GREENHOUSE PRODUCTIVITY USING A RECIRCULATING DESALINATION SYSTEM SUPPORTED BY SOLAR ENERGY: A REVIEW

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ABSTRACT

Water shortages in Egypt, as one of the Mediterranean countries, are major challenges affecting the productivity of crop plants. The exploitation of seawater and wastewater through desalination is an important means of avoiding the exploitation of groundwater and limited natural water resources in the provision of water for crop production. Solar energy is a sustainable renewable resource that ensures the long-term sustainability of agriculture by providing the thermal energy needed for desalination. The integration of solar water desalination systems in greenhouses to overcome water shortages in some areas like Egypt is, therefore, one of the preferred technologies in crop-growing areas. In the greenhouse, control of crop growth is achieved through adequate treatment of climatic variables in the environment, the quantity of water and fertilizers used in irrigation. Economic analyses, including water costs and farmer income, suggest that the greenhouse concept with solar-based solar desalination technologies is one of the most cost-effective technologies in water deficit countries such as Egypt. This chapter highlits on the exploitation of the solar distillation in water desalination and the provision of water for irrigation required by crop plants, and desalination in MENA and its energy implications beside their environmental effects.

Keywords: Water Scarcity, Desalination, Greenhouse, Crops, Agriculture, Solar

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1 INTRODUCTION

By the end of this century, rainfall and freshwater availability might decrease by up to 40 percent for some MENA countries. The critical task is how to cope with the future and transform the region's economy into a sustainable trend. Desalination plays a vital role in water supply in the Middle East and North Africa region. The desalination process is expensive and consumes a large amount of energy in addition to its effects on the environment. By 2050, Saudi Arabia and many other countries in the Arab region are expected to consume most of the oil they produce (World Bank 2019). The use of desalination by using solar energy is one way of avoiding the exploitation of aquifers in crop irrigation to guarantee long-term sustainability. A more complete analysis of a system combining a solar still with a greenhouse was first offered by Trombe and Foex (1961), and advanced more extensive experimental and theoretical investigations of the notion were presented by

Boutiere (1971) and Bettaque (1999). However, more recently, models have been developed for the use of solar power and predictive control of the operation of desalination plants with greenhouses in crop irrigation and adequate treatment of climatic variables of the environment and the amount of water and fertilizers applied through irrigation. There is an increasing demand for progressing conventional desalination technologies and developing novel solar-powered desalination processes. The different existing systems of solar energy utilization for seawater desalination include solar stills, solar powered humidification-dehumidification (HDH) desalination, solar diffusion driven desalination, solar membrane distillation, concentrated solar power (CSP) based desalination, and solar pond distillation (Alnaimat et al. 2018). This chapter focus on the utilization of the solar distillation in water desalination to use in crop irrigation as well as desalination in MENA and its energy implications beside their environmental effects.

2 SOLAR DESALINATION WITH GREENHOUSE

The water crisis that threatens the Arab region is strongly linked to food production because agriculture accounts for 70 percent of the total fresh water used, and attaining irrigation water in arid areas by conventional methods has thoughtful environmental effects. Kabeel and El-Said (2015) added that around 20 percent of the world's population lived in areas where there was no water needed to meet their needs, according to WHO reports, with the world population increasing by 80 million a year and a third of the planet likely to face water shortages by 2025. Recently, there has been progressing in the use of energy to desalinate salt or brackish water and pumping groundwater from deeper to be used in the agricultural sector.

van Henten (1994) developed a model by for total dry weight simulation. The used model gives a simulated crop growth which closely follows the general trend of the experimental measurements. These experiments clearly show that for the reference greenhouse compartment the higher transmission level of solar radiation gave a cumulative and constant increase in the dry weight production compared to the solar desalination greenhouse. Also clearly showed is the importance of high light intensity for the production of a high-quality lettuce crop with a high number of leaves and a compact morphology which is confirmed by Benoit and Ceustermans (1990) and many authors in the crop science field. Chaibi, (2003) improved simulation models with high accurateness for the water desalination, the light transmission into the greenhouse, and suitable environment for the crop growth in Tunisia. Significantly less stress environmental conditions were recorded at an experimental greenhouse with roof desalination compared to a conventional greenhouse. A system integrated in 50% of the roof area of a wide span greenhouse has the capability to cover the annual demand for a low canopy crop. Similar ability for high canopy plants requirements asymmetric roof design and desalination scheme in the whole roof area. The yield can be attained using more light glass materials in the roof absorption. Economic analyses, suggest that the greenhouse concept is integrated with solar-based technologies to provide the necessary water needs.

