and quality. The following parameters were used to classify the drainage water availability and suitability in the Delta region:

- Drainage Rate (DR) to measure drainage availability and drainage generation.

- Total Dissolved Solids (TDS) to measure water salinity and hence its suitability for irrigation in its status and after mixing with fresh water.
- Adjusted Sodium Absorption Ratio (adjusted SAR) to measure the effect of drainage water on crops and soil conditions, particularly infiltration.

Based on these parameters Delta region is classified into different zones, where each zone is characterized by certain estimates of these selected parameters. Three zones would be considered in Delta. The first zone (south of Delta) with drainage rate of less than 1.0 mm/day and a TDS usually lower than 1000 ppm. The second zone has a drainage rate ranging from 1.0 to 3.0 mm/day and a higher TDS (greater than 1000 ppm but lower than 2000 ppm). The third zone (north Delta bounded by Sea) has the highest DR (greater than 3.0 mm/day) and TDS (usually greater than 2000 ppm and reaches sometimes 4000 ppm). The high rate of drainage in the north of Delta is attributed to the high rate of upward seepage (El-Quosy and El-Guindy, 1989). Fig. 5, 6, and 7 present the classification of drainage water in according to the above mentioned parameters. TDS and SAR increase as moving northwards. The high values of TDS and SAR in these areas would limit the drainage reuse or increase the needed of fresh water for mixing to reduce the salinity of mixed water. Therefore, although the drainage rates are high in northern areas, drainage reuse may not be recommended compared to the southern areas. However, crop diversification plays an important role on the management of drainage water in these areas. This means cultivation of less-sensitive crops in the northern area would be preferable in order to increase the potential of drainage reuse.

