NON-CONVENTIONAL WATER RESOURCES MANAGEMENT

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ABSTRACT

The gap between fresh water supplies and demands in arid zones is rapidly increasing due to population growth and limited water resources. The population of Egypt increased from 23 million in 1955 to more than 70 million in 2003. The major part of Egypt water resources is limited to Egypt’s share from the Nile waters due to 1959 treaty between Egypt and Sudan. Under these conditions, non-conventional water resources could be the challenge for Egypt to survive. Non-conventional water resources considered in this study include desalination of brackish and sea water and cloud seeding. The study presents the possibility of management of non-conventional water resources and highlights the main obstacles in their production.

It's revealed that cloud seeding process needs high technologies to be performed correctly and requires huge investments in terms of financial costs. Also, the area targeted is extremely difficult to be defined and costs required for water management would be expensive.

The study revealed that a huge quantity of desalinated water is needed as a future requirement especially in the expected developing areas like the coastal areas where tourism and industry activities are widely spread. It is concluded that the desalinated water in Egypt is considered the most available non-conventional water resources with few production obstacles especially in case of suitable economic return.

Keywords: Desalination, Cloud seeding, Non-conventional, Water resources

INTRODUCTION

There is a very few number of countries worldwide that depend upon a single source of water as Egypt which depends on the Nile River. The Nile River in Egypt sustains more than 95 percent of the population on a narrow green strip of land in the Delta and valley bisecting a land that otherwise desert. Meanwhile water demand is continuously increasing due to population growth, industrial development, and the increase of living standards. Because of population growth, the per capita share of water has dropped dramatically to less than 1000 m^3/capita, which by international standards is considered, the "water poverty limit". The value may even decrease to 500 m^3/capita in the year 2025, Attia and Mohammad [2]. The Egyptian government's strategy is to increase the inhabited area of 4% to about 25% of the total area of the country by developing new agricultural, industrial, and tourism communities, Tawfik [9]. Often the lack of human settlements in these regions stems from shortage of fresh water, a condition that may be adjusted by developing available non-conventional water resources in these regions.

Non-conventional water resources production could be the perfect match between future demands on water and potentially available supplies. This paper emphasis some technologies of non-conventional water resources as desalination of sea and brackish water and cloud seeding.

El-Zanati and El-Khattib [4] reported that integration of many membrane operations improve the performance of seawater desalination unit. Thus 76.2% of water recovery is obtained. Azmeh et al. [2005] reported that the cost of 1 cubic meter of desalinated water of Adraa wastewater treatment in Syrian was 0.28 US $ while, Wilf [10] reported that the cost breakdown for a large capacity (200,000 m^3/day) Sea Water Reverse Osmosis (SWRO) desalination ranges from 0.481 $/$m^3$ to 0.706 $/$m^3$.

Luis et al. [7] reported that in mountainous areas, cloud seeding could be effective, but these are often unpopulated regions and benefits to the populations can result only from augmentation of runoff due to that increased rainfall. Khouri et al. [6] reported that during the 1980 drought in Morocco, cloud seeding over the Atlas Mountains increased the rainfall by 10 to 15%, which caused runoff that could be stored in small dams downstream, and contributed to alleviation of the drought.

This paper presents the possibility of non-conventional water resources management and highlights the main obstacles in their production.

METHODOLOGY

The management of non-conventional water resource necessitates studying the following elements:

- The non-conventional water resources alternatives;
- The production technology of non-conventional water resource;
- The accessibility of non-conventional water resources;
- The cost / benefit ratio of non-conventional water resources;
- The non-conventional water resource supply (brackish and sea water & cloud seeding);
- The water demand (water requirement for different sectors) and
- The relationships between water resource supply and demand.

Non-conventional water resources alternatives

In the current study, non-conventional water resources alternatives are the desalination of brackish and seawater and the cloud seeding.

Desalination alternative - Desalination technology

Seawater and brackish water desalination is progressively being used by many countries in their efforts to cope with water scarcity. This is especially accentuated by the growth of urban areas, the development of arid areas, and tourism activities.

Desalination is a water treatment process that removes salts from saline water using one of different technologies to produce water that is low in total dissolved solids (TDS). These technologies include distillation, membranes that include Reverse Osmosis and Electro-Dialysis. A desalination plant can be pictured as a black box into which water and high-grade energy are fed and from which low-grade energy; brine and desalinated water are produced Semiat [8]. The TDS of feed water may range from 500 to 50000 mg/l. The feed water must be treated to the level for which the plant was designed before it is fed into the plant itself. This treatment may include physical filtration, chemical conditioning and others. The desalinated water produced by the plant is usually in the range of 50 to 500 mg/l TDS and to be used for human consumption, it must comply at least with WHO limits.

