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Water Desalination for Agricultural Use

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Paragraphs

I. INTRODUCTION

1. In the water stressed Near East, water desalination is now a well established technology for municipal and industrial water supply and in some countries it is becoming the main source of potable water. Estimates suggest that *desalinated water use in the Region is 3.2 BCM/year* – over half of the total worldwide. *Saudi Arabia, Kuwait, and United Arab Emirates are the largest users and account for 74 percent of this*. Over 45 percent of Kuwait's water use comes from desalination. *Saudi Arabia produces over 2.7 MCM/day* of desalinated seawater; while the world's largest desalination facilities are at *Jebel Ali in the United Arab Emirates* which has a capacity of almost *1 MCM/day*.

2. Desalination now accounts for over 40 percent of 'non conventional' water use (desalinated water and treated wastewater) in the Near East, about 17 percent of the total water use for domestic and industrial purposes.

Table 1. Non-conventional Water use in the Near East (MCM/yr)

Country	***Municipal and Industry Water Use***	***Desalinated Water***	***Treated Wastewater***	***Total Non-conventional***
Algeria	2 130	17	0	17
Egypt	9 300	100	2971	3071
Libyan Arab Jamahariya	740	18	40	58
Mauritania	200	2	1	3
Morocco	1 590	7	0	7
Tunisia	480	13	21	34
North Africa	***14 440***	***157***	***3033***	***3190***
Bahrain	200	102	16	119
Kuwait	420	420	78	498
Oman	150	109	37	146
Qatar	180	180	43	223
Saudi Arabia	2 840	1033	166	1199
United Arab Emirates	690	950	248	1198
Yemen	340	10	6	16
GCC States and Yemen	***4 830***	***2805***	***594***	***3399***
Iran (Islamic Republic of)	7 300	200	0	200
Iraq	14 000	7	0	7
Jordan	330	10	84	93
Lebanon	530	47	2	49
Syrian Arab Republic	2 030	0	550	550
Middle East	***24 180***	***265***	***636***	***900***
Total Near East	***43 440***	***3226***	***4263***	***7489***

Source: Compiled from FAO AQUASTA, 2007

3. There is some evidence that desalinated water is now being used for irrigated agriculture. But there are concerns that this is not yet justifiable both from an economic and environmental point of view. This note briefly examines the current state of the art of desalination, the costs involved, and the potential for using desalinated water for irrigated agriculture.

4. Saline water includes both seawater (30-50 g/l) and brackish water (0.5-30 g/l), which is less saline than seawater. Brackish water is often a mix of seawater and freshwater such as in river estuaries, in over-abstracted groundwater aquifers at risk from saline intrusion, in deep fossil groundwater, and in land drainage networks that collect return flows from irrigation schemes.

II. TECHNOLOGIES AND COSTS

5. Desalination is a process to remove salt from saline water to produce freshwater. Desalination processes have developed significantly over the past 30 years and this has led to the general acceptance of two main technologies – thermal and membrane – which together account for almost 98 percent of the world's current desalination operating capacity – now in excess of 35 MCM/day. A third option involves the use of solar energy for desalination but this is very much in its infancy.

Thermal Technologies

6. Thermal technologies are now mature and further major developments are not expected. They are primarily used to desalinate seawater by exploiting the distillation process – heating saline water to produce water vapor which is then condensed to produce freshwater. There are several processes being used– multistage flash (the most common process), multiple-effect distillation, and vapor compression distillation. Thermal technologies usually treat large volumes of water (>50 000m^3/d), they have large capital installation costs, and have high energy requirements. For this reason they are often built in combination with power plants.

Figure 1. A 2 500m^3/day Reverse Osmosis Plant Treating Brackish Groundwater in Spain (by membrane technology)

7. Membrane technologies are still developing rapidly. They include *Reverse Osmosis* – which involves forcing saline water under pressure through a semi-permeable membrane to remove the salt ; while E*lectro-dialysis* – which uses an electric load to achieve a similar result. Whereas electro-dialysis is suitable only for brackish water, reverse osmosis is used for both brackish water and seawater. Membrane technologies provide opportunities to scale plant size for a particular purpose – from large plants (above 5 000 m^3/d), to medium plants (500 to 5 000 m^3/d), and small plants with maximum of 500 m^3/d capacity. Energy requirements are directly proportional to the amount of salt to be removed. A disadvantage of membrane processes is the need for pre-treatment when the water to be treated contains impurities.

8. In some cases both thermal and membrane technologies are used in combination to make better use of seasonal energy surpluses and address power/water mismatches caused by changes in daily and seasonal demands.

