POTENTIAL OF DESALINATING BRACKISH GROUNDWATER IN GAZA STRIP BY THE UTILIZATION OF A HYBRID ALTERNATIVE ENERGY SYSTEM

Imad A. Khatib

Palestine Polytechnic University, PO Box 198, Hebron, Palestinian National Authority
Telephone: +972-2-2228912, Facsimile: +972-2-2228912, email: imadk@ppu.edu

Abstract

Water for domestic use in Gaza Strip is facing a severe shortage in the coming few years. With a steady population growth of 3.5% in a highly populated area, and an extensive pollution of the available costal brackish groundwater resulted from the intrusion of seawater and untreated wastewater into the aquifer, the scarcity of water may affect all aspects of life in a region already shattered by a serious political conflict. Creative solutions should be introduced to ameliorate the serious situation and to meet the increasing public demand on water. Desalination is considered as a possible solution however, the cost of conventional energy required is high and that certainly will adversely affect the feasibility of desalination. The proposed method is the utilization of a hybrid alternative energy system in a membrane desalination system for the desalination of the brackish groundwater.

Key words: *Gaza Strip, Direct Contact Membrane Desalination, Solar Energy, Thermal Collector, PV cells and Modules, Hybrid Energy System*

1. Introduction

The Gaza Strip forms part of the coastal foreshore plan bordering the Hebron Mountains in north-east, Negev desert in the south-east and Sinai desert in the south. The topography of the area varies from 0 m at the coast to around 100 m ABS, comprises of five Kurkar[1] ridges gradually sloping eastwards, underlying by a series of geological formation form the Tertiary to the Quaternary periods. The five ridges vary from sand dunes in the coastal belt extending over a 40 km length, loessial sandy to loess soil in the eastern part of the Strip and alluvial soil in the north-eastern part.

The climate of the Gaza Strip forms a transitional zone between semi-humid zone coastal zone of Israel in the North, the semi-arid loess plains of northern Negev desert in the east, and the arid Sinai desert of Egypt. The average daily temperature is 25 °C in summer and 13 °C in winter, and varies between 29

[1] Composed of a kind of porous sand stone

– 17 °C in summer and 21 – 9 in winter. Relative humidity varies between a minimum value of 60% to a maximum 80% in both summer and winter. The average daily solar radiation recorded in Gaza Strip is more than 600 W/m^2. Solar radiation is available around more than 300 days around the year. The annual rainfall in Gaza Strip amounts to about 400mm. It varies widely from one year to another between 200 to 900 mm. High rainfall in the northern part of the Strip and decreases towards the south falling mostly between mid October to the end of March.

The population of Gaza Strip accounts for 1,178,199 (July 2001 est.), with an annual growth rate of 4.1 percent, in addition to around 6,900 Jewish Settlers (2000 est.) controlling more than 20 percent of the Strip's total area of 360 m^2. It is obvious that the population in Gaza Strip is much more urban, averaging more that 2,000 persons per km^2, however if we consider the Israeli controlled areas (settlements), this number shall exceed 3,000 inhabitants per km^2, which is the highest in the World. The large majority of the population living in either cities or refugee camps distributed along the Strip. The refugee camps alone are populated with more than 60% of the population. Sustainable development issues is Gaza Strip is so critical especially for a place where the annual per capita GDP ranges between US$610 and US$2,400, which is about 16% of that of the Israelis.

Agriculture is of vital importance in Gaza Strip, accounting for about 30 percent of both Gross Domestic Product (GDP) and employment, with about 50 percent of Palestinian people benefiting directly from agricultural returns. Agriculture is characterized by intensive irrigated agriculture (60 percent of the agricultural land), which is practiced by both Jewish Settlers and by some Palestinian farmers and rainfed agriculture, which makes up 40 percent of the agricultural land. The Strip is experiencing intensive discharge of ground water and use of fertilizers, pesticides, and other chemicals and non-degradable materials such as plastics. Definitely, all these practices contribute to the pollution of Palestinian natural resources including surface and ground water.