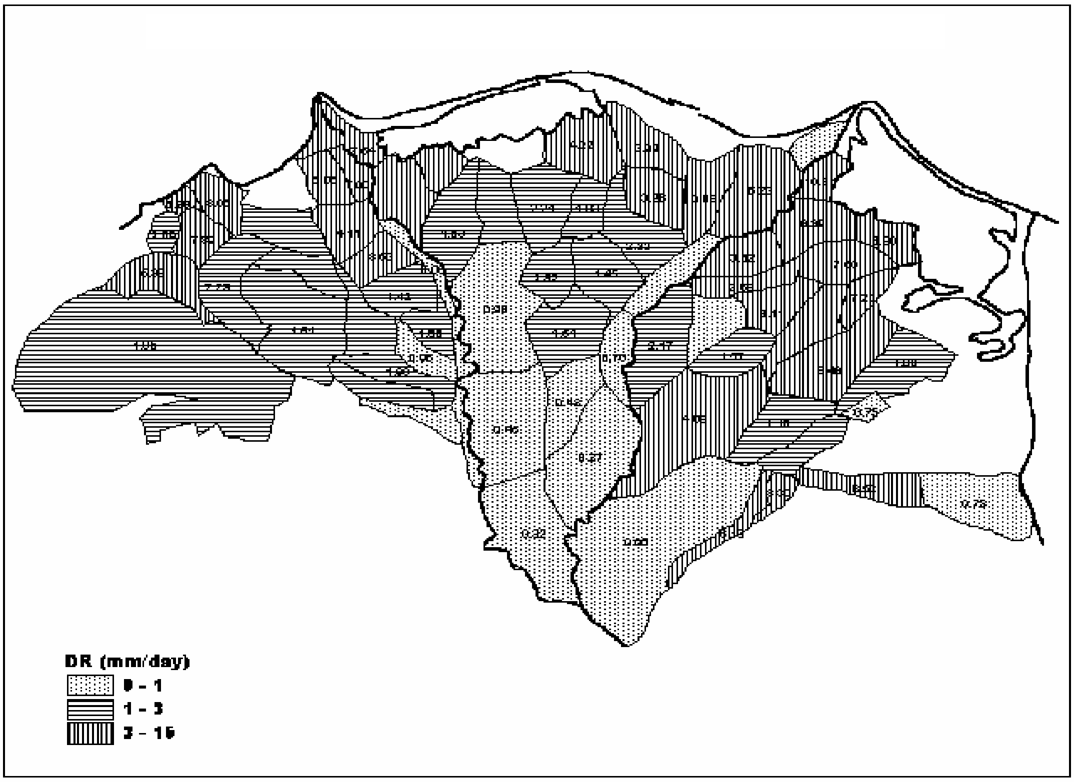

Figure 5. Drainage rate (DR) over Delta region

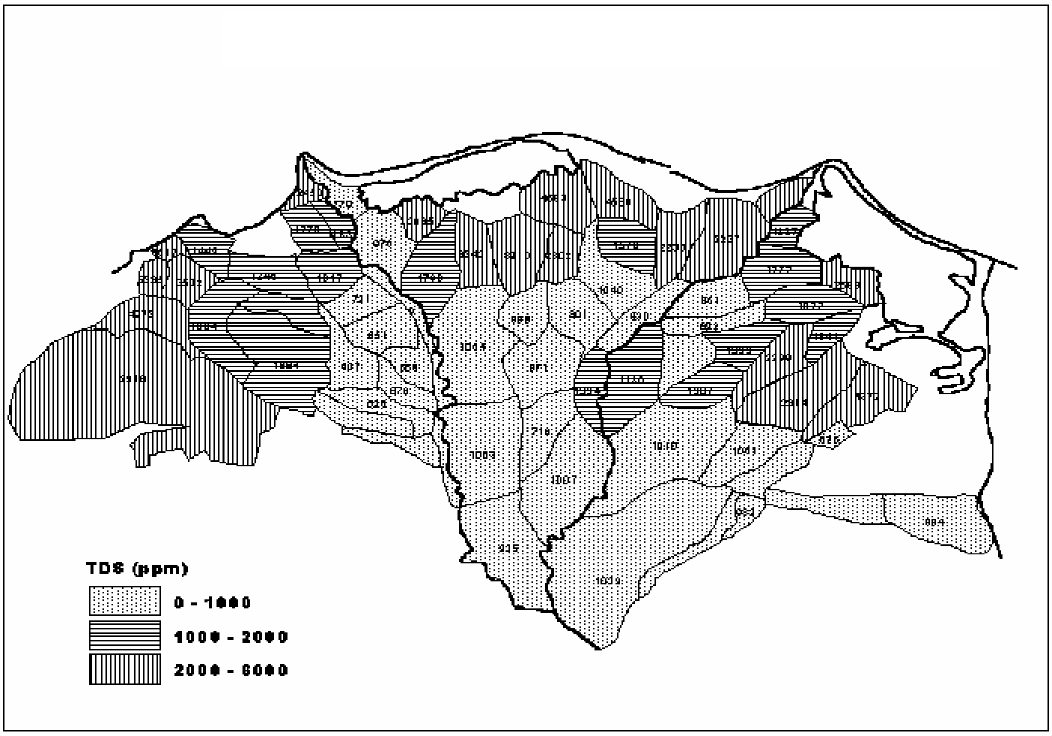

Figure 6. Total Dissolved Solids (TDS) in drainage water over Delta region

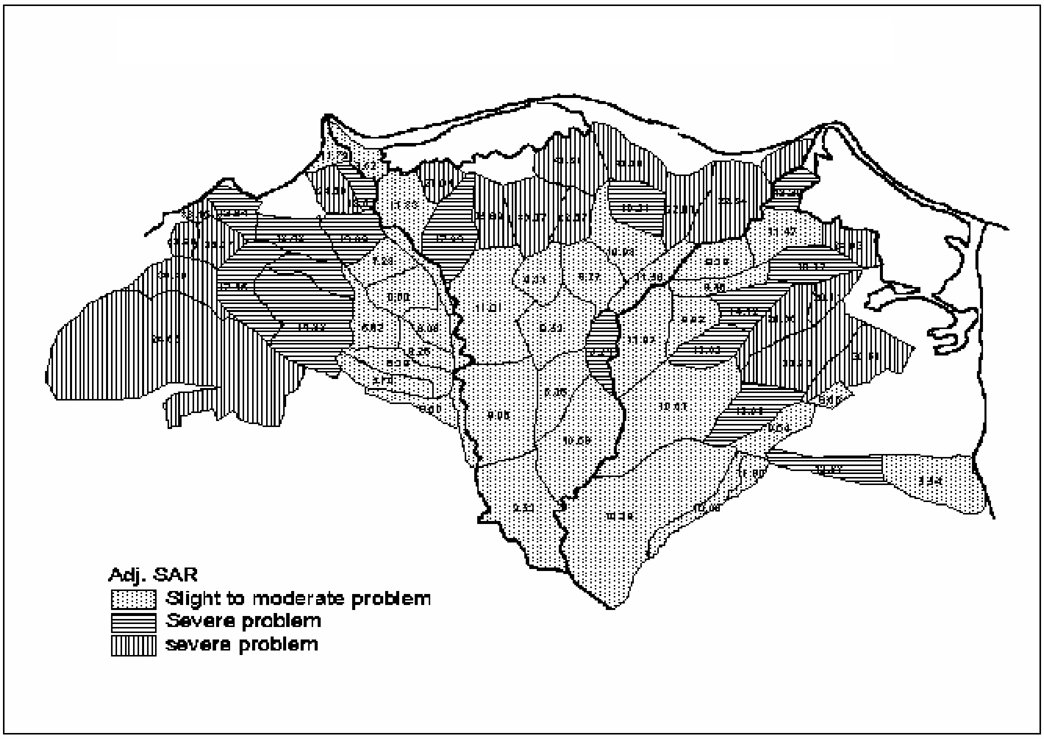

Figure 7. Adjusted SAR in drainage water over Delta region

POLLUTION ISSUES

With growing population and intensified industrial and agricultural activities, water pollution is spreading in the Delta region. Huge amounts of urban municipal and industrial (M&I) wastewater and rural domestic wastes discharge into agricultural drains without treatment. Because of the limited land source and the lower elevation of the topography of the Delta plain, agricultural drains have become easy dumping sites for all kinds of wastes. After the construction of the High Aswan Dam, the seasonal Nile floods, which used to flush Delta's lowlands periodically, no longer reach the Delta, and the pollutants brought by M&I wastewater are accumulated in the drain system year by year. There is an increasingly serious threat in the region's drainage reuse programme.

The total sewage volume in the Delta region, either treated or untreated, is about 6.02 MCM/day, or 2.17 BCM/year. Seventy-two percent of which is from larger cities and towns, and 28%, from smaller towns and villages. Wastewater from Greater Cairo (including part of Giza), Alexandria, and Tanta (Gharbia) together account for 3.40 MCM/day, which is more than half of the total sewage volume in the Delta. This fact indicates the importance of controlling sewage flows from large cities. The existing capacities of sewage treatment do not cope with the produced sewage. Thus, raw sewage flows to drains causing big constraints for reuse of drainage water. Three pump stations have been shut down in Delta due to heavy pollution in drainage water either sewage or industrial. This problem is a serious one where sewage and industrial pollution is increasing in future and cost of treatment is high. Options for pollution control may include investigation of low-cost treatment plants, conducting awareness at different levels, and rely on new technologies for use of sewage in water such as production of biogas.

