DESALINATION TECHNOLOGY IN THE GAZA GOVERNORATES

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ABSTRACT

Fresh water demand in the Gaza Governorates became year by year so high that it can not be satisfied from the local natural resources. High attention was paid for searching and exploration of new water resources.

Many options are suggested to overcome this annoying dilemma, such as water transfer from West Bank or water importing from Egypt or Turkey. The current political and economical conditions make it so complicated in order to implement one of the said suggestions. Other alternative was planned, getting potable water from the brackish groundwater or seawater desalination.

The objective of this paper is to highlight and to present the potential of the water desalination technology application in the Gaza Governorates. This paper illustrates the water situation in the Gaza Governorates. Also, it clarifies the justifications of the desalination's necessity. The paper discusses the existing situation and the major constraints of the existing desalination plants. In addition the paper will determine the appropriate and suitable desalination technique that can be used with a good efficiency and harmonize with the various circumstances.

Key words:

Desalination technology, Water availability, Fresh water demand, Water consumption, Reverse osmoses, Multiple-stage flash distillation, Multiple-effect distillation, Dual co-generation plant.

1. INTRODUCTION

Water availability in any zone is considered as one of the main important elements, which has a great influence in the size of the national development. The situation of the natural water resources in Palestine as well as other countries of the Middle East and North Africa (MENA-region) became unbearable and affected negatively the life style of the inhabitants throughout the last decades.

The location of the Gaza Governorates close to the Saini and Negav deserts, the long years of the Israeli military occupation, highly populated area and the intensive agriculture's activities are the notable reasons that led to the different water problems: shortage, pollution and salinity. These problems forced about 1,000,000 Palestinian in the densely narrow area named Gaza Governorates to live under very difficult and primitive living conditions in the various fields of life.

The water demand in the area does not coincide with the availability of the natural resources. So, the water situation throughout the last 30 years in the area can be described as continuous shortage of water quantity year by year and substandard quality of the available water for human use as well as for many agricultural crops.

2. WATER CONSUMPTION

The Gaza Governorates depends greatly on the extracted groundwater in addition to water purchased from the Israeli Water Company (Mekorot). The yearly consumption of water is estimated to range from 110 - 130 Mm^3/year. In addition to that about 5 - 20 Mm^3/year are consumed by the Israeli; most of it is transferred behind the armistice line. Rainfall is the only renewable source of fresh water. It is estimated at an average annual volume of 126 Mm^3/year, where only about one third of it percolates to the aquifer underlies the area. The current annual water deficit regarding the irrigation and domestic return flow (about 30 Mm^3/year) is quoted of 50 - 60 Mm^3/year, *Naim* [1].

3. WATER DEMAND

3.1 Domestic and Industrial water demand

Increasing demand for domestic and industrial purposes in Gaza Governorates is caused by the following factors: Natural growth of population, improving living standard and the returnees. The Gaza's population is expected to increase to 1.150, 1.450 and 1.850 million (5% total annual population growth rate) in the years 2000, 2005 and 2010 respectively. The Industrial water demand can be considered as percentage of the domestic water use, ranged from 10 % - 15 %. A summary of the estimated domestic water demand in the Gaza Governorates during the period till 2020 is show in Table (1).

Table (1): Domestic water demand in the Gaza Governorates

Year	Population (000's)	[74 l/c.d](1) Mm^3/year	[129 l/ c.d] (2) Mm^3/year	[120 l/ c.d] (3) Mm^3/year
1996	0.963	26.01	45.3	42.20
2000	1.170	31.62	55.06	51.29
2005	1.494	40.35	70.28	65.47
2010	1.907	51.50	89.69	83.55
2015	2.433	65.73	114.47	106.64
2020	3.106	83.89	146.10	136.10

(1) Zero losses (2) Regarding present losses (3) minimum that human needs

By examining the results in table (1), it is noticed that there will be a progressive increase in domestic water demand, which leads to an increase in the problems, related to water in the Gaza Governorates.

3.2 Irrigation water demand

Regarding the rapid spread of the built up area and the limitation of the land, the cultivated area decreases gradually. In the case of irrigation system improvement, the expected irrigation water demand considers to be decreases or stay in the same rate as it is now (about 80 Mm^3/year).