2. Availability and quality of water in Gaza Strip

Water scarcity has played a very large part in the Arab-Israeli conflict especially in the occupied West Bank and Gaza Strip. In Gaza Strip, part of the scarcity is the result of the inequitable distribution of water. In 1967 Israel declared all water resources to be state owned and controlled by the military. In Gaza Strip the Palestinian water consumption was regulated by strict quotas, while Jewish settlers had no restrictions on water consumption, rather, their consumption is subsidized, encouraging overuse and misuse (*Isaac 1997*). They have also been favored through selective appropriation of agricultural land having the best groundwater quantity and quality, and uneven pricing schemes. Palestinian population in Gaza Strip consumes annually 80 MCM for both irrigation and domestic uses whereas the few thousands of the Jewish settlers consume 20 MCM for the same purposes. These consumptions can be interpreted per capita per annum, which is less than 70 m^3/capita/annum for Palestinians inhabitants, compared to 290 m^3/capita/annum for Jewish settlers, i.e. 1:4. In addition, Palestinians pay up to $1.20/cubic meter while Israeli settlers pay only $0.10/cubic meter for water. Elmusa (1994) states that "relative to per capita income, Palestinians pay as much as twenty times what Israeli settlers pay for water." The problem is not the only demand induced scarcity. Population growth of more than 4 percent which makes per capita water availability decreased dramatically with time to an extent where drinking water might exceed safe supply levels in the very near future. The increase of population resulted in coastal aquifer over-pumping for some time, out-striping its sustainable supply of 65 MCM. Moreover, Israel has been tapping this aquifer and its replenishment from outside Gaza Strip (*Shawa 1994*). Consequently, the aquifer's water table has been pumped far below its recharge rate, making it susceptible to severe saltwater intrusion and causing supply-induced scarcity (*Isaac 1997*). The Over-pumping of the coastal aquifer draws approximately 15-20 centimeters from its original level of 3-5 meters above sea level. As the water table falls, saltwater from the Mediterranean and nearby saline aquifers introduces itself into the Gaza aquifer. The intrusion of the Mediterranean Saltwater has been detected in some cases up to more than 1 kilometer inland, and continues to threaten the salinization of the entire aquifer. In many parts, the water is so saline that it may damage soil and crop yields, and hence is unsuitable for irrigation. In land cultivated with citrus, which is considered the main agricultural product of Gaza Strip, the intrusion of the salt water caused a decline in the quality of the crop yield.

Salinity of groundwater is not the only drinking water quality problem. The decades of unregulated use of pesticides, herbicides, and fertilizers have chemically contaminated Gaza's groundwater (*Bellisari 1994*). The Palestinian National Authority has in 2000 drafted the National Strategy and Action Plan in which the authority sets plans for regulating the use of the pesticides and other materials banning these which known to have any chemical contamination. However, since the aquifer is close to the surface, it is highly sensible to this type of pollution.

The quality of coastal groundwater is also contaminated by the improper disposal of waste matter, mainly sewage. This problem arose from the improper infrastructure serving the populated areas of Gaza Strip. It is estimated that more than 10 percent of the population in the Strip are not connected to any type of wastewater management system, and thus dumps raw sewage onto sand dunes. Another large percentage of population uses poorly maintained septic tanks and soaking pits frequently overflow into streets and homes. All refugee camps have solid waste collection.

These various contaminations of the Gaza water supply have drastically decreased the amount of potable water available. These effects obviously pose serious health hazards for the people of Gaza who suffer high incidence of kidney and liver complaints, high infant mortality, cancer, waterborne infectious diseases such as cholera, and intestinal parasites.

