A Comprehensive Study of Greenhouse for Agriculture and Water Desalination for Jordan Valley and Red-Dead Sea Region

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Abstract

Jordan is characterized by an arid to semi-arid climate and its population increases at a high growth rate. The water demand in Jordan is steeply increasing, and the gap between water supply and demand is getting wider. The annual rainfall on Jordan ranges from 50 to 600 mm. Desalination of Red Sea water might be technically and economically viable to cope with water scarcity and overcome the water deficit in Jordan. Also, Jordan is relatively poor in conventional energy resources and is basically a non-oil producing country, i.e. its energy supply relies to a very large extent on imports. It is therefore unlikely that any future energy scenario for Jordan will not include a significant proportion of its energy to come from renewable sources such as solar energy.

The Dead Sea is drying up, with severe negative consequences on the ecosystem, industry and wildlife in the area. There have been several proposals for a canal to transport Red Sea water to the Dead Sea. The present study aims to shed some light on the technical and economic feasibility of using the greenhouse concept to create a suitable environment for growing valuable crops and produce fresh water in the region covered by the Red Sea and Dead Sea. The Red Sea-Dead Sea project can produce power and desalinated water is being currently considered as a viable project. The salty Red sea water is to be pumped to a higher elevation and allowed to drop by gravity a net potential head of over 400 meters to generate hydroelectric power. Part of the power produced will be used for seawater desalination for agricultural crop growing in the project area which extends over 300 km along the project route. The area covered by the project is characterized by dry and hot climate with virtually no fresh water sources. Considering the huge amounts of sea water transferred from the Red to the Dead seas the potential of sea water desalination alongside the project area with solar energy becomes obvious.

Keywords: Greenhouse, Water Desalination, Red-Dead Seas Conduit

Introduction and background

Jordan is an arid to semi-arid country with land area of 92000 km^2 located to the east of the Jordan River. Jordan's topographic features are variable. A mountainous range runs from the north to the south of the country. To the east of the mountain ranges, ground slopes gently to form the eastern deserts, to the west ground slopes steeply towards the Jordan Rift valley. The Jordan valley extends from lake Tiberias in the north, at ground elevation of -220 m, to the Red Sea at Aqaba. At 120 km south of lake Tiberias lies the Dead Sea with water level at approximately -405m. Due to the variable topographic features of Jordan, the distribution of rainfall varies considerably with location. Rainfall intensities vary from 600 mm in the north west to less than 200 mm in the eastern and southern deserts, which form about 91% of the surface area. The average total quantity of rainfall which falls on Jordan is approximately 7200 MCM/year, and it varies between 6000 and 11500 MCM/year. Approximately 85% of the rainfall evaporates back to the atmosphere, the rest flows in rivers and wadis as flood flows and recharges groundwater.

Summer maximum temperatures average 32 °C for the highlands and 38 °C for the Jordan Valley and the eastern deserts. Winter maximum temperatures average 14 - 17 °C in the highlands and the desert areas, and 21 °C in the Jordan Valley. Winter's minimum temperatures average is 1-4 °C in the highlands and desert area with occasional snowfalls on the highlands, while it rarely falls below 8 °C in the Jordan Valley. Jordan's population is growing rapidly at about 3.5%. In 1997, the population of Jordan was approximately 4.6 million. The settlement pattern is heavily influenced by water availability.

Jordan is known to be one of the most water scarce countries in the world, where water shortage has become of permanent nature and meeting water demands is a challenge. Jordan has reached its water crisis; present water use already exceeds the renewable freshwater resources by more than 20%. After the year 2006, freshwater resources will be fully utilized and there remain no more known resources within the country to develop.

Jordan’s Renewable freshwater resources are estimated to about 850 million m^3/year, consisting primarily of surface and ground water. Options for non-conventional water resources that can be mobilized are modest where nearly all of Jordan’s renewable water resources have been developed and most citizens in Amman receive water only once a week. The options for augmenting water supply are limited; some additional rainwater can be harvested and some brackish water can be pumped from sandstone aquifers. The per capita share of renewable water resources is among the lowest in the world, and is declining with time. It is projected to fall from 140 /capita/year at present to 90 m^3/capita/year by 2025.

Jordan's water resources comprise surface water, renewable and non-renewable groundwater and treated wastewater, which are used by agriculture (69%), industry (10%) and municipalities (21%), e.g. [1]. With the exception of springs and the King Abdullah Canal, surface water resources are exclusively used for irrigation. The municipal water supply and industry mainly depend upon groundwater and springs, which are limited and often over-drafted. The adoption of non-conventional sources (e.g. desalination) for water supply reinforcement is inevitable in the near future for Jordan's sustainable development. For instance, desalination has been widely and successfully used in Middle Eastern oil-producing countries [2]. Although water and energy resources are scarce in Jordan, desalination of seawater from the Red Sea might be economically feasible by efficient use of non-conventional energy resources [3-6]. Hydropower and solar technologies are the most effective non-conventional energy resources for water desalination.

