4th International Conference on Water Resources and Arid Environments (ICWRAE 4): 439-446
5-8 December 2010, Riyadh, Saudi Arabia

Reusing of Agricultural Drainage Water an Option to Resolve Problems of Water Shortage in Saudi Arabia

Maged H. Hussein

Department of Civil Engineering, Faculty of Engineering,
King Abdul Aziz University, Jeddah, Saudi Arabia

Abstract: The Kingdom of Saudi Arabia has an area of about 2.25 million km^2, most of which is located in arid regions. The available surface water and groundwater resources are limited, precipitation rates are low and evaporation is high. Moreover, due to the rapid development of urban and rural domestic water supplies, conventional water resources have been seriously depleted. Non conventional water sources such as salt water desalination and wastewater reclamation are gained increasing role in the planning and development of additional water supplies. Wastewater treatment and use for irrigation has been expanded considerably the last few decades in Saudi Arabia. Reuse of wastewater comprises urban wastewater (sewage and storm), agricultural drainage water and industrial wastewater. In many regions where irrigation water is scarce, drainage water is used. Re-use is only sustainable if the drainage water is of sufficiently good quality. Although Saudi Arabia is not an agricultural country, the arable area is about 48.9 million ha representing 22.7% of the total area, while the reclaimable areas are about 3.8 million ha. The irrigated area is 1.9 million ha and 2.7% of the area is supplied with drainage systems. While the agriculture consumes 86.5% of the country water consumption, the reused agricultural drainage water is only 40 million m^3. This paper elaborates the benefits and problems associated with agricultural drainage water reuse as non-conventional water resource in Saudi Arabia and emphasis reuse practices and their future prospective uses for irrigating agricultural crops, within acceptable levels of risk.

Key words: Reuse • Agricultural drainage water reuse • Water pollution • Water conservation

INTRODUCTION

Irrigated agriculture has made a significant contribution towards world food security. The water consumption for agricultural purposes in Saudi Arabia predominates, representing about 86.5% of total water consumption. It reached around 17,530 Mm^3 in 2004 as shown in Figure 1, [1]. However, water resources for agriculture are often overused and misused. The result has been large-scale water logging and salinity. In addition, downstream users have found themselves deprived of sufficient water and there has been much pollution of freshwater resources with contaminated irrigation return flows and deep percolation losses. Irrigated agriculture needs to expand in order to produce sufficient food for the world's growing population. The productivity of water use in agriculture needs to increase in order both to avoid exacerbating the water crisis and to prevent considerable food shortages.

Irrigation with agricultural drainage water is a widespread practice all over the world where it is usually used when no alternative water source is available. This practice can bring considerable benefits, yet, it is associated with some health and environmental risks. When compared to freshwater, drainage water supply is cheap, reliable and available to farmers on demand allowing them to grow crops they would not otherwise be able to grow. It can ensure crops all year round.

Investment in reuse of agricultural drainage water can offset water scarcity in Saudi Arabia and preserve better-quality water for higher-value uses. Both wastewater reuse and drainage water recycling represent an important agricultural water management investment opportunity. Large and reliable volumes of drainage water are available close to reuse sites and investments to enable reuse are low and can be added on to existing schemes [1]. Conversely, the use of raw or partially treated drainage water can cause pollution of soil,

Corresponding Author: Maged H. Hussein, Department of Civil Engineering, Faculty of Engineering, King Abdul Aziz University, Jeddah, Saudi Arabia

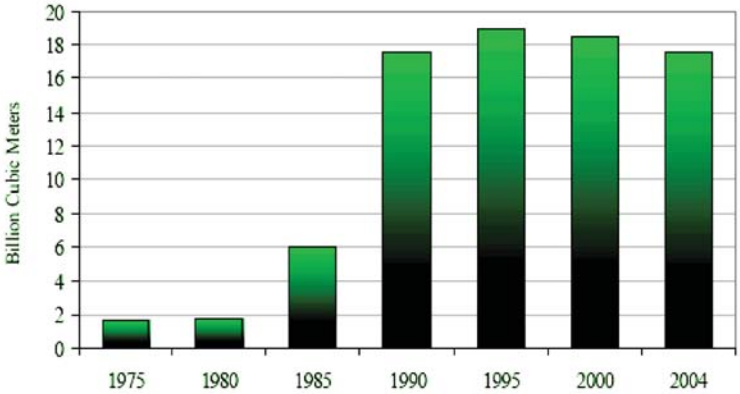

Fig. 1: Water Consumption for Agricultural Purposes in Saudi Arabia

surface water and groundwater due to increase in nitrate concentrations. In-appropriate drainage water use poses direct and indirect risks to human health caused by the consumption of polluted crops and fish. Farmers in direct contact to the drainage water and contaminated soil are also at risk.

