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Water production for irrigation and drinking needs in remote arid communities using closed-system greenhouse: A review

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ABSTRACT

Water needs for agriculture, food production and drinking are considered one of the most critical challenges facing the world in the present days. This is due mainly to the scarcity and lack of fresh water resources, and the increasing ground water salinity. Most of these countries have a high solar energy potential. This potential can be best developed by solar desalination concepts and methods specifically suited for rural water supply, irrigation. In this paper, a humidification–dehumidification (HD) water desalination system with several technologies for irrigation and drinking needs in remote arid areas is introduced from technical and economic point of views. This study has investigated (1) detailed discussion of technical developments, economical and sustainable aspects; (2) benefits of the new design over traditional applications, desalination and other irrigation methods; (3) specific requirements and implementation challenges in remote and cold regions; (4) performance and reliability improvement possible techniques. Recommended researches and projects leading to high efficiency, economical and sustainable applications of some desalination devices driven by solar energy are highlighted.

1. Introduction

About 20 percent of the world's people live in regions that don't have enough water for their needs (according to the World Health Organization), With the global population increasing by 80 million each year, a third of the planet will likely face water shortages by 2025. This looming water crisis is inextricably linked to food production because agriculture accounts for 70 percent of all fresh water used, and obtaining irrigation water in arid regions by classical methods has serious environmental impacts. Drilling wells can deplete ground water, and desalination is energy-intensive and leaves behind concentrated brine. The goal of sustainable agriculture in arid and semi arid regions is challenged as farm management needs to address the needs of crops under often difficult conditions. Plants growing in the more arid areas confront a number of stresses causing factors including drought, high temperatures, high winds, low humidity, high radiation, dust and salinity. These factors become realistic both as direct physiological stresses in the plants and indirectly, via alterations to the physical environment. To overcome these difficulties, the use of greenhouses can provide a proper environment to plant growth. There are more than 50 countries now in the world where cultivation of crops is undertaken on a commercial scale under cover. In hot climates, however, the greenhouse inside temperature can reach so high value that prevents its utilization or, otherwise, a costly mechanical air conditioning system should be used [1].

The agriculture inside greenhouses assisted by a humidification dehumidification desalination system produces crops year-round in hot, dry areas using salt water and sunlight. cucumbers, tomatoes, peppers, lettuce, strawberries, herbs-anything that can be grown in traditional greenhouses-can be grown in GHHD. The award-winning technology was inspired by the natural water cycle where salt water heated by the sun evaporates, cools to form clouds, and returns to earth as precipitation. The system involves pumping salt water (or allowing it to gravitate if below sea level) to an arid location and then subjecting it to two processes: first, it is used to humidify and cool the air, and second, it is evaporated by solar heating and distilled to produce fresh water. Finally, the remaining humidified air is expelled from the greenhouse and used

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to improve growing conditions for outdoor plants. This enables the year round cultivation of high value crops that would otherwise be difficult or impossible to grow in hot, arid regions. Fig. 1 shows the basic GHHD model cycle within a controlled environment [2].

Inside the greenhouse The plants do not expose to salt. So whilst it is interesting to understand how salt hampers the growth of plants in a GHHD. The water used in the greenhouse is distilled from salt water by processes in the greenhouse and the result is that the plants get distilled water, no salt at all [3].

A few literature have been published in GHHD such as [4–6]. The technical and economical review of the GHHD system with different methods for irrigation and drinking needs in remote arid areas from technical and economic point of views studied. A several technology's applicability of solar desalination systems is also reviewed. The main objective of this work is to analysis the influence of humidification–dehumidification technology related parameters on fresh water production and the growth of crops in a greenhouse system.