4. NATURAL WATER RESOURCES AND WATER DEMAND

In the Gaza Governorates, ground water resources are scarce, over-pumped and mainly characterized by high salinity. In most of the area, chloride and/or nitrate contents exceed the WHO standards (Chloride < 250, Nitrates < 50). Also the fresh water area is diminishing continuously due to the over abstraction. The available brackish water in the Gaza Governorates is estimated at 3500 Mm^3. This is about 80% of the total resources. Table (2) summarizes fresh and brackish water potential throughout the Gaza Governorates, PWA [3]. Figures given in table (2) are based on:

1. Fresh groundwater salinity is considered < 500 ppm.
2. The groundwater quantities inside Israeli settlements were excluded.
3. Agricultural demands are not included.

Table (2): Groundwater quantities in the Gaza Governorates 1996

Governorates	Renewable (Mm^3/yr.)		Available (Mm^3)		Area (km^2)	
	Brackish	FRESH	Brackish	FRESH	Brackish	FRESH
North	1.2	10	230	400	6	40
Gaza	10.5	3.5	1040	200	70	20
Middle	8.4	0.35	780	20	56	2
Khan Younis	5.8	0.6	740	80	58	8
Rafah	5.4	2.1	690	140	53	14
Total	31.3	16.55	3530	840	243	84

Source: Adapted from Al-Jamal, PWA, 1996

5. SEAWATER DESALINATION PROSPECTS IN THE GAZA GOVERNORATES

The capacity of the Gaza Governorates' potable water facilities must be expanded in the near future in order to meet the unbearable increasing demand for qualitatively good potable water. So that, short and long term solutions are suggested. For the short-term solutions, some measures are concerned with wastewater reuse, storm water collection and water conservation. For the long-term solutions, three main options are to be discussed:

1. Desalination of brackish groundwater and / or seawater.

2. Transfer of fresh water supply from West Bank.
3. Importing fresh water from outside the Palestinian Territories.

The later option can be reliable and feasible only in cases where plenty of water exists in the neighboring countries. This option may not be sustainable due to the overall shortage of water in the MENA countries. In addition to the political stability, transfer of freshwater from West Bank to the Gaza area is an option, which needs to have abundance of good quality water.

At present there is three RO brackish water desalination plants in the Gaza Governorates. All of them consider as pilot plant. In 1993, the first one was established in Dir El-Balah City. The other two plants located at Khan Younis City. They were installed in two years ago. The plants have mostly the same technical specification and the same capacity, 60 m^3 /hr and with 60 ppm TDS. These plants were designed to operate at a recovery ratio of 75%.

The operation of the existing desalination plants is influenced by many constraints. Some of them could be summarized as follows:

1. Chemicals supply is not secured due to the Israeli closures and the frequently drop of electricity cause unlikely stops of the plant for days or weeks.
2. A large part of the water distribution system is not specified for desalinated water, so that, corrosion problems are expected.
3. The amount of produced water is not enough to satisfy all of the consumers in the area at the same time. Shift-arrangement supply is applied, which causes uncontrolled mixing of desalinated water with the brackish water. Therefore, a large percentage of the produced water is recognized as irrecoverable water from the network.

Brackish water desalination could be cheaper compared with seawater desalination, but because of environmental justifications, that can not be a reliable solution any way, where to get 80 m^3 of fresh water, about 100 m^3 should be abstracted. It means increasing of groundwater abstraction rates that leads to enlargement of the water problems in the area. On the other hand, Considering the location and the Groundwater quality, it seems that the Seawater desalination is a strategic alternative, where the Gaza Governorates have about 45 km shore along the of the Mediterranean Sea coast.

6. SUITABLE DESALINATION TECHNIQUE

There are five main processes being used in commercial desalination; they are based on two technological approaches, being distillation and membrane separation. Multiple-stage flash distillation (MSF) and multiple-effect distillation (MED) are distillation processes which are use an external supply of heating steam as the primary heat source. They are most efficiently operated as dual purpose plants in co-generation with power plants and are typically available in unit capacities of 5,000 - 20,000 m^3/day for MED and up to 60,000 m^3/day for MSF. Vapor compression (VC), also a distillation process, is available for small unit capacities, currently up to only 2,400 m^3/day. VC uses electricity as do the membrane processes, reverse osmosis (RO) and electrodialysis (ED). All three processes are operated as single purpose plants. Due to their modular structure, RO and ED can be easily adapted to any plant size and can be found in all capacity ranges, Ribeiro [4]. The selection of the most suitable of the above mentioned processes to be applied in a certain region is influenced by multiple criteria that are related to:

1. The amount of needed potable water "size of the process ".
2. The characteristics of the feed (raw) and product water.
3. The investment and the operation cost.
4. The form of energy that will be used.
5. The environmental impacts.
6. Simplicity of the process construction, maintenance and operation.