The problem of the quality and availability of water in Gaza necessitate policy makers to introduce strategic actions that take into account the treatment of bad quality water, including brackish water, and the reuse of treated water for both domestic and irrigation usages. The potential of wastewater treatment and reuse for agricultural purposes is the most promising solution. However, for providing alternative drinking water resources, desalination of brackish and seawater seems to be one of the most acceptable solutions not only for Gaza Strip but also for other areas in the region.

3. Desalination option and the availability of needed energies

Desalination of saline water is becoming worldwide an acceptable alternative to conventional water resources as natural water resources are depleted and the need for diversification of national income increases. Desalination has been, therefore, experienced improvements and advancements in the technology and usage. In the Arab region, desalination has been promoted as an important alternative especially in the Arabian Gulf region. There, the availability of conventional energy sources, petroleum, in low prices has reduced significantly the cost of desalination that utilizes energy in both thermal and electrical forms. Reduction in the cost of desalinating saline water is also owed to the technological efforts that were concentrated on reducing the capital and the O&M. This has been resulted in increasing the desalination plant life span considerably.

As desalination technologies require a considerable amount of energy, this was considered a problem especially for areas where energy produced from conventional resources is expensive. Considering Gaza Strip aforementioned geopolitical and socio-economical situation, desalination based on the energy status means a non feasible solution considering the situation governing the energy sector, especially electricity production. Through the last three decades, some 95% of the Palestinian electricity was imported from the Israeli Regional Electricity Company. After Oslo agreement between Israel and the Palestine Liberation Organization (PLO), the Palestinian National Authority (PNA) was established. PNA recognized the fact that energy plays a dominant role in the process of development and construction, and as a backbone for the Palestinian economy as a whole. The PNA has, in cooperation of concerned donors, drafted feasibility studies for building a generating power plant in Gaza with a total capacity of 220 MW run by private sector together with another project which was planned for a 220 kV transmission system interconnecting Palestine regionally with the neighboring countries in an electric pool. The studied highlighted the need for extra energy to be utilized to solve in finding alternative drinking water resources, i.e. desalination option. The first phase of the proposed project was scheduled to start production by mid 2000 with 110 MW to cover the demand of Gaza Strip. However, due to the eruption of the Al-Aqsa Intifada and the following measures taking by Israeli occupation forces, major developments related to the project have witnessed a major setback. In Table 1 below, patterns of consumptions over 1994-1998 period is presented and the record for the period 2000-date should have increased by a factor of 1.3. The cost of the 1 kWh is US$ 0.11 which is considered high in the region.

Table 1: Consumption and Demand in the Gaza Strip
(Source: *Palestinian Energy Authority, 2000*)

Year	Consumption (GWh)	Maximum Demand (MW)	Load Factor (%)
1995	487	94	59.1
1996	503	93	61.6
1997	546	103	60.8
1998	600	106	64.3

To overcome the energy problem, the PNA has suggested several options including drafting legislation encouraging the development and use of renewable energy resources, especially solar energy, in all sort of applications. As for desalination system, the availability and intensity of solar radiation together with the available state of the art design and operation of solar energy conversion systems, both thermal and direct conversion to electrical energy, may present a promising solution for providing the proper thermal and electrical energies needed to run desalination systems. The potential of utilizing solar energy is enhanced through realizing the level of average daily solar intensity that is around 19 MG/m^2.day. The Figure below represents the yearly trend of solar average daily insulation.