Table 2. Desalination Technologies, Capacity, Energy Requirements, and Costs of Product Water[1]

Desalination Technology	Intake Salt Concentration (g/l)	Plant Capacity (m^3/d)	Energy Requirements (kWh/m^3)	Product Water Cost (US$ m^3)	Worldwide Capacity (%)
Thermal Distillation	>30	>55 000	1.5-3.5	1.00-1.50	52
Membranes	10-30	500-5 000+	4-7	0.50-1.50	45
Others	-	-	-	-	2

[1] *Source: FAO (2006) Water Desalination for Agricultural Applications. Land and Water Discussion Paper No 5 Rome.*

9. Desalination costs in terms of US$/$m^3$ of freshwater produced depend on the technology, the size of the plant, and the salt content of the intake water. Membrane technologies can produce good quality water at US$0.50/$m^3$ for treating brackish water. Costs, however, are higher for treating seawater. Thermal technologies tend to be more expensive than membranes.

10. Current trends suggest that costs of both technologies are falling. Both can reap the economies of scale but membrane technology costs are falling as well due to continued development which leads to efficiency improvements.

Solar Technologies

11. In view of the high energy demands of both thermal and membrane technologies and their dependence on fossil fuels, attention is turning towards renewable energy sources and in particular the use of solar energy for desalination. There are two approaches to this. The first is the use of solar energy directly to produce water vapor which is then condensed on a cooler surface to produce freshwater. The second is to collect and convert solar energy into electrical energy to drive more conventional thermal and membrane desalination processes.

12. Technologies which produce water vapor mimic the natural water cycle but over a much shorter time period. So far the technologies available are very modest in size and output. ‘Solar stills’ are an example of this approach but their yield is very low – on average only 2-5 liters/day depending on sun-hours. Solar ponds are also used to capture and store the sun’s energy. They comprise a pool of saline water in which the lower, more saline layers absorb solar heat which cannot escape because the density difference prevents natural convection taking place. This traps heat at the bottom of the pond which can then be used to produce water vapor or drive other distillation processes. Solar ponds have the distinct advantage of making good use of brine which is a waste product from distillation and a potential environmental hazard.

13. Solar photovoltaic systems directly convert solar energy into electricity using cells made from semiconductor materials such as silicon. Additional equipment such as power conditioning and energy storage equipment is needed to control and convert the energy for use in desalination.

14. At present solar desalination is a useful option for providing basic energy and water needs in remote regions where it is not possible or cost-effective to connect to the public electricity supply, and where physical water scarcity is most severe. They are small in scale, low maintenance, and have low environmental impact.

15. There are several pilot plants now operating successfully on a larger scale. But as yet, there are few data and experiences to be drawn from this. However, the commercial viability for agriculture is questionable. Costs for installations in the Middle-East, North Africa, and Spain range from US$1-4/$m^3$ for solar distillation and as much as US$8/$m^3$ for reverse osmosis using photovoltaic cells. So they are still not competitive with conventional systems.

16. There are a variety of novel technologies being developed such as solar energy driven membranes and thermal distillation systems with heat recovery processes. More cost-effective hybrid systems are also being designed which combine conventional technologies with solar energy systems to extend their use when solar radiation is not available.

III. DESALINATION WATER FOR AGRICULTURE

17. Desalinated water is mostly used for domestic and industrial purposes, usually because the high cost of production cannot be justified for agricultural purposes. However, concerns about food security, globalization of food markets and prices, water scarcity, and rising energy costs, are continually changing perceptions about the viability of agricultural production systems. In the sophisticated export markets the financial returns of growing ‘out of season’ high value crops may well justify the use of more expensive sources of water in some circumstances. In less sophisticated local markets in the Near East, however, such costs are unlikely to be justified for basic staple crops and even cash crops without significant subsidies.

18. So using desalinated water for irrigation is technically feasible, the only constraints are economic – can water be desalinated at a low enough cost to be commercially viable? Or, can high value production justify the use of desalinated water in irrigation ? And are there possible environmental constraints that may limit its use?

Putting Desalinated Water into an Agricultural Context

Agriculture is a large consumer of water in comparison to domestic and industrial water use. A large-scale reverse osmosis plant producing 5,000 m^3/d would be enough to irrigate approximately 50 ha of cropping in an arid environment. So, although the volumes of water produced through desalination are significant from a domestic and industrial point of view, they are rather modest when viewed against the large volumes of water that agriculture consumes. There is also the possibility of re-using water from domestic and industrial sources, whereas water used for irrigation is consumed and is not returned, except via the natural hydrological cycle.

19. In spite of the advances in desalination technologies which are bringing down unit costs, agricultural irrigation using desalinated water is not widely practiced – estimates indicate that less than 10 percent of the world’s desalination capacity is used for irrigation. This figure probably includes amenity (urban landscaping) and sports turf (golf courses) irrigation in an urban context which can often justify the high unit cost of desalinated water.

20. *Spain* is one country that is leading in the use of desalinated water in agriculture. In 2006 it was reported that some *40 percent (about 550 000m^3/day) of the country’s desalinated water capacity was used for agriculture* to help relieve the pressure on over-exploited aquifers and to overcome problems of saline intrusion along the Almeria coastal plain. However, in spite of the Spain’s recognized technical excellence in desalination, there is very little information on this experience and few data available on crops, areas irrigated, or justification of costs for agricultural use.