The selection of desalination method depends largely on several factors as the required capacity, the salinity of the feed water, the available energy used, operation properties and the nature of the site. Reverse Osmosis (RO), electro dialysis (ED), thermal system and ion exchange are the predominate technologies of desalination used in Egypt as shown in figure (1) and table (1). The reverse osmosis method is widely spread in Egypt because it represents more than 50% from the produced water for tourism, petroleum, and industry and health sectors. The electro dialysis can be used in the field of ground water as its salinity ranges from (5000-10000) part per million (ppm) and used in remote areas like petroleum fields, public communities in Sinai and North West coast.

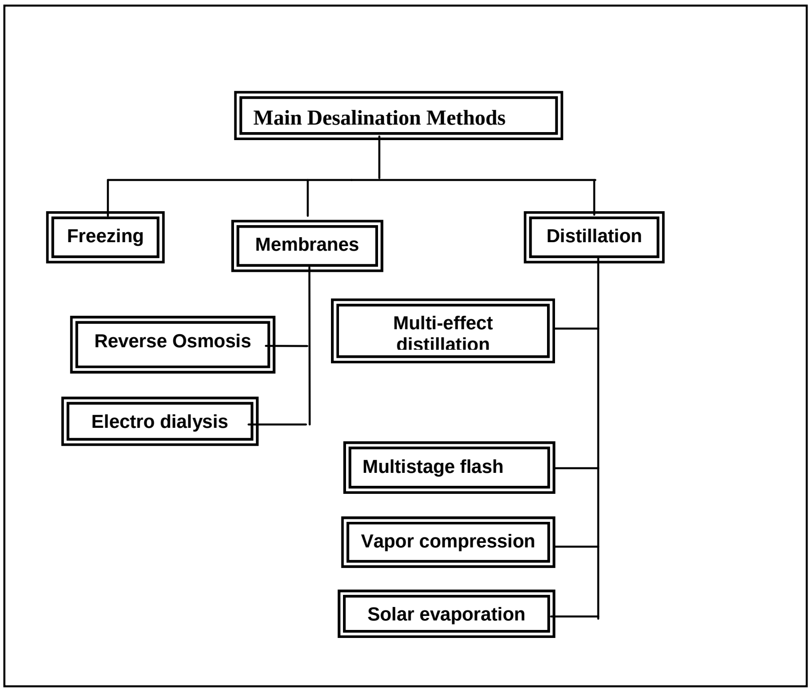

Figure (1) Main Desalinations Methods

Table (1) the Effect of Water Salinity on the Selection of Suitable Desalination Method

Method	**Low Salinity (1000) to (3000) ppm**	**Moderate Salinity (3000) to (5000) ppm**	**High Salinity (5000 to 50000) ppm**
Distillation	Possible but not economic	Possible	Good
Electro-Dialysis	Good	Possible	Possible but not economic
Reverse Osmosis	Good	Good	Good

Accessibility of desalination

The raw material of desalination technology is widely available as Egypt has long shorelines of more than 3000 km on both the Mediterranean and the Red Sea. Salt concentration in the Mediterranean water is about 35000 mg per liter while in the Red Sea is about 40000 mg/lit. Desalination of seawater is being practiced in Egypt in some locations along the Mediterranean coast, the Red sea coast, and in North and South Sinai as small-scale desalination plants. Most of these plants provide potable water for tourist resorts and urban centers. Moreover, the required experience for desalination process is available as the number of desalination plants in the world reached more than 13600 plants, which produces more than 26 million cubic meters from fresh water per day IDA [5].

Cost /benefit of desalination

Desalination process is an energy intensive process and the cost of energy can account for up to 50% of the overall production cost. It is also important to notice that low energy requirements do not necessary indicate the least cost of desalination method. Selection of desalination process requires a comprehensive cost analysis of the system parameters such as capital cost, operation and maintenance cost, etc. Cost of the desalination of water depends, among many factors, on the feed water salinity and the required output salinity. Regardless of the energy source, the cost also depends among other factors on the production capacity of the plant, the technology used, cost of transportation of water, pretreatment, etc. Table (2) presents the total cost for the production of 1 m^3 through different desalination technologies in Egypt and in the world referred to Richard Morris, 1997 as the dollar equals 3.4 L.E at that time.

Table (2) Total Cost for Production of 1 m^3 in Egypt and in the World

Desalination Method	Total Cost in Egypt		The world total cost
	(Dollar /m^3)	L.E/m^3	(Dollar /m^3)
Sea water			
Multistage Flash (MSF)	0.7	2.37	0.77-2.45
Multi Vapor Compression (MVC)	1.57	5.34	0.71-3.15
Reverse Osmosis (R.O.)	1.66	5.66	0.61-2.13
Brackish Water			
Electro-Dialysis (E.D.)	0.87	2.96	0.22-0.82

The desalination of sea and brackish water is economically feasible as it is used in tourist villages along the Mediterranean and the Red Sea coasts and in chemical and pharmaceutical industries, which require high level of water purity.