The utilization of income energy sources is very attractive because they are nondepletable sources of energy and they are relatively pollution free, which is a very important consideration. Solar energy can be considered as the most abundant continuing source of energy available to the human race. While solar energy is not being used as a primary source of fuel energy at the present time, a large research and development effort is underway to develop economical systems to harness solar energy and make it a major source of fuel energy. The two principal disadvantages are associated with the fact that it is very dilute and that it is not constant for terrestrial applications.

The price of oil is increasing and the energy bill is very expensive for Jordan. As it is known, Jordan is imported oil from neighboring countries and this oil costs too much. Currently, a local study on renewable energy reported that solar technologies are potentially suitable for wide scale applications in Jordan. These results show that Jordan need to begin to rely more on solar energy in order to reduce the dependence on imported expensive sources of energy. The energy demand, in Jordan, was doubled during the last 20 years, and expected to continue at the same rate. Hence, all recent energy forecast scenarios showed that the national consumption might double between 2015 and 2020. Due to increasing oil prices, the financial aspect of this problem has increased and its resultant outcomes are clearly observable these days in Jordan.

Oil and natural gas is used to desalinate water from sea- water in multi-effect evaporators and a large quantity of heat is required to vaporize the water. It is also common in some places to use electric power to run reverse osmosis units for water desalination and this method requires electric power to generate high pressure to force the water component of seawater through a membrane. Both methods consume large amounts of energy and require high skill operation. Due to the fossil fuel based energy consumption in both methods, CO2 emission will always be an issue of environmental concern. However, also there are many places where energy is too expensive to run such type of desalination processes. Sometimes fresh water is required at locations far from the energy grid-lines, requiring a local source of energy. Water shortage occurs most at places of high solar radiation. It is usually peaks during the hot summer months of maximum solar radiation. Hence, solar desalination could be one of the most successful applications of solar energy in most of the hot climate countries having limited resources of fresh water, e.g. [7].

The Red Sea-Dead Sea canal will feed water to Dead Sea in addition to produce power and desalinated water to the region covered by the Red Sea-Dead Sea area. Solar energy can be used to make a suitable environment for growing valuable crops and fresh water production by desalination. The outcome of this work will revolutionize both water desalination and agricultural crop cultivation in the area targeted by the Red Sea-Dead Sea project. A greenhouse represents a controlled environment crop-growing space where temperature, light, humidity, soil, and other conditions essential for plant growth (i.e., CO_2 fertilization) can be controlled. The planned 180km conduit, consisting of tunnel and canal sections, would carry1.8 billion m^3/year of seawater to associated power / RO desalination projects and provide 850 million m^3/year of fresh water to Jordan, Israel and Palestine.

Current Water Situation in Jordan

In common with most countries in the Middle East, Jordan is experiencing a severe water shortage which will only get worse. Furthermore, Jordan is considered to be one of the 10 poorest countries worldwide in water resources, and has a population growth rate of about 2.9%, the 9th highest in the world. The available renewable water resources are dropping drastically to an annual per capita share of 160 m^3 in recent years, compared to 3600 m^3/capita in 1946. Factors prompting such a decrease include, aside from the most prominent one of steep population growth, sudden influx of refugees due to political instability in the region. Competition between demands on limited fresh water quantities is ever increasing (National Water Master Plan. 2004). The expanding population and the climatic and topographical conditions of the country have caused enormous pressure on the limited water resources and created a severe water supply-demand imbalance where the deficit is about 220 MCM/year. Despite the huge investment in the water sector, a considerable water deficit will still be facing Jordan. This deficit will double by 2025 even if all unconventional water sources are used. At present there is said to be some availability of additional surface water, but most renewable groundwater reserves are fully exploited.

Predictions are that by 2025 water supplied will exceed available renewable resources by 33%. The result is that there is increasing focus on unconventional sources such as wastewater re-use and the improvement of demand management. The former brings a whole new set of variables into scenarios since legislation at present is poorly geared to innovations. It also creates a new interdependence between water availability, consumption and demand management within agricultural, domestic and industrial water supply which needs to be explored. The later would suggest the provision of initiatives to increase availability and productivity of water.

Water resources consist primarily of surface and ground water resources, with treated wastewater being used on an increasing scale for irrigation, mostly in the Jordan Valley. Renewable water resources estimated at about 750 million cubic meters (MCM) per year, include ground water at 277 MCM/year and surface water at 692 MCM/year of which only 70% is of economic use. An additional 143 MCM/year is estimated to be available from fossil aquifers. Brackish aquifers are not yet fully explored but at least 50 MCM/year is expected to be accessible for urban uses after desalination.

In order to carefully plan for the future, Jordan has adopted a National Water Strategy. The strategy is a comprehensive set of guidelines employing a dual approach of demand management and supply management. It places particular emphasis on the need for improved resource management, stressing the sustainability of present and future uses. Government policy objectives currently include developing and optimizing the use of available natural and agricultural resources, hence increasing farmers' income and consequently improving their standard of living accordingly. Typical water related problems in Jordan include the inefficient management of national water resources; subsidized water to end users; poor aquifer and surface water quality; inefficient irrigation networks, illegal water use; and inefficient use of irrigation water, e.g. [8].

