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DESALINATION FOR SYRIA

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SUMMARY – Desalination may be a viable option to overcome water shortage problems in the Middle East. Several countries, such as Saudi Arabia, The United Arab Emirates and Qatar have indeed implemented vast desalination programmes with success. This paper is however interested in the potential of such technology for Syria, a country which has yet to implement such an initiative. A feasibility study is presented that compares the geographical, demographic and water resources conditions, as well as the country's infrastructure and economics in countries where desalination has been implemented, in order to identify key features and compare them with the Syrian context. A technical review of water desalination methods is subsequently presented. Key features and problems relevant to Syria are highlighted. Furthermore the suggestions made by the Desalination Commission in Syria are analysed. Finally, an attempt is made to identify potential scientific and technical progress that could be beneficial to the Syrian model and ambition.

Keywords: desalination, Middle East, Syria

1. INTRODUCTION

There is no doubt that water is the lifeblood of human beings and natural systems. There are some parts in the world have plentiful water resources, while there is inadequate resources of drinking water in other parts of the world. In 1990, there were about 20 countries suffering from sever water shortages, and based on population projections it is expected that by 2025, about 33 countries worldwide will have a chronic water shortages. What is more, that this projection has not take into account the possibility of that the climate changes could create further water shortages. Current water shortages are nowhere so sever as in the Middle East.

Arab countries are represented as arid or semi arid countries and water shortages is already affecting this region and it is continuously going up and increasing. In a short time most of these countries possibly will run out of fresh water. Their ground water resources is being over pumped and salty seawater is encroaching tens of kilometres inland, hence it is expected that groundwater in Arabian region will be undrinkable by the year 2007 (Kliot, 1994). The Arab world suffers from increasing demand on fresh water because it represents 10% of the world area, and 5% of the world consumption, but it only has 0.5% of the world regenerated water resources.

The possible methods for developing future water resources in Arab region is considered to be either by conveyance of water for a long distance, or by desalination or recycling. Conveyance of water schemes is very difficult to agree on, especially if it involves more than one country. For water recycling, a computer model showed that the cost of desalinated water makes improvements in some or all parts of water recycling processes, which include distribution, storage, sewage collection and treatment (Dabbagh *et al.*, 1993). Therefore, desalination is becoming a major source of potable water and power production in many parts of the world to cope with the population growth and industrial and social changes. Whilst many Arab countries have embraced this technology, Syria has been lagging behind and is only just investigating a development strategy for desalination, which this paper addresses taking into account Syria's situation and the available technology.

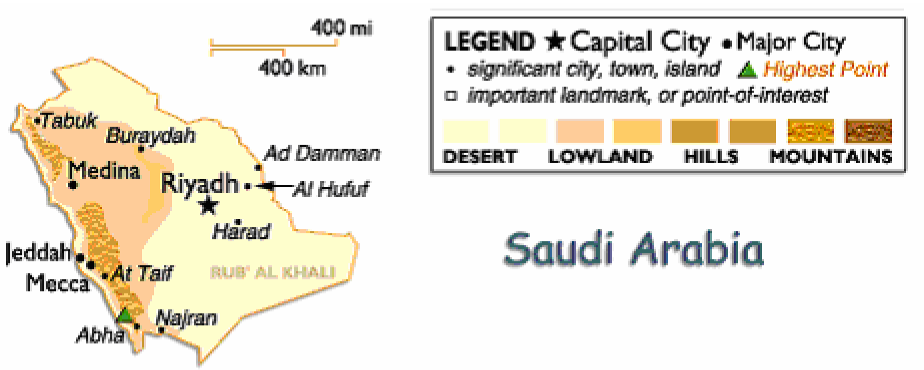
2. KEY ACTORS THE MIDDLE EAST

2.1. Saudi Arabia

Saudi Arabia is the largest country in the Middle East. It is considered the biggest mass of sand on the planet because 95% of its lands form a dry desert (Saudi Arabia Map and Information Page, 2004). Water shortages in the kingdom of Saudi Arabia has been increased by numbers of factors such as limitation of ground water sources besides that it is deeply buried and salty, unreliable surfaces sources, rapid growth of population with a natural rate of Saudi nationals is probably over 3 % (FAO, 1997 a) and now its population is 22,735,000 capita with 2.7 million in the Capital City of Riyadh, development of industry and difficulty of water treatment by conventional processes. Therefore, the government has decided to use seawater desalination to provide source of potable water for the whole main area of the Kingdom.