Water supply (Desalination)

The study considers the coastal governorates where the Nile river water can't reach there as Red Sea, South Sinai, North Sinai and Matroh. The number of the desalination plants, the method of desalination used and the production capacity in the study areas are presented in Table (3).

Table (3) Desalination Method, Capacity and Numbers in the Study Areas

Governorate	No. of Plants	Method	Capacity (m^3/day)
Red Sea	31	R.O.	21600
South Sinai	32	M.V.C., M.E.D., E.D., R.O.	52380
North Sinai	15	E.D., R.O.	3800
Matroh	20	E.D., M.V.C., R.O.	6400

M.E.D.: Multiple Effect Distillation

Water demand of the study areas

Table (4) shows the total water demand of different sectors in the year (2017) in the coastal governorates.

Table (4) Total Water Demand of Different Sectors in the Year (2017)

Governorate	Tourism Sector	Agriculture Sector	Population Sector	Industry Sector	Total Water Demand
Red Sea	130551	1020000	71000	113600	1335151
South Sinai	93272	34000	14000	22400	163672
North Sinai	-	6992100	57000	91200	7140300
Matroh	-	10676000	86000	137600	10899600
Daily Total	223823	18722100	228000	364800	19538723
Annual Total	81695395	6833566500	83220000	133152000	7131633895

Comparison between the required water demand and that produced from desalination

Table (5) shows the comparison between the total water demand required to fulfill the future development in tourism, population and industry sectors in the year 2017 and the quantity of produced water from desalination in the study areas for the same year. To fulfill the water supply for future development in tourism, population and industry sectors in the year 2017, it is necessary to save water for all these sectors from non-conventional water resources. Figures in the tables indicate the gab between water demand and supply in the study areas. The gab is as much as 7.100 milliard m^3/year. This challenge could be met through different scenarios or alternatives as cloud seeding.

Table (5) Comparison between the Required Water Demand and that Produced from Desalination Plants

Governorate	Tourism Sector (m^3)	Population Sector (m^3)	Industry Sector (m^3)	Total Water Demand (m^3)	Produced Water (m^3)
Red Sea	130551	71000	113600	1335151	21600
South Sinai	93272	14000	22400	163672	52380
North Sinai	-	57000	91200	7140300	3800
Matroh	-	86000	137600	10899600	6400
Daily Total				19538723	84180
Annual Total				7131633895	30725700

CLOUD SEEDING ALTERNATIVE

Cloud seeding technology

Cloud Seeding is a process of augmenting rainfall by adding substance to the cold clouds that act as nuclei for the formation of larger water drops that otherwise would not fall to the ground. These substances such as ice, frozen carbon dioxide and silver iodide bomb the clouds using aircraft or rockets. Its interest is however limited by the lack of cold wet air masses traveling over the arid low-lying areas where populations live. The seeding effect is often visually noted by simple observations or more specifically by radar which can document increases in cloud top height, precipitation covering a larger area, and precipitation lasting for a longer time period than noted from non- seeded clouds in adjacent areas.

Cloud seeding accessibility

The accessibility of cloud seeding depends on whether the rain over a specified area could be increased by seeding clouds with silver iodide released from aircraft or not and it depends on the following:

- The occurrence of suitable cloud condition.
- The availability of seeds.
- Meteorological data about the atmospheric variables.
- Radars image of storms and rainfall regions.
- Satellite images for target area.
- Imagination of ideal flight plane for seeding process considering the target area, the suitable time and the flight time, and
- Scientific team for cloud seeding process.

Cloud seeding cost /benefit

In addition to the budget of the scientific and highly qualified technical staff, the cloud seeding economy depends on the cost of several factors:

Seeding cost

The seeding cost differs from one country to another according to the economic case, the availability of such seed material in the country or the need for importing it from another country.

Flight cost

The flight cost depends on the project duration and the flight hours required for monitoring and seeding process. The flight wings are supplied with seeding substance as shown in figure (2).

Cost of meteorological data

The total cost of the required data for cloud seeding process comprised the cost of different items:

- The meteorological data of the atmosphere;
- The remote sensing station;
- Meteorological radars;
- High technology computers.

Figure (2) Fixing Silver Iodide Bombs in the Aircraft

Cost / benefit of cloud seeding process

The economic evaluation of cloud seeding is difficult; this refers to the difficulty in the determination of the anticipated benefit from cloud seeding project. The cost of the project is calculated with high accuracy. The difficulty is in the prediction of the outcome from the project i.e. the increase in the precipitation quantity.