The water strategy stresses on the need to tap the full potential of surface and ground water to a feasible extent, the marginal quality and brackish water support irrigated agriculture, seawater desalination produce additional water for municipal, industrial and commercial consumption. The strategy also ensures that wastewater is collected and treated to standards that allow its reuse in unrestricted agriculture and other non-domestic purposes, including groundwater recharge. Resource management aims at achieving the highest possible efficiency in the distribution, application and use of water. Previously developed resources must be sustainably used with special attention to the protection against pollution, quality degradation and depletion. The government adopts a dual approach of demand management and supply management. Priority in water resources allocation is given to the basic human needs; as such first priority is given to allocation of a modest share of 100 litres/capita/day to domestic water supplies, followed by tourism and industrial purposes, e.g. [9]. The Red Sea-Dead Sea canal has several goals such as producing power by exploiting the gradient between the Red Sea and the Dead Sea, which is 400 meters below sea level; a source of water for desalination facilities in Jordan; and saving the Dead Sea, which is suffering from a severe fall in its water level, due to diversions of the Jordan River. The project has many opponents, headed by environmental organizations that claim that canal will damage the environment and utterly destroy the Dead Sea by allowing an inflow of water from the Red Sea, which has a different chemical composition

Energy Policy in Jordan

Energy is one of the most important factors in wealth generation, economic growth and social development in all countries. Based on historical data, one can observe that there is a strong relationship between the development of economic activities and the availability of energy resources, i.e. energy is of vital importance all over the world for production and manufacturing processes, and as such is a key element in the sustainable development of countries. This also applies to Jordan, especially with the clearly observable attempts of the present government to lead the country into increased economic growth. It is clear that the government’s plan requires consideration of the increased energy demands of the country and the undertaking of research and development efforts towards solutions of current problems.

The energy demand in Jordan has doubled during the last 20 years, and is expected to continue at the same rate, or even higher. Hence all recent energy forecast scenarios have shown that national energy consumption might double between 2015 and 2020 (MEMR [10,11], NEPCO [12], CEGCO [13], Badran and Abid [14], Jaber et al [15-17]). Such a rapid increasing demand is due to the high growth rate of the population and the expansion of economical activities in various fields. The estimated investment for increasing the capacity of the energy supply by 2015 is about US$ 2.5 billion, or even more depending on actual capacities and prices in the international market (MEMR [10]). This high financial demand is considered to be the most important limiting factor in increased economic development owing to scarce financial resources considering the serious prevailing national problems, such as poverty and unemployment. However, also triggered by high oil prices, the government is undertaking new measures to improve the situation in the energy sector by formulating and implementing an adjustment plan (Al-Rai Newspaper [18]).

Jordan is relatively poor in conventional resources and is basically a non-oil-producing country, i.e. its energy supply relies to a very large extent on imports. There are small reserves of traditional fossil fuels, its indigenous natural gas supplies satisfying less than 4% of the present national annual primary fuel demand (NEPCO [12], MEMR [10,11], Badran and Abid [14], Jaber et al.15-17]). The country produces about 30 million cubic feet per day of natural gas, which fuels 4 x 30 MW gas turbine plants (NEPCO [12], CEGCO [13]). Also, the hydroelectric potential is low at 24 MW, of which 20 MW are produced close to the Syrian border.

The demand for primary energy in Jordan in 1999 was 4.8 million tons of oil equivalents (toe), showing a 3% annual growth and with clearly observable further increases during the years to come. The primary energy consumption that was required for electricity generation in 2000 was equivalent to 1.8 million toe compared with 1.75 million toe during the previous year (MEMR [11], NEPCO [12], CEGCO [13]). The average energy consumption per inhabitant in 1999 was 970 kg oil equivalent, already providing at that time large burden on the annual energy requirements for the population. Due to increasing oil prices, the financial aspect of this problem has increased and the resultant outcomes of it are now clearly observable in Jordan.

It is predicted that electricity generation of Jordan will be around 12500 and 15000 GWh in 2010 and 2015, respectively [MEMR, NEPCO]. At the end of 2001, the installed capacity was 1660 MW, of which two-thirds are provided by conventional steam turbines. In 2001, Jordan produced 284 x 10^3 toe from its local primary energy resources, but consumed 5.15 million toe. It is clear from the country's present and future developments that the difference between local production and consumption is increasing from year on year (MEMR [10], Jaber et al. [17]). In 1995, the annual imported-oil bill was approximately US$ 4.75 x 10^8 (representing ~10% of Jordan's GDP). Without the exploitation of indigenous oil shale, the input it will probably be around US$ 1.15 x 10^9 per annum by 2010, when the annual rate of fuel consumption in Jordan will have approximately doubled; the exact value will depending on the prevailing international unit crude-oil prices {Jaber et al. [18]).

All the above-mentioned attempts to ensure Jordan's energy supply do not eliminate the need to search for new energy sources in the country. Jordan has a rapid population growth, 3.6% per annum (MEMR [10], Jaber et al.[17]), and lies in the heart of Middle East, which is politically fragile. As already mentioned, Jordan is poor in terms of natural resources, including energy, compared with neighboring Arab countries.