21. Desalination of brackish groundwater for *agricultural use is also practiced by a few private farmers in the Near East, such as the United Arab Emirates*. High value crops, such as lettuce, strawberries and cut flowers, are practiced; however, little information is available on the cost of desalination and its economic returns.

22. A carried out recently in Morocco with FAO’s support indicated that seawater desalination for agricultural use can be economically viable, provided that high value cash crops are grown and the treatment plant covers and irrigated area of 7,000 to 10,000 ha. Farmers would be able to support 30-40% of the capital investment and the total Operation and Maintenance costs.

23. The quality of water required for irrigation purposes and sustainable agriculture may not be as high as those required for domestic consumption. Thus the water quality required will depend on climate, soils, cropping, and water management practices. Indeed there are concerns that desalinated water may be too 'pure' for agricultural use as it may lack the natural minerals that plants need for healthy growth.

24. In some countries desalinated water is used to dilute brackish water and make it more suitable for crop production. Blending of fresh water from the Nile River with "salty water" coming from the agricultural drainage system is a common practice in Egypt. There is a *Main Blending Station* for this purpose and pumping water through *Al-Salam Canal to Sinai*. Blending brackish water with desalinated freshwater can dilute the salt content of irrigation water to acceptable levels, reduce leaching requirements, and reduce the amount of 'expensive' desalinated water needed to grow a crop.

IV. ENVIRONMENTAL IMPACTS AND EXTERNALITIES

25. Using desalinated water is not without environmental impacts, both positive and negative.

26. Favorable environmental impacts include an increase in the availability of freshwater and, when freshwater is used for irrigation, it reduces the risk of build-up of saline conditions in the soil profile.

27. The most immediate problem is the safe disposal of highly saline waste brine coming from the desalination plant. This effluent is quite harmful to plant and animal life and care is needed to avoid any damage to the local ecosystem. Brine and residues disposal from desalination will impact on the receiving water body. Disposal of brine in coastal and inland areas will have different implications. Inland disposal can be quite complex but one way is to use salt ponds from which it is possible to recover heat energy to drive the desalination process. However, there are potential groundwater pollution hazards unless ponds are well lined. Direct coastal discharge may seem simpler but it can significantly impact on the marine environment by changing salinity and temperature.

28. Desalination is energy intensive and relies almost entirely on fossil fuel energy. It is estimated that $1m^3$ of desalinated water requires 1 liter of fuel. So desalination using the accepted technologies can add significantly to greenhouse gas emissions and the problems of climate change.

29. The infrastructure required to house desalination plant can impact visually on the landscape and there is also the problem of noise pollution. However, there may be less opposition to desalination plants than other options for improving water supply, like dam/reservoir construction with the consequent disturbance that can occur during construction.

30. Technology and management options are available to reduce adverse impacts; but continuous monitoring of effluents and research on brine disposal is needed.

31. Environmental Impact Assessments are an essential part of monitoring to correct unfavorable impacts. However, as yet there are no detailed and accepted environmental guidelines which deal specifically with desalination plant.

V. CONCLUSIONS AND RECOMMENDATIONS

32. Seawater desalination offers a viable solution to the problem of water supply for domestic and industrial uses in water scarce areas, particularly in the Near East where groundwater resources are being severely overexploited.

33. However, desalinated water for agricultural purposes is still generally not cost-effective, except under special circumstances such as desalination of brackish water or the production of high value cash crops. Although unit costs of desalinated water are falling, the main purpose for desalination for the time being will still be to supply water for domestic and industrial uses where it can be more economically and

socially justified. Focusing desalinated water in these sectors can have the indirect benefit of releasing other water sources, particularly groundwater, for irrigation.

34. Of the non-conventional water resources available for agriculture, wastewater, suitably treated for re-use, offers viable and growing opportunities. It is released close to cities (and therefore to markets) and usually offers stable and reliable flow of water to users. However, wastewater re-use is not without problems in the Near East, including for cultural reasons (using such water in a domestic and even in an agricultural context is not always socially accepted). This percpetion is nevertheless gradually changing.

35. FAO promotes the safe reuse of treated wastewater as an alternative water source to farmers in water scarce countries. It has varied experiences in assisting Member Countries in comprehensive and integrated approaches to water resources and environmental management with sustainable development as a goal. Currently, FAO maintains a collection of wastewater databases (http://www.fao.org/nr/water/infores_databases_wastewater.html) and is co-author of the new "*Health Guidelines on the Safe Use of Treated Wastewater and Greywater for Agriculture"* published by the World Health Organization – WHO ((http://apps.who.int/bookorders/anglais/detart1.jsp?sesslan=1&codlan=1&codcol=15&codcch=3653)). It manages networks in the application and development of safe use of reclaimed water and has recently published Water Report 35: The Wealth of Waste*: the economics of wastewater use in agriculture.*

36. FAO will continue to monitor desalination technology developments and economic feasibility with respect to agricultural applications and inform Member Countries accordingly. FAO can also facilitate linkages between countries and international experts for assessing the potential of water desalination in agriculture under site-specific conditions.

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