Among various techniques of seawater desalination, the most outstanding and available on the market is: the reverse osmoses, Multiple-stage flash distillation and the multiple-effect distillation.

a. MSF Process:

It based on vacuum distillation of seawater preliminary preheated to a temperature ranging between 80°C and 120°C. This distillation results from successive flashing of seawater within a series of cells. The energy consumption in this process is in heat and electric forms.

b. MED Process:

It based on vacuum evaporation of a quantity of seawater, preheated to a temperature ranging between 70°C and 100°C. This evaporation occurs over a surface of heat exchanger. The energy consumption in this process is in heat and electric forms.

c. Reverse Osmosis:

It consists of separating water and dissolved salt by means of membranes submitted under a gradient of pressure. This process works at ambient temperature. The energy consumption in this process is in electric form.

6.1 Type of plant and energy consumption

The estimated energy consumption today of the different seawater desalination processes is summarized in Table (3). The share of thermal energy used in MSF and MED processes has been recalculated and expressed as an electric energy equivalent. Generally, desalination is a high energy consuming productive process, where the energy sharing amounts to 35-60% of total production cost, Morris [5]. Therefore, the two issues, water (from desalination) and energy are inextricably mixed and must be dealt with simultaneously. Regarding the energy consumption, for new communities without electrical power and freshwater sources, but with salt water resources or where both electric power and fresh water is needed dual purpose may be an appropriate solution. Analyzing the above mentioned fact indicates that the Gaza’s desalination plant should be essentially a dual-purpose plant. From energy consumption point of view the preferable alternatives are MED and **hybrid MED/RO** processes in Combination with power plant.

Table (3): Estimated Energy Consumption by seawater Desalination Processes

Process	Exergy of Steam (kWh/m^3)	Electric Energy Consumption (kWh/m^3)	Electric Energy equivalent Consumption (kWh/m^3)
MSF	7.5 –11	2.5 - 3.5	10 - 14.5
MED	4 – 7	2	6 - 9
SWRO	-	4 - 8	4 -8
MED/ SWRO	-	-	3.2 - 3.6

Source: adapted from J. Ribeiro, 1996

The Gaza Governorates has no indigenous energy resources. So, it is profitable to look for a desalination process where the running cost represents a small weight in the specific cost of fresh water production. Dual-purpose plants are more likely to be built where both electric power and fresh water are needed in the area. In this case, the distillation processes may benefit from shared facilities and favorable energy costs.

6.2 Size Of plant required

Available data shows that the estimated domestic water consumption in the Gaza Governorates is about $45Mm^3/yr.$, including the industrial consumption (about 2 $Mm^3/yr.$) and the different losses (about 43%). So, the real domestic consumption is not more than 26 $Mm^3/yr.$ That is equivalent to 74 l/c/d.

A person needs only about 10 - 15 liters of fresh water for drinking and cooking. Considering the Gaza's population, so that 10000 - 15000 m^3/day are the water quantities that should be desalinated per day in order to cover the urgent needs for fresh water in the area. According to the above-mentioned figures, the capacity of the desalination plant should be in the range of 10000 - 15000 m^3/day, (2.64 - 3.96 MGD). In case that the desalination plant capacity has to cover the deficit in the currently domestic demand, it should be in the order of 67000 m^3/day, (17.7 MGD).