In recognition of the country's needs, the government has acknowledged, in its final energy master plan, the need to improve energy efficiency in all sectors and to reduce the energy intensity in the GDP (MEMR [11]). Energy intensity, which is measured as toe per US$1000 of GDP at current prices and exchange rates, was approximately 0.58 during the last 4 years, i.e. 1998-2001 (Jaber et al. [17]). The relatively high energy intensity over the last 20 years is mainly due to the expansion of the infrastructure and energy- intensive industries, such as phosphate and potash mining and fertilizer and cement production. However, there were also huge developments in the commercial and services sectors, which consume significant amounts of energy. Nevertheless, the country needs this growth of its industries. The economy of Jordan could grow even more with proper utilization of its indigenous energy resources.

Solar Energy in Jordan

One of the most important energy sources in our economy is still oil, which is not renewable considering our lifetime. Hrayshat and Al-Soud [19] pointed out that the share of solar energy in the total energy mix in Jordan is estimated to be around 1.7% during the year 2002. They also showed that the expected share of solar energy in the total energy mix in the year 2007 is estimated to be around 2.1%. During the Renewable Energy International Conference which was held in Bonn, Germany during 1-4 June 2004, Jordanian authority has been committed to have 5% of its total energy requirements from renewable energy resources for the next coming 5 years, e.g. 2010. In fact, Jordan is blessed with huge amounts of renewable energy resources, particularly solar energiy [20,21]. In order to reduce dependence on the imported oil, Jordan has pursued programs for promoting solar energy involving systematic monitoring and assessment of technological developments combined with the implementation of appropriate technologies, demonstrations and pilot projects [22–26]. The current tendency in Jordan is to use in future various solar energy applications in the over all mix of energy in Jordan, as well as identifying potential areas for utilizing future technologies and recommending future courses of action to encourage the commercial utilization of solar energy technologies.

The duration of solar radiation and its energy that reaches the ground are becoming important spatial data. Solar radiation research is significant not only for meteorologists but also for foresters, agronomists, geographers and others. Solar energy, on the other hand, is almost unlimited and it is considered to be the energy of the future. The sun is also the main energy source of the life on the earth and it enables photosynthesis. Solar radiation affects all physical, chemical and biological processes in the terrestrial ecosystem. The sun provides a natural influence on the earth's atmosphere and climate. Many aspects of solar radiation were researched in the last few years. Daily solar radiation is a common input in crop growth and development models yet given the sparse coverage, e.g. [27]. Solar radiation is one parameter used in crop growth models, being a driving force for biomass production. The impact of solar radiation on plant development has been investigated for a long time. Insolation, through its influence on the energy and water balance at the earth's surface, affects such processes as air and soil heating, evapotranspiration, photosynthesis, winds, and snow melt, e.g. [28-30].

Solar radiation energy depends mostly on incidence angle, which is defined by astronomical and surface parameters. Solar radiation is the major energy source on earth and solar energy can play an important role in meeting the ultimate goal of replacing fossil fuels. Currently, a local study on renewable energy reported that solar technologies are potentially suitable for wide scale applications in Jordan. These results show that Jordan need to begin to rely more on solar energy in order to reduce the dependence on imported expensive sources of energy. Therefore, we recommend that government activities on solar energy should be increased to get benefits from the large number of sunny days during the year and the large value of global solar radiation as was shown in the results. Referring to the models and measurements on radiation as well as to the variation in the topography and climatology of Jordan, the country is divided into five regions [31–33].

- The southern region (29–30.5˚N, 35–38˚E): In this region, the annual daily average values of global irradiance are between 6 and 7 kWh/m^2 day.
- The eastern region (30.5–32.5˚N, 36.5–39˚E): In this region, the annual daily average values for global of about 5.0.
- The middle region (30.5–32˚N, 35.5–36.5˚E): In this region, the global irradiance is about 4.5 kWh/m^2 day in this region.
- The northern region (32–33˚N, 35.5–36.5˚E): In this region the annual daily average value of global irradiance is about 5.5 kWh/m^2 day.
- The western region (30.5–33˚N, 35–35.5˚E): In this region, the annual daily average values of global irradiance are between 4.5 and 5 kWh/m^2 day.

In general, the abundance of solar energy in Jordan is evident from the annual daily average of global solar irradiance, which ranges between 5 and 7 kWh/m^2 day on horizontal surfaces. This corresponds to a total annual value of 1600–2300 kWh/m^2 year. The measurements data that including horizontal solar irradiance and sunshine duration of solar irradiance for Jordan has been taken. Al-Salaymeh [34] predicated global solar radiation data on a horizontal surface for Jordan as shown in Fig. (1). The mean value of energy of quasiglobal radiation for Jordan is larger than 5300 kW.hr/m^2.day. It is also obvious from Figure (1) that Jordan receives the most solar energy in June and July (mean value 7995 kW.hr/m^2 in June and 7875 kW.hr/m^2 in July) and the least in December (mean value 2676 kW.hr/m^2).