Need for Drainage of Irrigation Lands: The challenge to the irrigation sector of agriculture is to produce more food by converting more of the diverted water into food. Increased food production will leave even less water for other uses. Although the water resources for agriculture are often overused and misused, the general belief is that irrigated agriculture has to expand by 20-30 percent in area by 2025 in order to produce sufficient food for the growing population. Seepage losses from the irrigation network and deep percolation from farm irrigation has accumulated into the underlying groundwater. In many irrigated areas around the world, rising water tables have subsequently led to waterlogging and associated salinity problems. The overuse and misuse of water in irrigated agriculture has also depriving of downstream users of sufficient water and in the pollution of fresh water resources with contaminated irrigation return flow and deep percolation losses. This has happened where drainage development has not kept pace with irrigation development or where maintenance of drainage facilities has largely been neglected [2]. The agricultural drainage can be 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.

In Saudi Arabia, the establishment of irrigation and drainage projects in certain agricultural areas to overcome the problem arising from high level of underground water and to reduce soil salinity, enhance its structure and improve efficiency of irrigation through using modern techniques such as drip and sprinkler irrigation methods. Waterlogging and drainage problems occur in the central and southern parts of the country, due to the existence of shallow, impervious layers. A prominent example is Al-Hasa Oasis Project, which was completed and put into operation in 1972. It is considered one of the projects that help to improve environmental, social and health conditions. In addition to the other agricultural and drainage projects annexed to the project about 44,000 ha, or 2.7% of the irrigated area, have drainage facilities. The drainage systems mainly consist of open drainage canals. In several projects, such as the Al-Hassa irrigation project in the east, agricultural drainage water is reused for irrigation after blending with fresh groundwater. Old irrigation networks are replaced with concrete lined canals. Soil salinity is being noticed in parts of the newly developed areas, due to poor irrigation water quality and the drainage conditions of some soils [3].

Need for Water Conservation and Reuse: In response to the increasing world population and economic growth, water withdrawals for human consumption will increase, so increasing the competition for water between municipal, industrial, agricultural, environmental and recreational needs. If present trends continue with water withdrawal under present practices and policies, it is estimated that by 2025 water stress will increase in more than 60 percent of the world. In order to avoid exacerbating the water crisis and to prevent considerable food shortages, the productivity of water use needs to increase. In other words, the amount of food produced with the same amount of water needs to increase. This is possible through the conservation and reuse of the available water resources in the agriculture sector, including usable drainage water. The drainage water management strategy is required for:

Table 1: Salinized and drained areas compared with total irrigated area, central Asia and Near East

Country	Irrigated area	Salinized area		Total drained area surface + subsurface drained		% subsurface drainage of irrigated area
	ha	ha	% of irrigated area	ha	% of irrigated area	
Central Asia						
Kazakhstan	3 556 400	242 000	6.8	433 100	12.1	0.4
Kyrgyzstan	1 077 100	60 000	5.6	149 000	13.8	6.1
Tajikistan	719 200	115 000	16.0	328 600	45.7	19.1
Turkmenistan	1 744 100	652 290	37.4	1 022 126	58.6	18.5
Uzbekistan	4 280 600	2 140 550	50.0	2 840 000	66.3	16.3
Near East						
Bahrain	3 165	1 065	33.6	1 300	41.1	
Egypt	3 246 000	1 210 000	37.3	2 931 000	90.3	38.5
Iran	7 264 194	2 100 000	28.9	40 000	0.6	0.6
Jordan	64 300	2 277	3.5	4 000	6.2	
Kuwait	4 770	4 080	85.5	2	0	0
Lebanon	87 500			10 800	12.3	0
Mauritania	49 200			12 784	26.0	
Pakistan	15 729 448			5 100 165	32.4	
Saudi Arabia	1 608 000			44 000	2.7	
Syria	1 013 273	60 000	5.9	273 030	26.9	
Tunisia	385 000			162 000	42.1	42.1
Turkey	4 185 910			3 143 000	75.1	

Source: FAO, 1997a, 1997b.