MAXIMUM DRAINAGE REUSE IN THE NILE DELTA

There are many constraints that may limit the potential of drainage water reuse in the Delta region such as the drainage water availability and its quality, required minimum drainage outflow to sustain the sea water intrusion, the grown crops and its tolerance to drainage water salinity, and the leaching requirements. However, drainage -water salinity was considered as one parameter to determine the achievable drainage water reuse assuming that the drains will be free of pollution.

The drainage water pump stations as well as drain outfalls were investigated separately to test the amount of drainage water that can be reused at each location in the Delta region (Abdel-Azim, 2000). The drainage water reuse was tested at different levels of water salinity; 1000, 1500, 2000, 2500, 3000, 3500 and 4000 ppm. The additional water reuse was then added to the current reuse level as estimated by DRI for the Refrence year 93/94. It could be impossible to reach the high level of targeted drainage water reuse in terms of salinity. The higher the drainage reuse is, the more the leaching requirements will be. Consequently, the pumped drainage water will not be totally used in meeting the crop evapotranspiration, but a considerable part of this water will be applied for leaching the accumulated salts in the soil. Leaching requirements depends on the soil salinity and crop tolerance. It is known that rice crop can resist high salinity levels. For soil salinity of 3.5 dS/m the rice crop will have 10% reduction in its yield (Ayers 1997). Other crops may have higher reduction if grown in such soil salinity. As leaching requirements are considered, the real drainage water reuse will be less than the actually pumped reuse. The real drainage water reuse is equal to total pumped reuse minus the leaching water requirements as shown in Fig. 8.