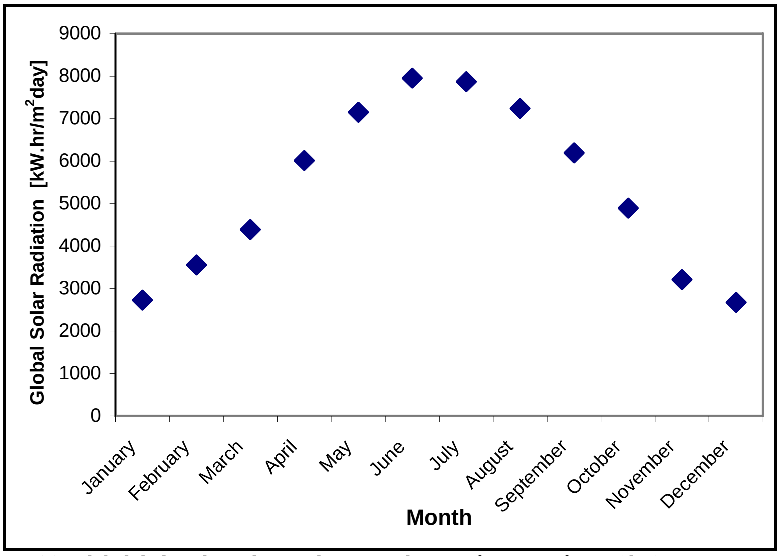

Fig. (1): Global daily solar radiation data in Jordan as a function of time (day).

Sunshine hour is a widely-available climatic variable measured at many meteorological stations. Figure (2) shows the Meteorological data for Sunshine duration in Jordan. It is clear from Figure (2) that the maximum value of sunshine duration in Amman occurs in June and July (mean value is 11.86 hr for June and 12.05 hr for July) and the least in December (mean value 5.14 hr).

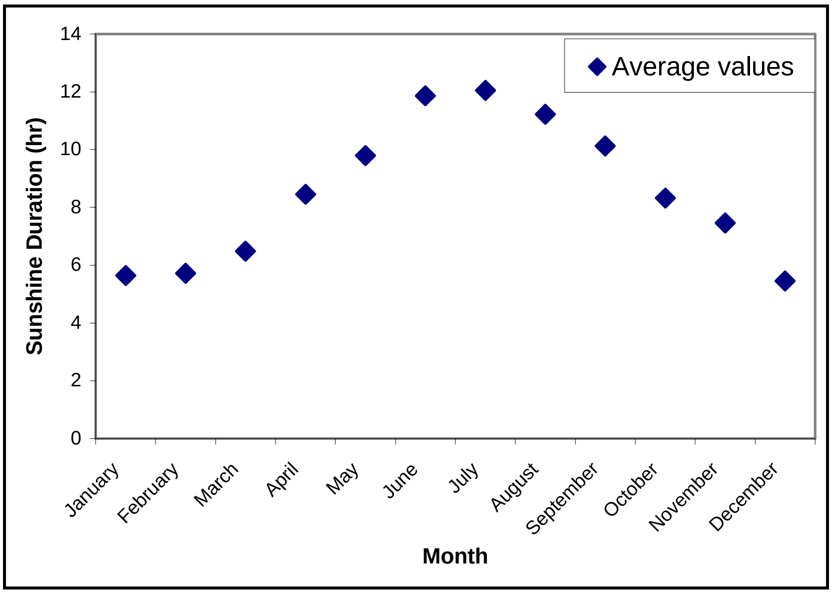

Fig. (2): Measured average values of sunshine duration (SH) in Jordan as a function of months.

Dead Sea Problem

The Dead Sea which is 400 meters below sea level, and considered in the basement of the world is drying up. The level of the Dead Sea has declined from -395 m below sea level to -410 m in the last 50 years causing damages to the entire eco-system of the Dead Sea basin. The inflow to Dead sea has decreased from 1300 million m^3/year in the year 1930 to approximately 300 million m^3/year in the year 2000.

The water of the Dead sea has the highest salt and mineral content 27% of all seas with especially high concentrations of Magnesium, Calcium with their anti allergic effects, Bromide with relaxing effect and of Bitumen which makes the skin more photosensitive and also has an anti inflatory effect. The Dead Sea water is much saltier than ocean water, containing about 25 parts per 100 as opposed to 6 parts per 100 by weight. As a result, a swimmer is extremely buoyant. Finding it impossible to submerge himself. Visitors to the Dead Sea come away with an unforgettable swimming experience, as the high density of the water makes sinking virtually impossible. Indeed, swimming is also difficult, as one is lifted too high in the water to be able to stroke properly.

The Dead Sea is 1.49 km^2 in area, 76 km long, and about 6-16 km wide. Its depth ranges from a maximum of 339 m in the north to less than 3 m in the south. It is fed by the Jordan River, but it has no outlet. Some of that water has been diverted for irrigation, reducing the flow into the lake and lowering its level. A tongue of land now cuts off the southern quarter of the lake, which is fed water through an artificial channel and consists almost entirely of evaporation ponds.