- Prevention of economic and agricultural losses from waterlogging, salinization and water quality degradation (Table 1);
- Quality degradation concern of shared water resources;
- Conservation water for different water users under conditions of actual or projected water scarcity. In addition, the need to comply with drainage water policies and regulations can provide a strong incentive for improved drainage water management [4].

Agricultural Drainage Water Reuse: The philosophy of drainage reuse is to lift out a portion of drainage water to be mixed with irrigation 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. The major aim of reuse is to reduce the amount of drainage effluent while at the same time making additional water available for irrigation and other purposes [5]. Reuse measures comprise: reuse in conventional agriculture; reuse in saline agriculture; Integrated Farm Drainage Management (IFDM) systems; reuse in wildlife habitats, wetlands and pastures; and reuse of water for other beneficial uses. Conservation measures can directly affect the need for and extent of reuse as well as the quantity and quality of drainage effluent requiring disposal and/or treatment. In many regions where irrigation water is scarce, drainage water is used to meet crop water requirements. Re-use is only sustainable if the drainage water is of sufficiently good quality. Agricultural water reuse is often included as a component in water reuse programs for the following reasons:

- Extremely high water demands for agricultural irrigation.
- Significant water conservation benefits associated with reuse in agriculture.
- Ability to integrate agricultural reuse with other reuse applications.

In Egypt, reuse of agricultural drainage water became national policy in the 1980s and now reuse is practiced on 90 percent of the irrigated area. Investment in reuse of both resources often disproportionately benefits the poor, contributing to livelihoods and household food security. The official reuse of agricultural drainage water in irrigation amounted to 8 km^3/year in new reclaimed areas. In addition, there exists significant unofficial wastewater reuse estimated between 2.8 and 4 km^3. This unofficial water reuse is not controlled by the government and poses threats to human health and environment. Unless adequate regulations are enforced, the quality of drainage water is threatened [6].

In Saudi Arabia the water consumption for agricultural purposes predominates, representing about 86.5% of total national water consumption. It was estimated at around 17,530 million cubic meters in 2004. Water is still provided for agricultural purposes irrespective of efficiency of consumption. The rate of water loss in agriculture is approximately 30%, which is relatively high. Moreover, the current Saudi water conservation code, which regulates licensed well-drilling operations, does not regulate water discharge rates. It, therefore, fails to protect ground water aquifers, adjacent wells and the environment from various forms of detrimental use. Reclaimed wastewater accounted for 12% of the volume of water supply over the last five years. This is low in comparison with many countries that consider reclaimed wastewater as one of the sustainable sources of water. The Al-Hasa Irrigation and Drainage Authority (HIDA) is also expected to utilize fully the treatment plants in Hofuf, Mubaraz and Thoqba; thereby adding in 2009 about 93 million cubic meters of reclaimed water per year to the irrigation resources of Al-Hasa project. In view of the importance of reclaimed agricultural drainage water, as an alternative to fresh water for agricultural, industrial and recreational purposes, projects aimed at utilizing of this reclaimed water for irrigation purposes were launched and operated in Riyadh since 2006. For agricultural uses, natural renewable water and reclaimed water are the most economically and socially feasible sources. In 2004, the water consumption of reclaimed agricultural drainage water was 40 Mm^3 and it is expected to increase to 60 M m3 by the end of 2009 [1]. Agricultural drainage re-use amounts reached to about 1500 Mm^3 in each of Syria and Iraq and 3800 million cubic meters in Egypt [7].