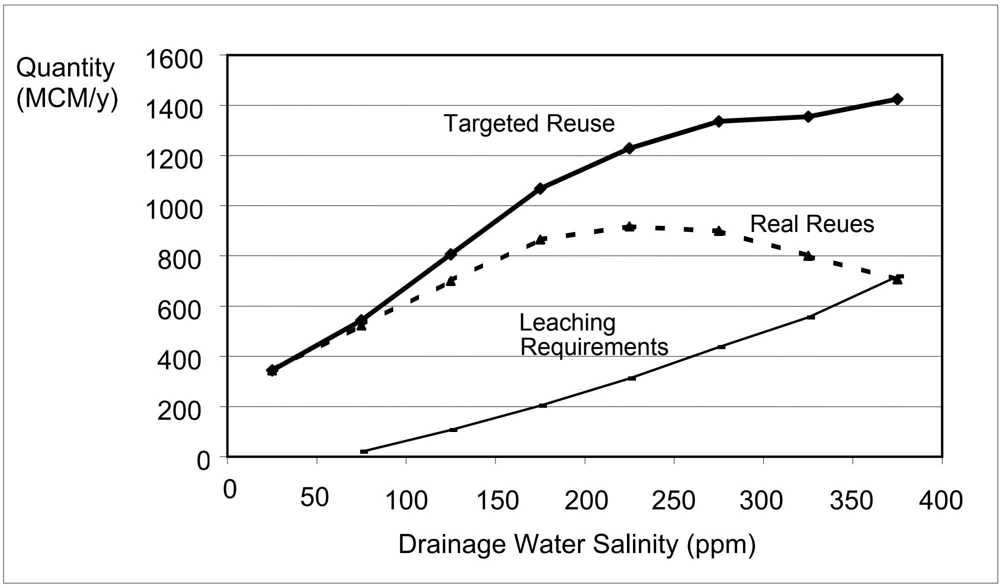

Figure 8. Potential drainage reuse pattern

The figure shows that the real drainage water reuse increases till a level of salinity of less than 2500 ppm, and then it decreases as the targeted salinity increases due to increase in leaching water requirements. At this level the drainage water reuse may reach 9.2 BCM/y and drainage outflow will decrease to be about 6.7 BCM/y. However in order to consider an estimate of 8.0 BCM/y as a minimum drainage outflow to keep the sea water intrusion, then the real (achievable) potential drainage water reuse will be about 8.6 BCM/y. Therefore, it is not recommended to expand the drainage water reuse beyond a salinity level of 2000 ppm. However, if salt-tolerant crops are to be grown, more saline drainage water could be reused and hence leaving higher saline water to flow to the sea. This requires further studies to investigate the impact of increase in drainage outflow salinity on the ecological system in the Northern Lakes and Mediterranean Sea.

MINIMUM DRAINAGE OUTFLOW TO THE SEA AND NORTHERN LAKES

Minimum drainage outflow should be maintained to sustain freshwater fisheries and environment in the northern lakes as well as to maintain sea water intrusion. The freshwater fisheries in the northern lakes depend on the entrance of the drainage outflows of the Delta for nutrient supply and lake water flushing. The use of the drainage outflow in fish production is a beneficial water use, as valuable as land-based agricultural crop irrigation. The economic value of the fish production in the northern Delta needs to be recognized. Four northern lakes, Mariut, Edko, Burullus, and Manzala, are fed by drain water, which maintains their freshwater lake status. The volume and quality of the drain water is the key for preserving and protecting the northern Delta coastal area. Lake fisheries produced about 52%. To preserve sustainable production of safe, edible freshwater fish in the northern lakes requires a sufficient inflow of drain water to provide adequate lake flushing to the Sea. The salts imported with the water and concentrated by evaporation need to be eliminated so that average lake salinity can be maintained below a maximum threshold. The minimum required drainage outflow from the Delta was estimated by many researchers to be about 8.5 BCM per year (APRP, 1998).

EFFECT OF TOSHKA PROJECT ON DRAINAGE WATER AVAILABILITY AND REUSE

The Government of Egypt has started already an intensive programme for the development of the west-southern part of Egypt (Toshka and East Elewainat). This programme involved supplying Nile water to those areas through constructing a canal called “Elsheikh Zayed canal” to deliver about 5.0 BCM/year upstream HAD to irrigate about 0.5 million feddans. In other words, the Nile flows down stream Aswan Dam will be reduced to be only 50.5 BCM/year. Therefore, the reduction in Aswan water releases to Nile valley and Delta will have its impacts on meeting the increasing water requirements. It should be kept in mind that with the reduction of Nile flows, particularly to the Delta, drainage reuse will consequently be intensified, either officially or unofficially to meet the increasing water demands. On the other hand, drainage availability will decrease and salinity will increase. Therefore, drainage water reuse will be questionable to mitigate the increased demand. Drainage water salinity will increase by about 13.6%, hence reducing the chance for capturing more drainage water for reuse. In fact, the per feddan consumptive use will be, consequently, reduced by about 16% and 12% in case of non-reduced rice option and reduced rice (at a level of 0.7 million feddans) option, respectively (Abdel-Azim, 2000).