As its name suggests, the Dead Sea is entirely devoid of plant and animal life. This is due to an extremely high content of salt and other minerals: 350 grams of salt per kilogram of water, as compared to about 40 grams in the world's oceans. This concentration is caused by a rapid rate of evaporation; about 1,400 mm annually. Its density keeps swimmers afloat. Only simple organisms can live in its saline waters. These natural elements give the water of the Dead Sea certain curative properties, recognized since the days of Herod the Great over 2000 years ago.

The area is hot and dry, with annual rainfall of only about 50 mm. The Dead Sea today is an important and rich source of minerals essential for agriculture and industrial development, as well as for the treatment of various medical conditions such as psoriasis. Temperatures in the rift valley averages 30°C in summer, but not less than 10 °C in winter. Atmospheric pressure at the Dead Sea reaches the highest levels anywhere on the planet. The air here is, equally, the driest and purest on earth, and contains the highest amount of oxygen (10 percent more oxygen than at sea level). The Dead Sea is known for it's unique climatic conditions: the area has 330 sunny days a year, there is less 50mm annual rainfall, and low humidity with dry air constantly high temperatures are known to soothe the symptoms of asthma, cystic fibrosis and certain lung diseases.

Benefits from Dead Sea bathing are attributed to a natural tar in the water, and also to high levels of minerals that may affect how the rate of skin cell growth. Dead Sea therapy proof to be of value in treating a number of dermatological, rheumatologic and pulmonary diseases, especially psoriasis, a topic dermatitis. Now, thousands of people seek relief at the Dead Sea for psoriases and other conditions. Hydrotherapy is a general term for a group of alternative treatments that use water for the relief of various diseases or injuries, or for cleansing the digestive tract. Many physicians and physical therapists recommend water therapy or water massage for rehabilitative therapy. The Arthritis Foundation is one such credible source and had found that the warmth, massage effect, and buoyancy, needed to both relax and exercise joints and muscles in the convenience of one's home is available in home whirlpool baths or spas.

Red Sea-Dead Sea Conduit

The Dead Sea is drying up, with severe negative consequences on the ecosystem, industry and wildlife in the area. There have been several proposals for a canal to transport Red Sea water to the Dead Sea. Current rate of decline is about 1 m/ year. Decline is caused primarily by diversion of historical water supply to address the fresh water demand of the riparian parties in water-scarce region. Fig (3) shows a comparison between the surface area of the Dead sea at the beginning of the century and at 1997. The importance of protecting the Dead Sea will lead to an opportunity for sustainable development such as huge tourism potential, unique medical and health resources and mineral products. Brings additional water to the Dead Sea will prevent the environmental damage and to restore the sea's level. Also, the project can help to meet the fresh water needs of Jordan, Palestine and regional countries. The conduit or water conveyance system will provide sufficient water from Red Sea to Dead Sea.

The Red Sea-Dead Sea Conduit is a water conveyance system designed to bring water from the Red Sea to Dead Sea. This project provides perhaps the only means to preserve the Dead Sea. In addition, the Conduit can enhance the overall supply of drinking water in this parched region by supplying feed water for sustainable seawater desalination at the Dead Sea. Renewable hydro-static energy rather than fossil fuels will be used to power the desalination plants.

Sufficient quantities of water can be returned to the Dead Sea in order to preserve or restore it to historical levels. This can serve to improve the overall environmental profile of the Dead Sea, protect cultural heritage and prevent further social marginalization of this region through job creation the facilitation of economic enterprises.

The Red Sea-Dead Sea project proposed long time ago to produce power and desalinated water is being currently considered as a viable project. The salty Red sea water is to be pumped to a higher elevation and allowed to drop by gravity a net potential head of over 410 meters to generate hydroelectric power. Part of the power produced will be used for seawater desalination for agricultural crop growing in the project area which extends over 300 km along the project route. The area covered by the project is characterized by dry and hot climate with virtually no fresh water sources. Considering the huge amounts of sea water transferred from the Red to the Dead seas the potential of sea water desalination alongside the project area becomes obvious. The feasibility of using a novel desalination technology termed the "green house desalination" has been studied by Paton and Davis [35]; Sablani et al. [36]. It consists of a green house equipped with humidification dehumidification devices to create the cooling and at the same time produce fresh water. Thus, the green house serves as an autonomous small scale desalination plant while creating the suitable environment to grow valuable crops. The hot and dry air entering the green house is humidified using sea water and thus evaporatively cooled and then heated inside green house by the energy absorbed through its envelope or released by the plants. This results in increasing the moisture absorption capacity of the air which absorbs the vapor generated by the plants evapotranspiration and that lost by the soil. The now saturated air exiting the green house is cooled below the dew point temperature at the condenser located at the exit of the green house to produce fresh water.

The idea of connecting the Dead Sea to the Mediterranean goes back to the 19th century, when engineers suggested the possibility of using the natural elevation difference between the two seas to produce hydroelectric energy. Then after one century an industrial engineering group from Chicago (Harza) introduced this canal and made an estimation to the whole project. The Harza plan is based on two principles: the location of the Dead Sea which is 400 m below the level of the Red Seas, and the canal project would take advantage of the natural drop to restore the lake to its normal level. The harza design consists of power generation and water pumping stations on the path that passes throw the Jordanian land from Aqaba to the Dead Sea, where the water desalination depends on the reveres osmosis. This process involves pressure being applied by an electric pump to the seawater which forces only water molecules through a membrane. The water may have to be passed through many membranes depending on the salinity of the water.