Types of Agricultural Drainage Water Reuse Applications: Every effort is exerted to use water more efficiently and to make use of every drop of water to ensure the well being of future generations. New trends are developed and practiced in the area of water resources use and water saving. These trends vary from one country to another according to the degree of water scarcity, economic situations and other factors. Developing non-conventional water resources is an example of the recent trends in developing new water resources and water savings. Unlike rainfall, rivers and groundwater which are considered conventional freshwater resources, the non-conventional water resources include sea water desalination, agriculture wastewater reuse and municipal wastewater reuse [2]. Suggested that agricultural drainage water reuse can be applied for:

- Irrigation of public parks and recreation centers, school yards and playing fields, highway medians and shoulders and landscaped areas surrounding public buildings and facilities;
- Groundwater recharge;
- Construction of wetlands;
- Commercial uses such as vehicle washing facilities, laundry facilities, window washing and mixing water for pesticides, herbicides and liquid fertilizers;
- Ornamental landscape uses and decorative water features, such as fountains, reflecting pools and waterfalls;
- Dust control and concrete production for construction projects and Cement industry;
- Fire protection through reclaimed water fire hydrants;
- Toilet and urinal flushing in commercial and industrial buildings;
- Industrial Cooling Water Systems;
- Pulp, Paper, Textile, Petrochemical (Table 2).

Agricultural Drainage Water Quality: Drainage water quality is the major concern in reuse possibilities as it defines which crops can be irrigated and whether long-term degradation of soil productivity is a major issue. On the other hand, the soil type, drainage conditions of the land and the crop salt tolerance define what quality drainage water can be used for irrigation in combination with the availability of other freshwater resources. Pollutants from surface runoff, i.e. sediments, pesticides and nutrients, play a minor role in reuse for crop production. However, for sustainable agricultural practices and to prevent environmental degradation, nutrients supplied with reused drainage water should be deducted from the fertilizer requirements in order to prevent imbalanced and excessive fertilizer application. Subsurface drainage water generally shows increased concentrations of salts and sometimes certain trace elements and soluble nutrients (Table 3). Salts and trace elements play a major role in the reuse of drainage water. Above a certain threshold value, high total concentrations of salts are harmful to crop growth, while individual salts can disturb nutrient uptake or be toxic to plants. A high sodium to calcium plus magnesium concentration ratio may cause unstable soil structure. Soils with unstable structure are subject to crusting, compaction and degrading soil conditions for optimal crop growth. Toxic trace elements such as boron can interfere with optimal crop growth and others such as selenium and arsenic can enter the food chain when crops are irrigated with water containing high concentrations of these trace elements [8,9] mentioned that there is an increasing trend in reusing poor quality waters for

Table 2: Industrial Process Water Quality Requirements

Parameter*	Pulp & Paper			Chemical	Petrochem & Coal	Textiles		Cement
	Mechanical Piping	Chemical, Unbleached	Pulp & Paper Bleached			Sizing Suspension	Scouring, Bleach & Dye	
Cu	-	-	-	-	0.05	0.01	-	-
Fe	0.3	1.0	0.1	0.1	1.0	0.3	0.1	2.5
Mn	0.1	0.5	0.05	0.1	-	0.05	0.01	0.5
Ca	-	20	20	68	75	-	-	-
Mg	-	12	12	19	30	-	-	-
Cl	1,000	200	200	500	300	-	-	250
HCO_3	-	-	-	128	-	-	-	-
NO_3	-	-	-	5	-	-	-	-
SO_4	-	-	-	100	-	-	-	250
SiO_2	-	50	50	50	-	-	-	35
Hardness	-	100	100	250	350	25	25	-
Alkalinity	-	-	-	125	-	-	-	400
TDS	-	-	-	1,000	1,000	100	100	600
TSS	-	10	10	5	10	5	5	500
Color	30	30	10	20	-	5	5	-
pH	6-10	6-10	6-10	6.2-8.3	6-9	-	-	6.5-8.5
CCE	-	-	-	-	-	-	-	-

Table 3: Considerations on the extent of reuse

Quality indicators for some main drains

Indicator \ Drain	Upper Serw	Hamul	Upper No.1	Edko	Limits set in Law 48
TDS (mg/litre)	1395	1348	717	1075	-
BOD (mg/litre)	25	34	32	54	< 10
COD (mg/litre)	118	101	133	250	< 15
NH_4 (mg/litre)	3.0	14.4	27.9	1.1	< 0.5
MPN (10^6/100ml)	1.2	480	0.2	0.2	< 0.005
TSS (mg/litre)	251	170	202	450	-