Elsaeed (2012) showed that an additional four billion m^3 water is extracted from the shallow aquifer. In arid and semi-arid regions of the world, it is important to encourage the use of alternative water sources, such as clean water and rain, intensive water collection as a secondary source, reuse of wastewater, development of new technologies related to water use efficiency. The idea of integrating solar water desalination systems into the agricultural environment to address water shortages in some parts of the planet is one of the simplest and inexpensive techniques, (Li et al. 2013), can be easily combined with greenhouses (Chaibi 2000). Chaibi added that water produced by a solar still is not enough for growing a crop, and the combination of a greenhouse and solar multi-effect distillation (MED) unit is essential. The operating process of the desalination plant to produce the daily water demanded by the crop is of paramount importance. Most of the improvement systems applied to desalination deal with the design of cogeneration plants (Hosseini et al. 2012 and

Wu et al. 2013). Roca et al. (2016) stated that water shortages in the Mediterranean region severely affect food production. The use of thermal desalination processes is one of the ways to avoid the exploitation of aquifers to supply water to the crops.

3 FEASIBILITY OF GREENHOUSE SYSTEMS WITH WATER DESALINATION IN AGRICULTURE

Desalination technologies have evolved in the last few years, from being low-end in the world, to some oil-rich countries where energy costs are low and are now used worldwide. Moreover, with improved technology and lower costs, their application extended to the agriculture sector. It is necessary to obtain the average cost of desalinated water, taking into account three factors; 1) Desalination technology and energy requirements, 2) Feed water quality, and 3) Water quality product.

Plants growing under the severe arid areas confront several of stresses causing factors including drought, high temperatures, high winds, low humidity, high radiation, dust, and salinity. These pressures directly affect plants physiologically or indirectly by changing the physical environment of the plant. To overcome these challenges, the use of greenhouses could be used to provide a proper environment to plant growth. Currently, there are many countries in the world growing crops on a commercial scale under greenhouses such as tomato, cucumber, pepper, lettuce, and flower. Under hot climates and with high temperatures inside the greenhouse, the mechanical air conditioning system should be used (Radhwan and Fath 2005).

Egypt is a nation heavily dependent on agriculture to cover gross domestic requirements. The agricultural production in Egypt, as in most Mediterranean countries, suffers from water scarcity, enhanced by increasing demand and climate change impacts. Elsaeed (2012) said that it is of importance to develop new water resources through desalinating brackish groundwater. Where Egypt has available freshwater reserves of 58 billion m3, and annual water demand is around 77 billion m3. The process of recycling is a technique to narrow the gap between supply and demand for water in Egypt

Furthermore, the integration of different sectors of agriculture, would provide both plants and fish with optimum environmental situations is a classical problem in the field of aquaponics. Numerous studies have attempted this problem by decoupling fish and plant systems. Desalination technology is used to achieve the balance between the two diverse components based on a modelling approach via solar energy source. Desalination engineering methods can improve the nutrient balances in multi-loop aquaponics systems in order to achieve optimal growth situations for both fish and plants. Also, in Europe, tomatoes, peppers, fresh garlic, strawberries, herbs, and lettuce are grown in aquaponics systems (Goddek and Keesman 2018).

4 RECYCLING IS VERY IMPORTANT GIVRN THE SCARCITY OF WATER IN MENA COUNTRIES

In light of the potential changes in climate impacts on water supply and the potential challenges, Egypt will face problem in the future where more than 80 billion m^3 in annual water demand in Egypt is currently needed. The effect of climate change on water resources (irrigation and domestic and industrial demand) for the 21 MENA countries have been evaluated (World bank 2012). The total water demand and unmet demand for each country were assessed. Demand will rise in all countries due to the higher evaporative of irrigated agriculture besides the increase in domestic and industrial requirements. Generally, from the 2009 baseline, the demand will rise by about 25% in 2020–30, and by about 60 percent in 2040–50. However, large variation happens when countries with relatively high domestic and industrial demand show greater proportional increases rather than the other countries. The higher countries with extensive agricultural demands account for the major portion of the increased future demand. The demand gap will be dramatic increased for all MENA countries. MENA Countries that currently face no or limited water shortages will be confronted with large water deficits in the near and long term. For example, Egypt, the Islamic Republic of Iran, Iraq, Morocco, and Saudi Arabia will suffer from annual water shortages increase by 10–20 km^3 in 2020–30, and up to 20–40 km^3 in 2040–50. Whereas the amount of the water gap in the least stressed countries looks relatively small compared to the enormous gap for Iraq in 2040–50, the challenge of meeting their water gaps appears formidable. In Egypt, as the Nile Basin is highly sensitive to the climate as a single source of water, water will be short by 50–60 km^3 per year based on the dry projections, nonetheless there will be no actual shortage in the situation of the wet projection. For other countries, the differences amongst the climate projections are more modest. For instance, in Morocco, the annual difference in expected water shortage in 2040–50 varied from 8 km^3 for the wet climate to 20 km^3 for the dry climate, and 15 km^3 per year for the average climate projection. Other countries appearance a similar performance. According to the above, alternative options to bridge the growing water demand gaps are better water management and new sources of water supply.