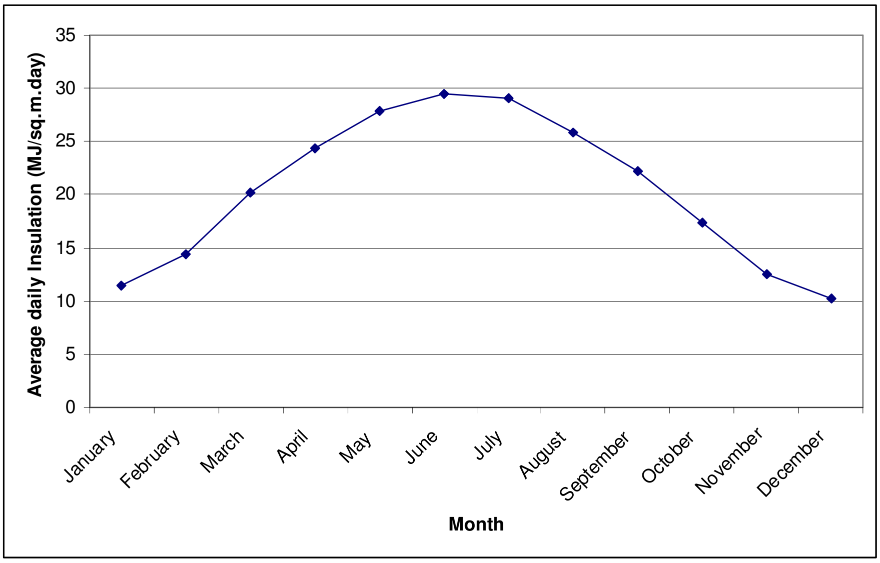

Figure 1: Average daily Insulation over Gaza
(Source: *Palestinian Ministry of Transport, Meteorological Office*)

Both Electrical and Thermal energies produced through solar energy conversion system would represent clean and feasible alternatives for the energy produced from conventional sources where thermal energy produced for desalination systems is provided using solar collectors and electrical energy is provided by utilizing proper Photovoltaic panels of direct energy conversion.

Solar thermal collectors are the oldest most advanced and most economical solar conversion systems yet developed. They invariably consist of a mechanism for capture of solar energy, its conversion to heat at a range of temperatures ranging from 30°C as the lowest to 2000°C as the maximum depending on the type of collector, the design, the concentration ratio and the material used. In Palestinian West Bank and Gaza Strip areas low and medium temperature collectors with temperature ranges 30°C – 60°C and 80°C – 150°C respectively are produced locally and available with feasible prices. They are used mainly for domestic uses, as it the case with low temperature collectors, as well as for some industrial applications where medium temperature collectors of evacuated tubes are used. Evacuated tubes collectors, may be the optimal solution for desalination technology. These types of collectors could be improved by utilizing selective surfaces for the thermal conversion that should increase their efficiency to above 60 percent for temperature differences greater than 70°C to 120°C which is the temperature range needed for the desalination system. Depending on the material and the design used, prices for a 1m^2 collector panel will be in the range \$70 - \$150 which is certainly feasible for such application in such location.

Electrical energy could be directly produced through the utilization of Photovoltaic (PV) cells. These cells are made from a variety of semiconducting materials. The advancement in PV cells production techniques has lead to conversion efficiency ranging from 18%-28% and subsequent low production cost. PV modules have been installed in different Palestinian locations to serve remotely located communities that are not yet connected to the grid system. Several international funding agencies such as the Global Environmental Facilities (GEF), the European Communities (EC) and others have funded programs and small and medium scale projects in which PV arrays have been installed.

The prices of PV cells and modules have experienced a substantial decrease worldwide since the year 1984. According to a report presented by the US DOE, only US shipment of PV cells and modules increased from 9912 kWp in 1984 to reach 50562 kWp in 1998, an increase of more than 500%. Today's average cell prices in the US are less than U$1.6/Wp to U$2.3/Wp and module average prices are U$3.0/Wp to U$3.5/Wp. In Palestinian areas, prices range from approximately $8/Wp - $14/Wp depending on the size of module and whether they are bought in bulk, and for complete functionality, PV modules require various components such as charge controllers, inverters, batteries and safety disconnects. These components add a further estimated $1/Wp - $3/Wp to the price depending on the size of the installation. The prices and O&M of these systems are feasible and could be employed safely to produced the required electrical energy for operating water pumps needed in any desalination system.