Source: DRI, 1997a.

irrigated agricultural production systems. Reusing poor quality water for irrigation can serve two purposes: one is to dispose of drainage water that would otherwise be costly to dispose and the other is to utilize poor quality drainage water as a water resource for growing crops that have economic value. Water reuse for agricultural crops has distinct economic incentives and a number of crops are known to be highly tolerant to salinity. However, as salinity increases in the irrigation water, there is a greater need to monitor and manage irrigation and drainage practices and to consider the sustainability of the system. It is possible to safely reuse agricultural drainage water if the characteristics of the water, soil and the intended crop plants are known and can be economically managed. Poor quality water requires selection of crops with appropriate salt tolerances, improvements in water management and maintenance of soil structure and permeability. Contaminated drainage water could lead to various problems including: impairment of soil physical and chemical properties, water related health problems and possible contamination of food products.

Need for Agricultural Drainage Water Treatment: The treatment of agricultural drainage water presents a challenge due to the complex chemical characteristics of most drainage waters [10]. Numerous technological solutions must be examined to enable safe reuse of the agricultural drainage water (ADW). Three technological sets must be addressed simultaneously. The first set is related to removal of suspended and soluble organic contaminants from the ADW. The second set comprises most of the known commercial desalting technologies. The third technological set includes hazardous contaminants removal systems. The appropriate schemes for treatment and reuse of ADW include the selection and integration of two or three subsets from the mentioned treatment categories [11].

Subsurface drainage water containing very high levels of salinity, selenium and other trace elements, the treatment objectives are:

- Reduce salts and toxic constituents below hazardous levels;
- Meet agricultural water management goals;
- Meet water quality objectives in surface waters;
- reduce constituent levels below risk levels for wildlife.

Reuse of Agricultural Drainage Water in Irrigation: The reuse of agriculture drainage water is a new trend in developing additional water resources. Environmental and human health considerations for drainage water reuse, especially in agriculture, should be considered. Irrigated land may become waterlogged and salinized as water tables rise and salts build up. Waterlogging and salinity are reducing water productivity over wide areas, yet investment in drainage is usually neglected in developing countries. Drainage and urban wastewater flows represent precious extra resources and floods can contribute to recharge the irrigation resources. Drainage water reuse requires an integrated approach to irrigation design and management. Most drainage projects have produced good rates of return and improved farmer incomes, yet investment has dwindled as projects have concentrated on upstream irrigation and farming. Investment costs are generally low, ranging from on-farm surface drainage systems at US$100 to $200 per hectare up to US$1,000 per hectare for pipe drainage in arid areas [12]. Beyond individual economic benefit, drainage can contribute to overall land and water management and the environment. Drainage is a proven but demanding discipline and technology. Best investments are often highly case and site specific and careful research and piloting are required. Integrated approaches address all on-site and off-site impacts of drainage. Although governments usually have to take the initiative, investment sustainability requires farmer involvement, as experience from pilots in Egypt [13].

Reuse in Conventional Crop Production: Drainage water of sufficiently good quality might be used directly for crop production. Otherwise, drainage water can be reused in conjunction with freshwater resources. Conjunctive use involves blending drainage water with freshwater. Alternatively, drainage water can be used cyclically with freshwater being applied separately. In cyclic use, the two water sources can be rotated within the cropping season, or the two water resources can be used separately over the seasons for different crops. The choice of a certain reuse option depends largely on: drainage water quality; crop tolerance to salinity; and availability of freshwater resources. The quantity and time of availability of drainage water is of major importance.

Table 4: Sensitivity of crops to main water quality parameters

Parameter	Min	Max	Cropping Restriction
ECiw dS/m	< 0.5		Sensitive crops to salinity
	0.5	1.5	Moderately sensitive crops
	1.5	4	Moderately tolerant crops
	4	6	Tolerant crops
		>6	Unusable or can be used with tolerant and moderately tolerant crops with reduction in crop yield
			Refer to table 13 b
SARiw	< 5		Sensitive crops to high SAR valyes
	5	9	Moderately sensitive crops
	9	15	Moderately tolerant crops
		> 15	Tolerant crops
			Refer to table 13 c
Boron (mg/l)	< 0.7		Sensitive crops to high SAR values
	0.7	3	Moderately sensitive crops
		>3	Tolerant crops

For example, where reuse takes place in an irrigation system in which water is distributed on a rotational basis, the probable mode of reuse is either direct or cyclic. Table 4 shows sensitivity of crops to main water quality parameters.