5 DESALINATION IN MENA AND ITS ENERGY IMPLICATIONS

Generally, most countries in the Middle East and North Africa have access to seawater as a source of water for desalination, along with historical regional linkages and the use of marine resources. Also, most countries in the MENA region have brackish groundwater resources. Desalination allows coastal communities to use an inexhaustible source of salt water. From the 1950s, desalination became economically acceptable for normal use. Subsequently, many countries in the MENA region have developed desalination facilities to cover the lack of available freshwater supplies. By 2007, about 54 percent of the world's desalination capacity was installed in the MENA region (Figure 1). The global production of desalinated water was about 44 km^3 per year: 58% of the sea water, 22% of the salt water, and 5% of the wastewater. By 2016, the Middle East and North Africa share of global demand is expected to account for about 70 percent of the world's growing desalination capacity. Of the 15 countries with the largest conventional desalination plants, 9 are in the MENA region. Desalination technology has proven to be a practical water supply solution for the Middle East and North Africa region. The dependency ratio is high in the GCC (Fig 2). However, dependence among Maghreb countries, particularly Algeria and Libya, is less than 5% of their water supply (Word Bank 2012).

The impact of climate change on irrigation, and domestic and industrial demand was assessed on 21 countries in the Middle East and North Africa (see Table 1). The results indicated that demand in all countries would increase as a result of the high demand for irrigated agriculture and increasing domestic and industrial needs. Of the baseline for 2009, overall demand will increase by about 25% in the period 2020-30 and by about 60% in the 2040-2050 period (Word Bank 2012).

“Tunisia has a long experience (since 1965) in using treated wastewater to irrigate the citrus orchards and olive trees of the Soukra irrigation scheme (8 km northeast of Tunis), which covers 600 ha. In 2008 Tunisia’s 61 wastewater treatment plants collected 240 MCM of wastewater. Less than 30 percent of it was recycled to irrigate vineyards, citrus, trees (olives, peaches, pears, apples, pomegranates), fodder crops (alfalfa, sorghum), industrial crops (cotton, tobacco), cereals, and golf courses in Tunis, Hammamet, Sousse, and Monastir. The wastewater effluent is treated to secondary levels, and farmers subsidized wastewater for irrigation” (Bahri 2008). So developed techniques will offer immense amounts of water available for the community and the environment, besides making irrigation water available using lower energy from saline water sources, FDFO desalination provides nutrient-rich water for fertigation (Phuntsho et al., 2011).

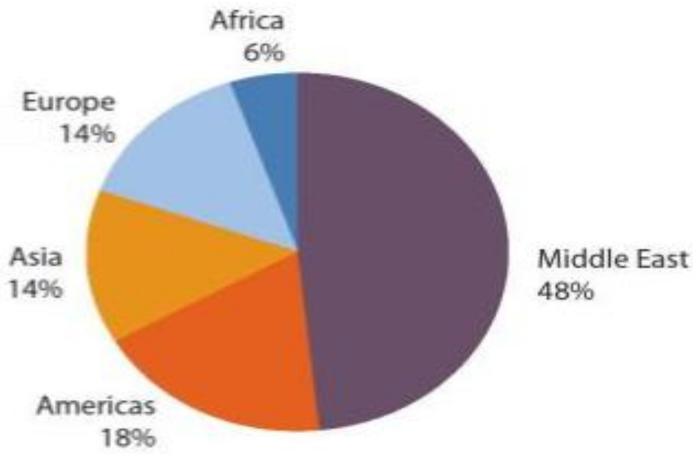

Figure 1. Distribution of worldwide desalination capacity, 2007 (World Bank 2012)