Table (4): Estimated Renewable, Demand and Deficit in the Gaza Governorates

Governorates	Renewable ($Mm^3/yr.$)		Demand ($Mm^3/yr.$)		Deficit [(1)] ($Mm^3/yr.$)	
	Fresh	Brackish	Drinking 10 *l/c/d*	Domestic 100 *l/c/d*	Drinking 10 *l/c/d*	Domestic 100 *l/c/d*
North	10	1.2	0.5	5	-	-
Gaza	3.5	10.5	1.5	15	-	11.5
Middle	0.35	8.4	0.5	5	0.15	4.65
Khan Younis	0.6	5.8	0.7	7	0.1	6.4
Rafah	2.1	5.4	0.4	4	-	1.9
Total	16.55	31.3	3.6	36	0.25	24.45

(1) Quantities to be desalinated

7. ECONOMIC EVALUATION

The factors that contribute to the 'overall' cost of produced water can be summarized in capital and running costs. Capital cost includes the plant cost and amortization that depends on the plant life and interest rates. On the other hand the running costs are subdivided into energy cost and operational cost. The energy costs are related to energy type used, the fuel price and the nature of the plant, while the operational cost includes the overhead, maintenance, labour and the used chemical costs. Specific seawater desalination cost ranges between 0.76-2.41 USD for MSF, 0.51-1.78 USD for MED and 0.64-2.54 USD for SWRO, Ribeiro [4]. Table (5) summarizes the costs of desalination for the different seawater processes. The range show the estimated lowest values, assuming an amortization interest rate of 5% and electricity prices of 0.05 USD / kWh and accordingly the highest Values based on 10% and 0.1 USD / kWh respectively. The costs are for typical plant size between 10.000 - 20.000 m3/day. The energy consumption rates show that the MED process has advantage of being cheaper than the MSF process. The MSF process could be applied at location with prevailing low energy prices.

Table (5): Total specific costs of seawater desalination

Process	Amortization USD / m^3	Energy Cost USD / m^3	Other Costs USD / m^3	Total Costs USD / m^3
MSF	0.29 - 0.86	0.38 - 1.14	0.10 - 0.44	0.77 - 2.45
MED	0.27 - 0.77	0.24 - 0.71	0.09 - 0.52	0.60 - 2.01
SWRO	0.23 - 0.68	0.20 - 0.81	0.18 - 0.64	0.61 - 2.13
MED / RO	0.25 - 0.47	0.17 - 0.47	0.18 - 0.46	0.60 - 1.28

Source: adapted from J. Ribeiro, 1996.

Obviously, an economic comparison between the main seawater desalination processes indicates that the MED/RO hybrid system is regarded as the first option if it is applied to dual-purpose plants (production of desalinated water and electricity). It follows by MED process then the SWRO Process.

8. DUAL PURPOSE (CO-GENERATION) PLANTS

It is known that there is power plant where the west heat from gas turbine may be used to generate additional electric energy through a steam turbine. Such plants are defined as combined power plant. This concept of combining the use of steam for production of both power and water is called dual-purpose generation and plants are called dual-purpose plants. The efficiency of such a plant depends on the type of power plant used, the configuration of the combined system and efficiency of both power and desalination subsystems. Figure (1) shows the principle of a dual co-generation plant. Due to economic and efficiency criteria dual-purpose plants are preferable to provide both electricity and desalinated seawater.

A measure of efficiency is the GOR (Gained Output Ratio) which expresses the amount of water produced in tones per tone of steam used. Presently a typical GOR value is 8, but values of 10 and 12 have also been reached. The UN for planning purposes for developing countries has recommended MW/MGD a power to water ratio of 8.33. This ratio is in the ranges from 8 to 20 MW/MGD in the case of applying a gas turbine station as an energy source for desalination.

8.1 Type of dual-purpose (co-generation) plants

1. Back pressure steam turbine
2. Extraction/ condensing steam turbine
3. Gas turbine with HRSG with supplementary firing.
4. Gas turbine with HRSG without supplementary firing.

In the case of the Palestinian power plant, the fourth option combined with one of the first two options is recommended.