4. The Proposed Desalination Plant for Gaza Strip

The proposed desalination system that may be produced locally and used for desalinating brackish water based on the direct contact membrane desalination DCMD technology that has high potential for drinking water production for both small and medium scale applications in addition to being suitable for rural areas where energy power lines are not available and/or the prices of energy produced from conventional energy resources are considerably high, as it is the case in several areas in Gaza Strip, and where potential of renewable energy such as solar energy is considered high. In DCMD technology utilizes a membrane distillation process in which both liquid feed and liquid permeate are kept in contact with the hydrophobic microporous membrane. The temperature difference between the two solutions gives rise to a trans-membrane vapor pressure difference that drives the flux. Due to their hydrophobicity the liquid can not penetrate into membrane pores, but the vapor can pass the pores due to the vapor pressure difference. The desalination is performed at ambient pressure and maximum temperature of 90°C, which can be attained using a medium temperature thermal solar collector of evacuated tube.

Cheng et al. (1981, 1983), Schofield et al. (1991) and Schneider (1998) have suggested methods of increasing the DCMD system performance and reducing their costs through the use of composite membrane. DCMD utilizing alternative energy sources, such as solar or wind energy sources have been proposed by other researchers. In a paper presented by Wenten et al. (2000), the use of hybrid solar and wind energy system was proposed that eliminate the problem of the unavailability of conventional energy supply both thermal and electrical.

The hybrid alternative energy system proposed to be used in Gaza Strip is a solar collector of evacuated tube type for producing the required thermal energy and a Photovoltaic panel for producing the required electrical energy required to operate the pumps. In addition to the hybrid energy system, a membrane module complete with shell and tube heat exchanger is also introduced. All components are arranged as in **Figure 2** below.