2. GHHD benefits over traditional greenhouse and other irrigation methods

The GHHD systems are designed to create an environment that is cool, humid and bright, a reverse of the warming effect of typical cold climate greenhouses. It is for use in desert climates adjacent to saline water. None of the methods currently used to supply irrigation water in arid regions, including over-abstraction from ground reserves, diverting water from other regions and energy-intensive desalination, are sustainable in the long term. Traditional greenhouses and other irrigation methods the GHHD as a whole sounds great, and has a several benefits as follows:

1. **Dry air treatment**; facing the prevailing the entire dry air from humidifier catch salt water and evaporates it. It increasing of the humidity inside the GHHD reduces water use and creates a cold and humid environment in the planting area.
2. **Airborne contaminants**; the saline water humidifiers are effective at removing or reducing airborne contaminants, including salt spray, dust, pests, pollen and insects [7].
3. **Fresh water production**; the fresh water produced is pure and distilled from salt water, without chemical additives or treatment.
4. **Renewable energy utilization**; the GHHD considered by developing small stand-alone desalination plants that can utilize renewable.

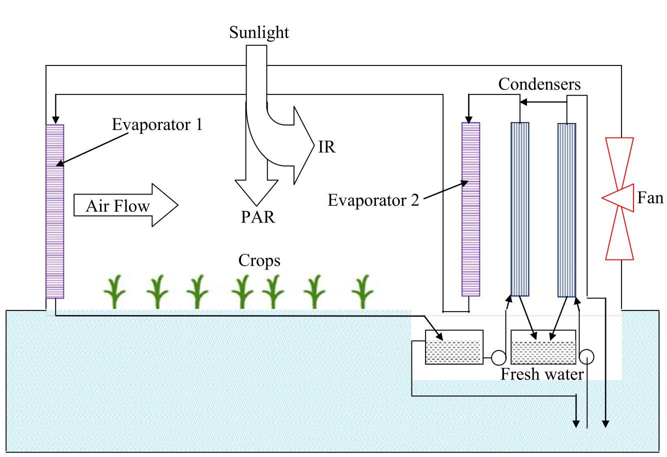

Fig. 1. Section through GHHD (figure is used with permission from [2]).

5. **Fossil-fuel requirements**; unlike traditional greenhouses, which often rely on gas or other fossil fuels for temperature control and CO_2 enrichment, GHHD use saline water and sunlight to control the growing environments, with low grade electrical power to feed pumps and fans.
6. **Water saving**; water collection and reduces water shortage in dry periods.
7. **Pesticide need**; the salt water humidifiers have a biocidal and a scrubbing effect on the ventilation airflow. This greatly reduces or eliminates the need for pesticides [8].
8. **Economics effectiveness**; commercial grade crop yields are coupled with significantly lower capital and operating costs result in enhanced operator economics [7].

Currently there are some 200,000 ha of conventional greenhouses in the Mediterranean region. Most of these, if not all, face water quality and availability issues and indeed many contribute to the depletion of ground water. By using greenhouses to create fresh water from salt water, the problem is reversed [7].

3. Specific requirements and implementation challenges of GHHD in remote regions

A GHHD produces crops in hot, dry areas using mainly salt water and sunlight. So, the main specific requirements are energy and water. The next section will discuss briefly these requirements in remote regions.

3.1. Energy requirements

In GHHD the thermal solar energy converts salt water to water vapor. The electrical requirements for fans are modest and, in the absence of grid power, can be provided by photovoltaic panels without the need for batteries, inverter or standby generator. Table 1 shows the performance of GHHD in terms of fresh water production and the power consumption of the fans and pumps per cubic meter of fresh water.

3.2. Water requirements

The GHHD system requires only a supply of salt water (seawater or brackish water) and discharges salt water into the sea or other reservoir. It is therefore intended for use near the coast or ground water wells. Table 2 shows the general water and environmental requirements for some crops.

3.3. Implementation challenges

That the provision of the necessary requirements for the GHHD is not enough to run it in the arid remote regions, but must also overcome some of the implementation challenges such as:

1. The process operation is not stable. The ventilation fans must change as the weather shifts and the wind blows in from different directions. These fans also always be powered. The

Table 1
Performance of GHHD for three climate conditions [9].

Climate conditions	Fresh water produced, m^3/year-ha	Power consumed, kWh/m^3
Temperate	20,370	1.9
Tropical	11,574	1.6
Oasis	23,529	2.3