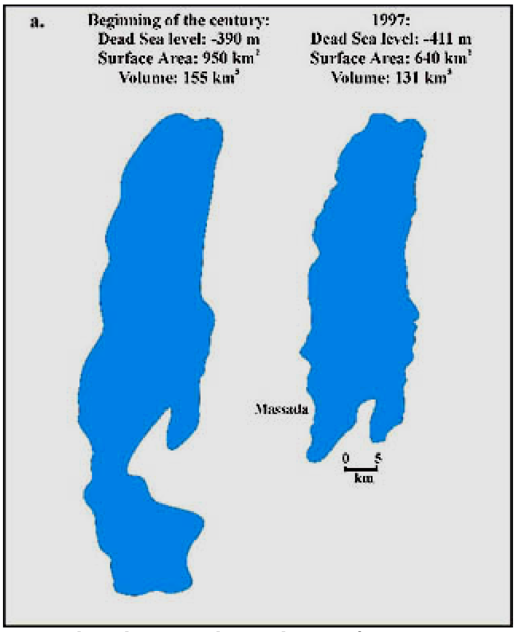

Fig. 3: The reduction in the Dead Sea surface area

Desalination of 800 to 850 MCM with 20 to 300 mg/l TDS, annually can be produced. The basic principle of hydropower is that if water can be piped from a certain level to a lower level, then the resulting water pressure can be used to do work on mechanical component which can be used to derive electrical generators.

The conduit can protect the Dead Sea and it has regional and global impacts such as: preservation of the historical and environmental values of the region, introducing a solution to regional water problems, economics such as tourism and industry. Also, it will exploit a unique renewable energy source (400 m drop to generate hydro-power energy). Energy will create new source of fresh water: Desalination plants will produce up to 850 MCM/year fresh water to meet future water needs in Jordan and other regional countries. Desalinated drinking water will be conveyed to Jordan via pipelines. Up to 1900 MCM /year feed sea water and 45% of the sea water will be recovered as fresh water, i.e. 850 MCM/year. Also, an additional electricity of 550 MW is required for pumping.

The required seawater supply capacity to produce 800 MCMY is about 2,000 MCMY. However the design refers to a 2,700 MCMY capacity, to enable the Dead Sea level to reach its target in about 15 years and to make the most effective use of the available hydrostatic energy. The cost saving of the desalinated water supply refers to the alternative production cost at coast-sited conventional desalination plants and the differential transmission cost to final consumers.

According to preliminary estimates, the initial investment in the Red Sea-Dead Sea Conduit comes to $800 million. This sum refers only to the component of conveying water from the Red Sea to Dead Sea. Desalination and additional water works can be financed by the private sector or through public/private sector partnerships. The construction cost around $5 billion and annual operational cost around $5 million. The economic benefit to tourism would amount to $320 million. The value of income from energy production for the first 18 years would be $80 million. The dilution of the Dead Sea water mass with sea water may cause losses for Arab Potash Company. The saltwater may leak to the groundwater contamination. The save of the external sources of energy in these projects is around 22% only taking into account the pumping of the desalinated water to Jordan and Palestine, e.g. [37-39].

Water Desalination Integrated with Solar Energy

The inhabited agricultural productive area of the country does not exceed 6% of its total area, and borders the Badia to the east, and the Jordan Valley to the west. Arid-agriculture in both regions is possible only through irrigation. The environment of the country is fragile, and the protection against desertification requires sustainability of agriculture. The Government notes that while 70% of water is allocated to the agricultural sector, the outputs of agriculture do not exceed 4% percent of annual GDP. The recognition that some crops are not only water inefficient, but also economically unstable, is a key lesson learned for Jordan, however, it is difficult to change attitudes given the socio-economic context of the sector.

Solar desalination has recently emerged as a promising renewable energy powered technology for producing fresh water. Due to the large energy consumption in the major commercial desalination processes, along with the growing concern about CO_2 emission, there is a strong interest in alternate sources of energy to run desalination units, and in particular renewable energy sources. In countries with abundant solar energy, solar desalination could be one of the most successful applications of solar energy. Solar stills developed as desalination units have inherently a major problem of energy loss in the form of latent heat of condensation of water.

Significant quantities of high-quality desalinated water can be produced for urban and agricultural use. Using low-quality irrigation water in agriculture reduces crop yield and damage soils and aquifer. Major desalination processes consume a large amount of energy. A major improvement in solar still is possible through the multiple use of the latent heat of condensation in the still. In case of using fossil fuel as the source of energy, the emission problem arises, because of emitting harmful CO_2. Water shortage occurs most at places of high solar radiation, which peaks during the hot summer months, e.g. [40-43].

Solar powered desalination has recently emerged as a promising renewable energy for producing fresh water. The cost of installations to improve the process increases the cost. Desalination process is justified because of the following reasons: water requirement for crops have a diurnal and seasonal fluctuation which is similar to the productivity variation of solar powered desalination systems, the system can be built as an integrated part of the greenhouse envelop.