Reuse for Irrigation of Salt Tolerant Plants and Halophytes: Where the irrigation water is too saline to grow conventional agricultural crops, irrigation of halophytes might be considered. The maximum amount and kind of salt that salt tolerant plants and halophytes can tolerate vary among species and varieties. Halophytes have a special feature as their growth is improved at low to moderate salinity levels [14]. In contrast, salt tolerant crops have maximum growth up to a threshold salinity level after which growth is reduced. Salt tolerant plants and halophytes have been grown successfully in many places in the world to produce fuel, fodder and to a lesser extent food.

Reuse of Agricultural Drainage Water in Wetlands: The re-use of subsurface saline agricultural drainage water for wetland management poses substantial challenges and can generate problems which could result in wildlife losses and habitat reductions. Although subsurface saline drainage water is typically free from contamination by applied pesticides or herbicides, it may contain soil or naturally derived toxicants or trace elements such as salts, nitrates, As, B, Cd, Cr, Pb, Hg, Mo, Ni, Se, Ag, U and V. Each of these constituents is potentially toxic independently, in combination with other constituents, or through the process of biomagnifications in wildlife through the food chain. Careful analysis of subsurface agricultural drainage water during several periods of a yearly cycle is required before any plans for re-use as a water supply for wetlands can be considered. The provision of an adequate volume of flow-through water is important to minimize concentration of toxic elements due to evaporation.

At present, there are no comprehensive standards which establish safe levels of trace elements in water used for wetland habitat management. However, because of the high potential for food-chain magnification, most wetland managers intentionally refuse to use subsurface agricultural drainage waters which contain levels of trace elements above background levels. The potential for and the costs of, clean up or remediation of a contaminated wetland dictate a conservative approach. In general, water with a TDS level of 2500 mg/litre or less is preferable for wetland management. Sometimes, water with a TDS level as high as 5000 mg/litre can be used for short periods. Standard management practices involve an autumn flooding to a depth of about 20-50 cm, with these depths being maintained. In late winter, the ponds are drained to discharge drainage water and accumulated salts. The ponds are then refilled with new water as deeply as practicable. After approximately 14 days, the water is drained again. The drainage cycle is repeated two to three times before the cycle is completed. This process removes salt concentrated in the surface water through evaporation and allows for a rebalancing of the water/soil salt equilibrium. Any wetland habitat supported principally with saline agricultural drainage water must be carefully managed and monitored to have productive wetlands. In addition, there must be an environmentally safe way (sea or salt lake) of disposing of the water as it is drained from any wetland area [2]. The potential of engineered wetland as a low cost technology for improving water quality is investigated. The technology proves to be successful and it can serve the following purposes:

- Preserve/ restore the ecology.
- Improve quality of drainage water so that it becomes suitable for different uses.

Injection into Deep Aquifers: Disposal by injection into deep aquifers is a process in which drainage water is injected into a well for placement into a porous geologic formation below the soil surface [10]. The oil and gas industries use deep-well injection to dispose of waste brine. In California, the United States of America, deep-well injection technology has been used for over 60 years for the disposal of oil field brines. The technology could potentially be applied for the disposal of agricultural drainage water provided the conditions of the receiving geologic formation are adequate, there are no environmental hazards and the costs are not prohibitive. The main environmental concern is leakage from pipes and confining aquifers. Drainage effluent can contaminate freshwater zones through leakage. The drainage and aquifer water should be compatible, as the mixture should not produce precipitates, which clog the wells. Furthermore, the receiving geologic formation should have sufficient porosity and thickness to receive the injected water. If water containing nitrate is injected into aquifers containing organic matter and ferrous iron, the growth of nitrate reducing bacteria might clog the pores of the receiving formation as they accumulate [15].