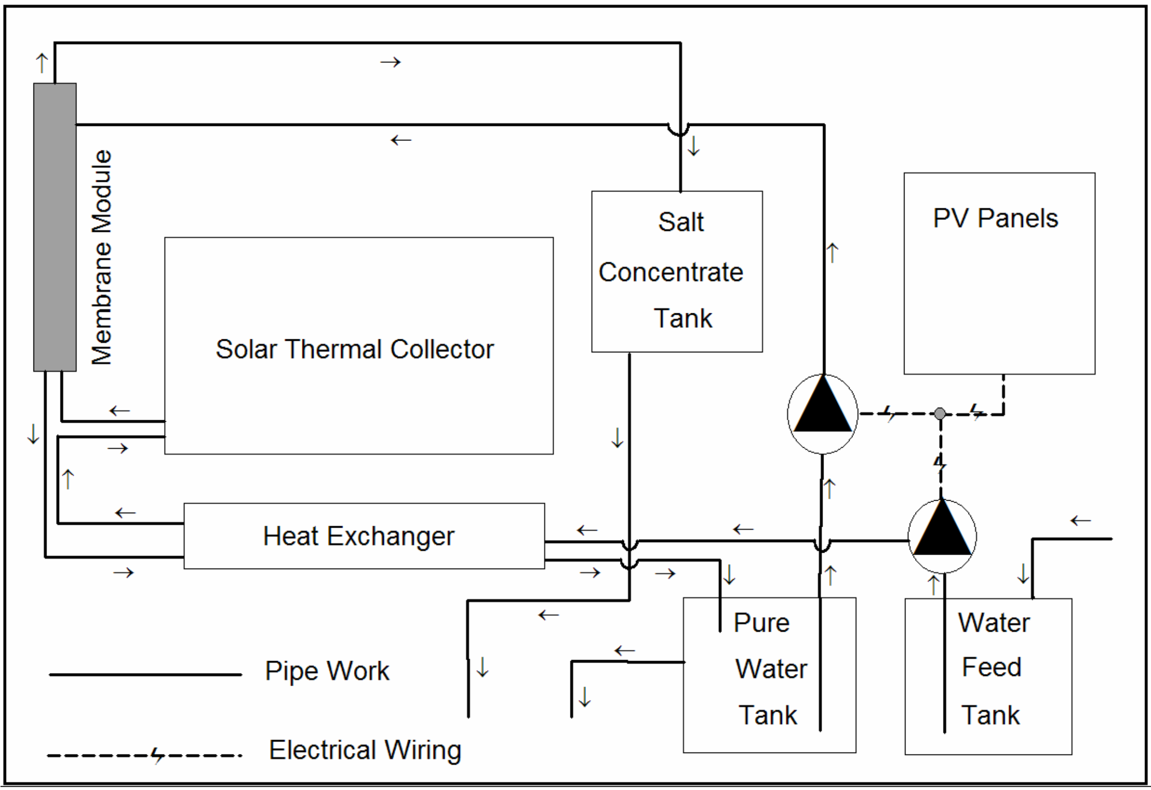

Figure 2: Proposed Direct Contact Membrane Desalination System (Based on Wenten et al. 2000)

The water in the water feed tank is sent to the system using an electric pump powered by a PV panel. The water feed is heated in heat exchanger using warm water from permeate outlet to increase its temperature. Furthermore, the water feed is further heated in solar collector in order to increase the feed temperature before entering the membrane module. From the solar collector, the liquid feed is flowed to the membrane module in lumen side. In the other side, pure water as permeate fluid is circulated through shell side of the membrane module. Because of the difference in vapor pressure between liquid and permeate which are separated by a porous hydrophobic membrane, vapor evaporating from the feed is transported through the pores of the membrane and condensed in the permeate side. In the case of brackish water the component evaporated is mainly water. The experience gained by running experiments on a prototype system by Wenten et al. (2000) showed some promising results. Applying the proposed system in Gaza Strip for small and medium size for desalinating the brackish water may present a feasible technical an economical solution for an area where a drop of drinking water might not be found in the future.

5. Future Work

The paper intended to shed lights on a regional important issue trying to propose a relatively non-expensive local technology by integrating alternative energy system in one efficient hybrid system that could supply the required energies for desalinating brackish water in Gaza Strip rural areas. Future work will concentrate on producing a prototype system with all its components and testing it in real operating conditions.

References

Bellisari, Anna (1994) "*Public Health and the Water Crisis in the Occupied Palestinian Territories*," Journal of Palestine Studies 23, no.2.

Berck, P. and Lipow, J. 1993. "*Water and an Israeli-Palestinian Peace Settlement*," Eurames Conference, Warwick University, England.

Bulloch, John, and Adel Darwish. 1993. "*Water Wars: Coming Conflicts in the Middle East*," London: Victor Gollancz.

Cheng, Y., and Hills, L.A. (1981) "*Method and Apparatus for Distillation*," US Patent No.4,265,713.

Cheng, Y. and Hills, L.A. (1983) "*Apparatus and Method for Thermal Membrane Distillation*," US Patent No.4,419,187

Elmusa, Sharif (1994) "*The Israeli-Palestinian Water Dispute Can be Resolved*," Palestine-Israel Journal, No. 3.

Isaac, Jad (1997) "*A Sober Approach to the Water Crisis in the Middle East*," Applied Research Institute -Jerusalem.

Schneider, K., Holz, W. and Wollbeck (1988) "*Membranes and Modules for Trans membrane Distillation*," Journal of Membrane Science 39, pp. 25-42.

Schofield, R., Fane, A. and Fell, C. "*Heat and Mass Transfer in Membrane Distillation*," Journal of Membrane Science 33, pp. 299-313

Shawa, Isam R. (1994) "*Water Situation in the Gaza Strip*," Water and Peace in the Middle East, ed. Isaac & Shuval. Amsterdam: Elsevier.

Shqueir, Adnan. 1995. "*The Environment in the West Bank and Gaza Strip*," Palestine-Israel Journal 2, no.5.

Wenten I. and Susanto H. (2000) "*Solar Powered Direct Contact Membrane Distillation,*" Report Number 975, Institute of Technology Bandung, Indonesia.