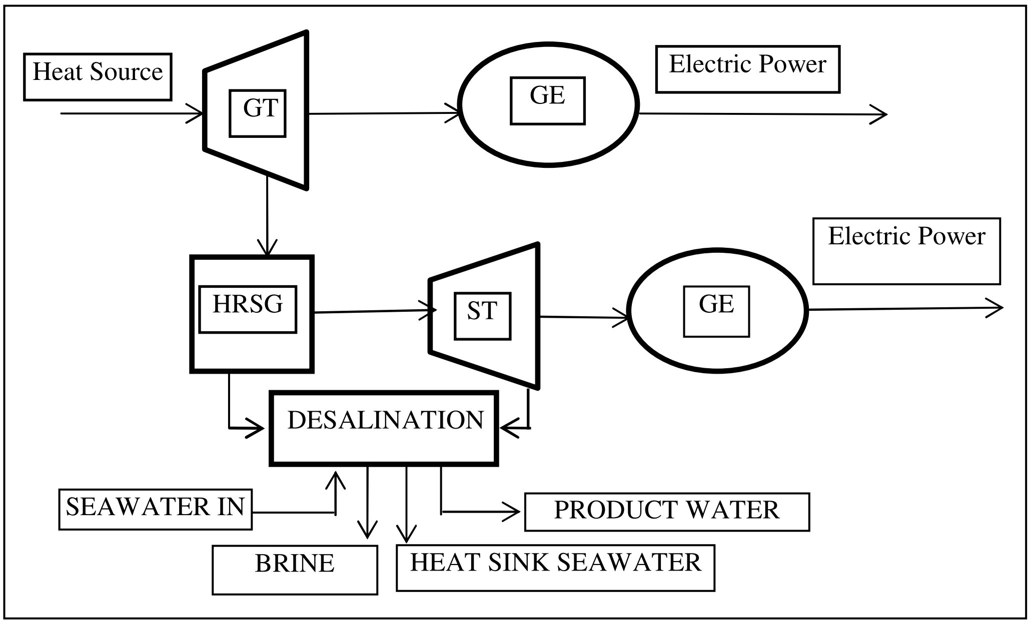

Figure (1): Principle of a combined dual-purpose power and desalination plant

9. CONCLUSION AND RECOMMENDATION

The Gaza Governorates as well as the other Palestinian Territories suffers from a continuous shortage of fresh water quantity and degradation of water quality. The Gaza Governorates depends greatly on the extracted groundwater and rainfall is the only renewable source of fresh water. In addition to water purchased from the Israeli Water Company (Mekorot). The yearly consumption of water is estimated to range from 110 - 130 Mm^3/year. Also, the area has no indigenous energy resources depending mainly on the energy resources, which exported from Israel. So, it is in necessitate need to look for new fresh water and energy resources.

The available brackish water in the Gaza Governorates is estimated at 3500 Mm^3. Under the present high groundwater abstraction rates and the water supply network conditions the water situation in the Gaza Governorates will become worse, where the expected water deficit could be hundreds of cubic meters of water and an urgent plan is required. For the short-term solutions, some measures are concerned with wastewater reuse, storm water collection and water conservation.

It is well known that the brackish water desalination can not be considered as a rational solution to the water crisis in the Gaza Governorates. Such solution may be leads to unbearable water situation with time because of the regularly groundwater overpumping.

Principle of a combined dual-purpose power and desalination plant is a concept of combining the use of steam for production of both power and water. Such plant called dual-purpose plants.

Seawater desalination option with other management measures could be more favorable scenario to overwhelm the water supply problems and to reserve the aquifer in a coastal area such as the Gaza Governorates. This option will be more efficient if it is applied with electricity production by means of duel-purpose plant (production of desalinated water and electricity), where the waste heat from the gas turbines' system will be use to generate steam.

According to the reported international prices, the specific seawater desalination cost ranges between 0.77 - 2.45 USD/m^3, 60 - 2.01 USD/m^3, 61 - 2.13 USD/m^3 and 60 - 1.28 USD/m^3 for MSF, MED, SWRO and MED/RO (hybrid system) respectively, depending on the amortization interest rate and energy cost.

Obviously, regarding the energy consumption, for new communities without electrical power and freshwater sources, but with salt water resources or where both electric power and fresh water is needed dual purpose may be an appropriate solution. Technical and economic comparisons between the main seawater desalination processes indicate that the MED/RO hybrid system is regarded as the first option for the Gaza Governorates area if it is applied to dual-purpose plants. It follows with MED process then the SWRO process. The MSF process is not preferable in Gaza because of its high-energy consumption rates and the scales' formation problem.

Therefore, dual-purpose plant it is reliable to begin in the Gaza area with MED desalination Process, which capacity about 15000 m^3/day. After that, it could be developed and implementing a RO Process jointed to the existing one completing the MED/RO hybrid system.

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