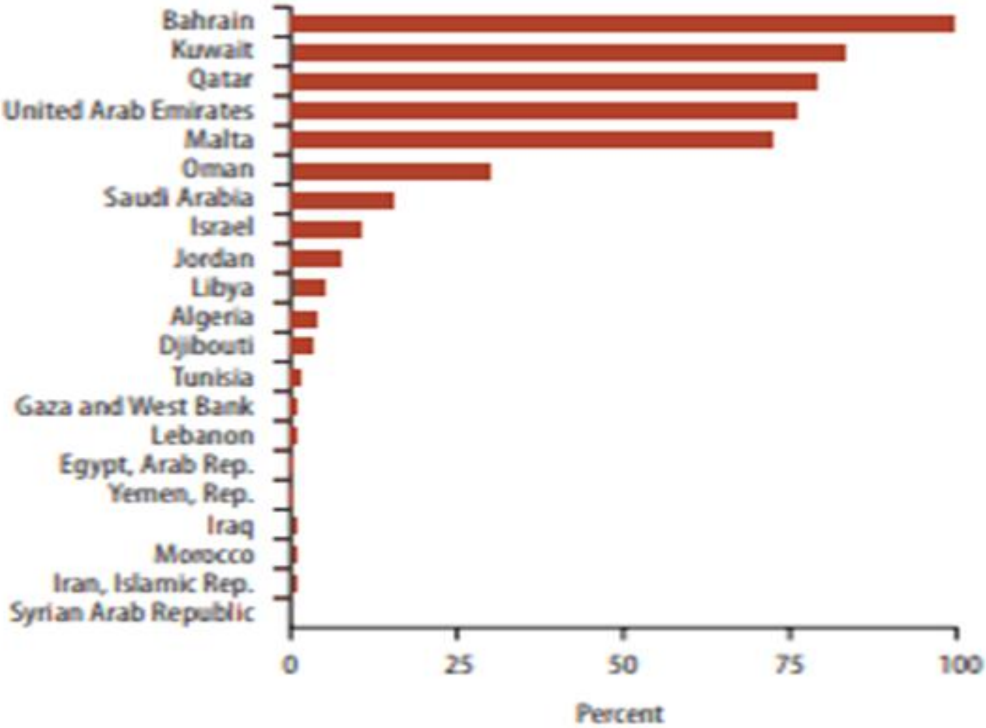

Figure2. Share of national water demand in MENA Met by Desalination, 2010 (World Bank 2012)

Table 1. Current and Future Water Demand and Unmet Demand Gap under the Average Climate Change Projection (km^3)

Country	Demand 2000–09	Demand 2020–30	Demand 2040–50	Unmet 2000–09	Unmet 2020–30	Unmet 2040–50
Algeria	6,356	8,786	12,336	0	0	3,947
Bahrain	226	321	391	195	310	383
Djibouti	28	46	84	0	0	0
Egypt, Arab Rep.	55,837	70,408	87,681	2,858	22,364	31,648
Iran, Islamic Rep.	74,537	84,113	97,107	8,988[a]	21,767	39,939
Iraq	50,160	67,235	83,803	11,001[a]	35,374	54,860
Israel	2,526	3,396	4,212	1,660	2,670	3,418
Jordan	1,113	1,528	2,276	853	1,348	2,088
Kuwait	508	867	1,216	0	313	801
Lebanon	1,202	1,525	1,869	141	472	891
Libya	4,125	4,974	5,982	0	1,382	3,650
Malta	45	62	75	0	22	36
Morocco	15,739	19,357	24,223	2,092	9,110	15,414
Oman	763	1,091	1,709	0	24	1,143
Qatar	325	381	395	83	209	246
Saudi Arabia	20,439	22,674	26,633	9,467	14,412	20,208
Syrian Arab Republic	15,311	17,836	21,337	323	3,262	7,111
Tunisia	2,472	3,295	4,452	0	0	837
United Arab Emirates	3,370	3,495	3,389	3,036	3,243	3,189
West Bank and Gaza	460	680	1,022	308	591	925
Yemen, Rep.	5,560	7,069	12,889	1,120	2,573	8,449
MENA	261,099	319,138	393,082	42,125	119,443	199,183

Source: Adapted from Future Water 2011. a. Current unmet demand gaps for Iraq and the Islamic Republic of Iran are estimated, respectively, at 11 km^3 and 9 km^3. Intuitively, these gaps look unrealistic for countries that normally have positive national level water balance. These gaps can be explained by the sustained drought experienced in the two countries in the last decade. Similarly, the current demand gap of zero for Djibouti, Kuwait, Libya, and Malta—especially the figure of zero demand gap for Djibouti until 2050—can be explained by (a) the generalized national water balance approach used in the hydrological analysis and (b) the extremely poor and unreliable data quality for some of the countries. For example, for Djibouti, although, in reality, the country suffers from chronic water shortage, every database, including FAO's AQUASTAT (2009) shows the opposite (https://mafiadoc.com/renewable-energy-desalination-inship_5c13dd7c097c47ab078b57).