This cost seems to be very low when compared with the reported costs for recently completed desalination projects. It should, however, be recognized that the reported $1/m^3 cost range was derived for relatively small plants (5-10 MCMY) and much higher commercial discount rates (8-10%). More advanced technology, economy of scale and soft financing substantially reduce the desalinated water cost. The lower desalinated water costs resulted from the very reduced energy requirements and the lower investment costs of the hydrostatic RO plants and solar energy, when compared with the conventional coast-sited desalination plants.

Conclusions

The Dead Sea is a severely disturbed ecosystem, greatly damaged by anthropogenic intervention in its water balance. During the 20th century, the Dead Sea level dropped by more than 25 meters, and presently it is at about 416 meters below mean sea level. This negative water balance is mainly due to the diversion of water from the catchment area of the lake by neighboring countries. The concept of the Inter-Seas Project is based on the exploitation of some 400 metre difference in height between sea-level and the Dead Sea for the desalination of the water and the production of hydroelectric power. The inflow of seawater into the Dead Sea will have a major impact on its limnology, geochemistry and biology. The issue will lead to

- Saving the Dead Sea: in less than 50 years the level of the Dead Sea has declined from -395 meters below sea to -415 meters, causing damages to the entire eco-system of the Dead Sea Basin.
- Increasing rate of deterioration: 80% of this decline has occurred since the 1970's. Current rate of decline is about 1 meter per year.
- Dilemma of water demand: Decline is caused primarily by diversion of historical water supply to address the fresh water demand of the riparian parties in a water-scarce region.
- Need for joint large-scale solution: Small-scale local measures will not be sufficient to preserve the Dead Sea. International cooperation is therefore required to save the Dead Sea.

The country's annual water demand currently exceeds 1 billion m^3 and is projected to rise to over 1.3 billion m^3 by 2005, having nearly doubled since the mid-90s. Jordan's renewable water resources can supply around 750 million m^3/year, leaving an annual deficit which has grown steadily, despite the huge program of investment in the water sector. Water desalination by using solar energy is very attractive and the produced water can be used for agriculture purposes by planting the area along the conduit route. The mean value of solar energy in Jordan is larger than 5300 kW.hr/m^2.day. As expected, Jordan receives the most solar energy in June (8000 kW.hr/m^2) and the least in December (mean value = 2676 kW.hr/m^2).

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دراسة شاملة لاستخدام البيوت الشمسية في الزراعة و تحلية المياه في منطقة وادي الأردن والبحر الميت

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يتميز الأردن بمناخه الجاف أو شبه الجاف و كما إن عدد سكانه يزداد بمعدلات عالية. إن الطلب على المياه في الأردن يزداد بحدة مما ادى الى توسعة الفجوة ما بين الطلب على المياه و مصادر المياه المتوفرة. ان معدل سقوط الأمطار على الأردن يتراوح ما بين 50 -600 ملم في السنة. ان تحلية مياه البحر الأحمر ممكن أن تكون قابلة للتطبيق من الناحية التقنية و الاقتصادية و أن تتغلب على العجز المائي في الأردن. و كما أن الأردن بلد فقير في موارد الطاقة التقليدية حيث أن الأردن دولة غير نفطيو و كما أنه يستورد احتياجاته من الطاقة من الخارج. لذلك فانه من غير المرغوب أن يكون اي مخطط مستقبلي للطاقة في الأردن لا يحتوي على جزء مهم من الطاقة المتجددة مثل الطاقة الشمسية.

ان البحر الميت يجف مما يؤدي الى تبعات سلبية على النظام البيئي و الصناعة و الحياة البرية في المنطقة لقد كانت هناك عدة اقتراحات لانشاء قناة توصل البحر الأحمر في البحر الميت. إن هذه الدراسة تهدف الى تسليط الضوء على الجدوى الاقتصادية و التقنية لاستخدام البيوت الزجاجية لخلق بيئة مناسبة لتنمية المحاصيل الزراعية و لتحلية المياه في المنطقة المحيطة في البحر الأحمر و البحر الميت. ان مشروع قناة البحر الأحمر و البحر الميت(قناة البحرين) ممكن ان ينتج طاقة كهربائية بالاضافة الى امكانية تحلية مياه البحر. ان مياه البحر الأحمر المالحة سيتم ضخها لارتفاع معين قبل السماح لها بالجريان بتأثير الجاذبية الأرضية مولدة طاقة كهربائية نتيجة

وجود طاقة الوضع بحدود 400 م. إن جزء من الطاقة سوف يستخدم لتحلية المياه للأغراض الزراعية في منطقة القناة التي تمتد 300 كم على طول مجرى القناة. إن المساحة المغطاة بالمشروع تتميز بمناخها الحار و الجاف و بافتقارها الى مصادر للمياه العذبة وبالنظر الى كمية المياه الهائلة التي سيتم نقلها من البحر الأحمر الى البحر الميت فان إمكانية تحلية المياه على جانبي القناة باستخدام الطاقة الشمسية سيكون واضحا.