Precipitation density

In case of low precipitation; it may be lost through the soil (high permeability) or by evaporation or not sufficient for irrigation purpose. In case of high precipitation; it may lead to flood, how to make benefit use of it and what is the expected impact from flood.

The additional precipitation timing and region

The additional precipitation can recharge the ground water reservoir in the region of falling. The precipitation may fall on the Delta where the clayey soil exists with low permeability, rainfall will be lost without any recharge process, but it may be help in irrigation process.

CLOUD MODELING IN EGYPT

Cloud models with detailed microphysics were used for cloud ensembles. The results are obtained from analysis of the seeding effects with respect to cloud distribution in region, presence of desert dust, wind direction, rain chemistry and the location of rain cloud systems.

Three cloud seeding numerical experiments were conducted in Libya, Israel and Jordan, and in Turkey representing the west, east and north of Egypt respectively. The three day randomized cloud seeding program conducted in Labia during the period from 24 to 26 of January 1981 showed that the increase in rainfall in Libya is always combining with decrease in Egypt ECRI [3]. The same effect of the (Turkey Rain Enhancement Experiments) in Egypt, during the period from 4 to 6 January 2000. This effect is shown in Figure (3).

RESULTS

The study revealed that the future development in tourism, population and industry sectors for the study areas in the year 2017 required a water demand quantity of 7.131 milliard m^3/year. This quantity could be saved from desalination of brackish and sea water with a total cost ranges from 2.96 to 5.66 L.E/$m^3$and there will be a suitable return corresponding to the total cost especially in the coastal zones.

For cloud seeding the statistical studies and analysis proved that if the average recorded increase in rainfall in the nearest countries (Libya, Syria, Jordan and Palestine) was applied on the North coast in Egypt. It is expected that the max additional rainfall on Alexandria will be about 25 mm in the raining months. This maximum excess rainfall would be obtained in case of the cloud seeding success. The benefit of cloud seeding depends on the precipitation density, the region of falling precipitation and the time of precipitation.

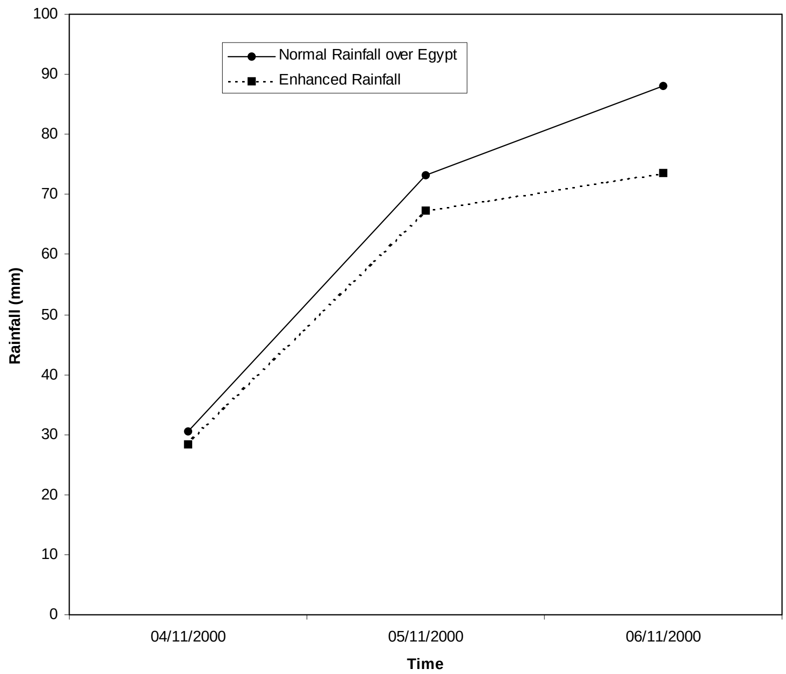

Figure (3) Effect of Turkey Rain Enhancement Experiments over Egypt

CONCLUSION

The desalination of sea and brackish water especially in the coastal zones (where no fresh water was arrived) is preferred than the cloud seeding as it is possible to desalinate the required water quantity for drinking purpose, domestic uses, industry and tourism requirements as long as there is suitable return corresponding to the construction and operation cost. For cloud seeding, there is doubt in cloud seeding as a continuous non-conventional water resource because of less accessibility, the natural restrictions such as the occurrence of clouds. Moreover, the cloud seeding requires high technologies to be performed correctly with high-qualified technical staff. Also, cloud seeding process requires huge investments in terms of financial costs.

RECOMMENDATION

Continuous research work for desalination technologies may lead to a reduction in the cost of the production of desalination water. For cloud seeding, it is required to follow the regional and the world future progress aspect and encourage the researches in this technology.

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