EFFECT OF IIP ON DRAINAGE AVAILABILITY AND REUSE

The main objective of the Irrigation Improvement Project (IIP) is to achieve the equity of water allocation among water users along the canal. On other words, IIP objective is to minimize the water losses, and then reduces the drainage flow in drains. In order to achieve this, IIP would have some physical changes to control water losses. Water losses were found to be caused by irrigation application at the field level which makes water goes to drain through percolation or through runoff. The second is water losses caused by direct spillage from canal tail-ends to drains. Consequently, the physical changes suggested by the IIP are to remodel the farm ditches and canals. There were found a number of monitoring programmes and evaluation studies to estimate the effect of IIP on improving the irrigation efficiency. It is reported that irrigation efficiency will increase, as the conveyance efficiency will enhance after implementing IIP. The conveyance efficiency was found to increase from an average of 60-65% (before IIP) to an average of 90-95% (after IIP) (Oad *et al.*,1995; APRP, 1998). This would be translated to a *local water saving* to achieve the adequacy of the water deliveries to the whole farmers along the canal, and then reducing the unofficial drainage water reuse, which implemented by the tail end users (before IIP) due to water shortage at the canal tail end. Thus, after IIP, drainage water generation would be reduced in both quantity and quality. Farmers will, then, likely encouraged not to use drainage water unofficially, as the canal fresh water is expected to reach the canal tail end at right quantities and at the suitable time. Drainage water in drains is, then, expected to include only the field water losses plus operational water losses of the canal tail ends (if there is). Assume that the operational losses from canals and Mesqas will be completely controlled by IIP, then only field water losses will flow to the drains carrying the leached soil salts.

The question that will be arisen is that “are the field water losses going to be reduced?”. In fact this is difficult to answer. The farmers' practices in irrigation such as required delivery, timing of irrigation, selection of crops, field leveling and other factors have the great effect on the field water losses. Most of researches (Elkadi, 1983) and monitoring programmes concluded that the irrigation application efficiency in the field is not higher than 50%. Under IIP, farmers may be encouraged to deliver more water to their fields as it is delivered by gravity (reduced cost of irrigation), i.e. without pumping. Continuous flow may help in delivering more water also. Anyhow, it could be concluded that the field irrigation efficiency, at least, would not increase if it is not reduced.

CONCLUDING REMARKS AND RECOMMENDATIONS

Potential of Drainage water reuse was found not to exceed 8.6 BCM/year under a targeted salinity level of 2000 ppm at which, 2.0 BCM/year of fresh water should be used for mixing to meet leaching requirements. Drainage water outflow at this targeted reuse will be 7.8 BCM/year, which is thought to be the minimum requirements for maintaining salt intrusion and lake fisheries. It was found also that expansion of drainage water reuse beyond salinity greater than 3000 ppm is not recommended where effective drainage water reuse will decline as the leaching water requirements increases. This draws the attention about adopting the new policy for drainage water reuse. This policy will mainly focus onintensifying reuse in the southern parts of Delta to capture the good water before getting saltier when it reaches the northern parts. However, pollution in drainage water should be considered. Polluted drainage water particularly water with high levels of heavy metals should be avoided so as not to pollute the groundwater aquifer in these areas (where soil permeability is relatively higher). On the other hand, fewer constraints could be applied to drainage reuse in north Delta because groundwater aquifer is not used in this area. Although drainage salinity and SAR are high in Northen

Delta, tolerant crops could be encouraged to be grown on such type of drainage water and hence saving fresh water for other areas and other users.

The full operation of Toshka project will have its impact on drainage reuse as well as the water allocation to crops. Drainage water salinity will increase by about 13.6%, hence reducing the chance for capturing more drainage water for reuse. In fact, the per feddan consumptive use will be, consequently, reduced by about 16% and 12% in case of non-reduced rice option and reduced rice (at a level of 0.7 million feddans) option, respectively.

Two major factors that would alter the drainage reuse policy and practices in future are the horizontal expansion programme (mainly Toshk project), and Implementation of Irrigation Improvement Programme (IIP). The full operation of Toshiqa project will have its negative impact on drainage reuse as well as on water allocation to crops. Drainage water salinity will increase by about 13.6%. This salinity increase will reduce the potential expansion of drainage water reuse practice.

Implementation of IIP may affect also the drainage reuse practices. As the main objective of IIP is to achieve the equity of fresh water allocation among the water users along the canal, then, the unofficial drainage water reuse may disappear. Consequently, drainage water reuse on the intermediate level will also be affected. However IIP may take a quite long time to be implemented. Then, drainage water reuse programmes should consider this in the operation plans. Drainage reuse could be viewed as the solution of next few decades to meet the increasing water demand.

Intermediate drainage reuse system should be encouraged and considered a part of water budget for local entities. This means that operation of intermediate reuse should be over the year and not for some seasons or periods to achieve the economic viability.

A comprehensive water monitoring programme should be implemented over Delta region to include canal/drain system and groundwater aquifer as well. This will measure possible changes in water quality and hence modification of reuse policy could be made according to monitoring results.

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