In Egypt, the National Company for Protected Cultures is establishing 100 thousand greenhouses, including five thousand greenhouses as the first phase in the areas of El-Hammam, Abu Sultan and the Tenth of Ramadan and the village of Hope in Sinai east of Ismailia. The project aims to expand the cultivation of various strategic crops, vegetables, fruit, and others and rationalize the use of available water resources and maximize the return on investment by applying modern scientific methods. The use of greenhouses for some crops is achieved by rationalizing the use of irrigation water for open crops by 50% in the regular greenhouses with a threefold increase in productivity, while high-tech greenhouses achieve 90% irrigation water, with an increase in productivity equivalent to six times the productivity in the same area of open crops, as well as working to increase the supply of different vegetable varieties in the market for citizens at appropriate prices throughout the year. In continuous, Fig 3 show solar-powered greenhouse at a school in Dakhla Oasis, Egypt.

Figure 3. Solar-powered greenhouse at a school in Dakhla Oasis, Egypt (Source: https://www.elbalad.news/3655122)

Furthermore, Egypt is aimed to build the largest seawater desalination plant in the world in the Red Sea city of Ain Sokha.Upon completion, the plant will be able to purify 164,000 cubic meters of seawater per day, and will provide water to development projects in the Suez Canal Economic Zone (Anonymous 2017).

6 ENVIRONMENTAL IMPACTS OF DESALINATION PROCESS

Although the several benefits of the desalination process, concerns rise over potential negative impacts on the environment. Dawoud and Mulla (2012) showed that Main issues are the concentrate and chemical discharges to the marine environment, the emissions of air pollutants and the energy required for the processes. To achieve sustainable and safe use of desalination technology, the study of the environmental impacts of desalination projects should be investigated by revising the environmental impact assessment (EIA) of the project and the location. The benefits and impacts of different water supply options must be balanced across regional management plans. In this respect, Word Bank (2012) identified the environmental impacts of desalination process in the incidence of atmospheric pollution, marine pollution, and brine disposal options that could be reduced by means of applying the proper measures. Batisha (2007) showed that economic evaluation of water desalination is assumed by analysis of numerous input parametersrs (seawater, brackish groundwater and agriculture wastewater) depends on Egyptian experience in technology, field features, energy and materials. International Journal of Environment and Sustainability ISSN:1927-9566Vol. 1,No. 3, pp. 22-37

7 CONCLUSIONS

The integration of solar water desalination systems in greenhouses to overcome water shortages in some areas like Egypt is, therefore, one of the preferred technologies in crop-growing areas. In some MENA countries, desalinated water is used to irrigate the citrus, olive trees, vineyards, fodder crops, industrial crops, cereals and golf courses. In Egypt, there is a huge project for the agricultural in greenhouses aims to expand the cultivation of vegetables, fruits and other and rationalize the use of available water resources through the application of modern technology. Besids, the environmental impact assessment of desalination is of importance

8 STRATEGIC ADVICE FOR FUTURE

It should be noted that each country had a cost-effective adaptation strategy based on its water resources, current levels of utilization and efficiency, as well as the material feasibility of alternative technologies to reduce the water gap. Many decision-makers have options, and nine options have been identified that can be classified into three major operational areas (World Bank 2012) .

Water productivity could be increased by the following methods, i.e.; firstly, improvement of agricultural procedures and selection of appropriate crop species and varieties, expansion of water reuse of household and industrial uses and increasing reuse of water in irrigated agriculture. Secondly, expand width thought; expand tank capacity (small scale), expansion of tank capacity (large scale), desalination of water by fossil fuels, and desalination of water through renewable energy. Thirdly demand reduction by reduce irrigated areas, reduce domestic and industrial demand for water supply. The implementation of computer-assisted desalination can improve aquaponics systems, increase nutrient concentration, and ensure optimal nutrient conditions for fish. Experimental parameters for growing both lettuce and tilapia are used with weather data for the system (Goddek et al. 2016).

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