Water Quality Concerns in Drainage Water Management: There are several factors to consider when determining the opportunities for and constraints on the safe use, treatment and disposal of agricultural drainage water. Information and data desired at the site of drainage water production include: rate of drainage water production per unit area, chemical concentration of constituents of concern and the rates of mass emission. Drainage water management requires additional information and data on drainage water quality and its suitability for the intended water uses as well as an understanding of environmental and health concerns. Upstream drainage water management affects the needs and water quality requirements of downstream water users. As reliable references are already available on estimating drainage water production volumes [16,17].

Recommendations

- Sustainable management of water resources and wastewater management policies of Saudi National Plan should be implemented.
- Reuse of agricultural drainage is a challenge for Saudi Arabia to cover the considerable increase of water demand.
- Adoption of efficient field agricultural drainage system in Saudi irrigated lands has its considerable benefits.

REFERENCES

1. NDP, 2009. The Eighth Saudi National Development Plan (2005 -2009), Chapter 23, Saudi Ministry of Economy and Planning.
2. FAO, 2002. Agricultural drainage water management in arid and semi-arid areas. FAO Irrigation and Drainage paper No.61, Rome, Italy.
3. MOA, 2005. A glance of Agriculture Development in the Kingdom of Saudi Arabia. Saudi Ministry of Agriculture. (www. moa. gov. sa).
4. Cosgrove, W.J. and F.R. Rijsberman, 2000. World Water Vision: Making Water Everybody's Business. Earthscan Publications. London, UK., pp: 108.
5. Abdel-Azim, R. and M.N. Allam, 2006. Agricultural drainage water reuse in Egypt: Strategic issues and mitigation measures. Options Méditerranéennes. Série B: Studies and Research, Number 53: 105-117. Proceedings of the 3rd WASAMED (Non-Conventional Water Use) Workshop, Cairo, 7-11 December 2004. International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM).
6. WaDImena, 2008. Wastewater Reuse for Water Demand Management in the Middle East and North Africa. General Water Demand Institute, Canadian International Development Agency.
7. ESCWA, 2005. Status and Needs of Water Statistics in the ESCWA region Report, Working Group on Environment Statistics Work Session on Water Statistics, Vienna.
8. EPA, 2004. Guidelines for Water Reuse. U.S. Environmental Protection Agency Municipal Support Division Office of Wastewater Management Office of Water EPA/625/R-04/108. Washington, DC.
9. Khalil, M. and S. Ragab, 2006. In UNESCO (United Nations Education, Science and Cultural Organization), Efficient Water Demand Management in Arid Regions, Sharm El-Sheikh, Egypt, pp: 17-21.
10. Lee, E.W., 1994. Drainage water treatment and disposal. In K.K. Tanji & B. Yaron, eds. Management of water use in agriculture. New York, USA, Springer-Verlag.
11. Talaata, H.A., M.H. Soroura, N.A. Rahmanb and H.F. Shaalan, 2002. Pretreatment of agricultural drainage water (ADW) for large-scale desalination. ScienceDirect of Elsevier B.V., 152(1-3): 299-305.
12. MWRI (Ministry of Water Resources and Irrigation), 2005. Water for the Future, National Water Resources Plan for 2017. Egypt.
13. Willardson L.S., D. Boels and L.K. Smedema, 1997. Reuse of drainage water from irrigated areas. Irrigation and Drainage Systems Magazine, Springer Netherlands, 11: 215-239.
14. Goodin, J.R., E. Epstein, C.M. McKell and J.W. O'Leary, 1999. Saline agriculture: salt tolerant plants for developing countries. Washington, DC, Panel of the Board on Science and Technology for International Development Office of International Affairs National Research Council.
15. Westcot, D.W., 1997. Drainage water quality. In FAO. Management of agricultural drainage water quality, by C.A. Madramootoo, W.R. Johnston & L.S. Willardson, eds. FAO Water Report No. 13. Rome.
16. Smedema, L.K. and D.W. Rycroft, 1988. Land drainage: planning and design of agricultural drainage systems. London, B.T. Batsford Ltd.
17. Skaggs, R.W. and J. Van Schilfgaarde, 1999. Agricultural drainage. Number 38 in the series Agronomy. Madinson, Wisconsin, The United States of America, American Society of Agronomy, Crop Science Society of America, Soil Science Society of America.