Saudi Arabia is now the largest producer in the world of desalinated water. The 27 desalination plants provide drinking water to major coastal cities and industrial centres and other cities through a network of water pipes running for more than 2,300 miles. Desalination provides 70% of the drinking water source in the Kingdom. It is expected that the network of desalination plants in the Kingdom will have a capacity of 3,028,329.6 m3 per day when the new desalination plants which are under construction completed. Desalination plants also use to generate electricity. In 2000, the desalination plants in the Kingdom generated a total of 28 million Megawatt Hours (Saudi Arabia Information Resources, 2002). Presently, several desalination plants on the Red Sea provide Jeddah, Mecca and Al-Medina with potable water and on the Arabian Gulf coastline to Riyadh, Dammam, Al-Khabar, Al-Jubail and Daharan, etc.

It can be seen in the topography map of the Kingdom in (figure 1) that there is no problem in conveying water from desalination plants on the Arabian Gulf Sea to other cities (Riyadh), but to convey desalinated seawater from the Red Sea to cities like Mecca and Al-Taif water pumps are needed. The country is the largest producer and exporter of oil in the world, and it spends much of the profits from the oil industry to run desalination plants and to improve the infrastructure of the country and the lives of its people (Saudi Arabia Map and Information Page, 2004).



http://worldatlas.com/webimage/countrys/asia/sa.htm#

Figure 1. Map and topography of Saudi Arabia

2.2. United Arab Emirates

United Arab Emirates is another Arabian country where the demand for water exceeds the available resources, and this demand is continuously increasing. This shortage is due to population increase at an average annual rate of over 3.5% and water resources limitation since there are no permanent rivers or lakes, and the rain average is 100 mm a year, while an average annual rainfall recorded in the UK is 4300 mm per year at Sty Head, Cambria. Nowadays, desalinated seawater forms a 35% of the total water used in UAE.

The present water policy in United Arab Emirates includes elements of both supply expansion and demand management by reducing amount of water consumed in domestic purposes (The interested reader should read (ERWDA, 2004)). This is necessary because building more plants is not only expensive, but it consumes a lot of energy. Therefore, people should reduce water consumption; otherwise there will not be enough water for future generations. Currently, there are desalination plants in all the emirates which are located on the Persian Gulf coast. Taweela, Mirfa and Umm Al-Nar in Abu Dhabi and Jebel Ali in Dubai are among these.

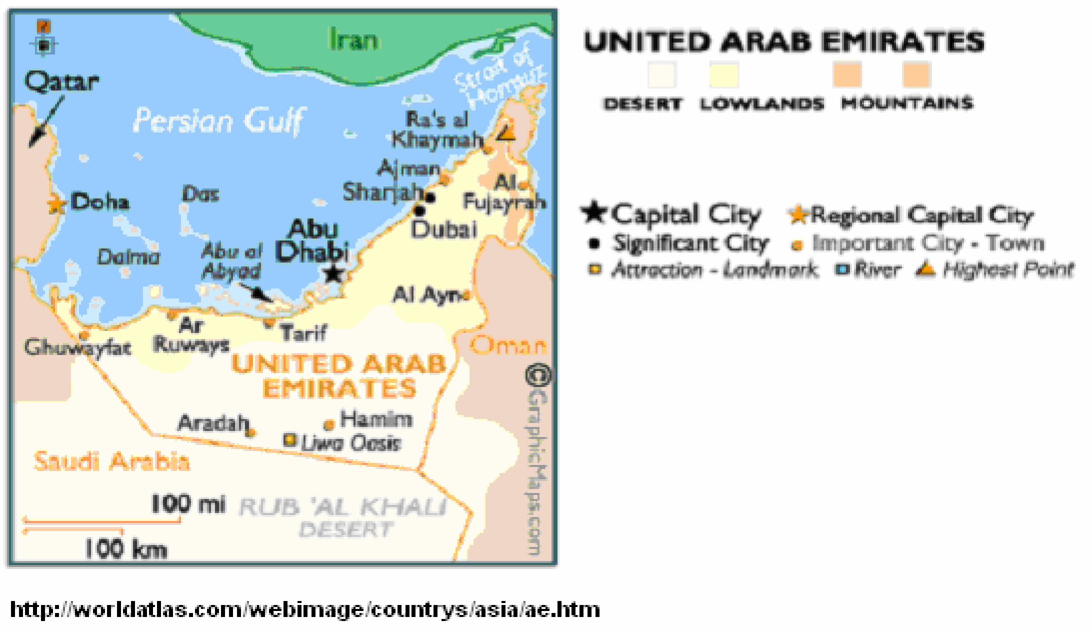


Figure 2. Map and topography of the United Arab Emirates

It is clear from the topography map of the UAE in figure 2 that the main cities are located on the Persian Gulf shore. Besides the coastal line is lowlands, while the internal region is a desert, which means that pumping may not be so essential to convey desalted sea water into pipes to other cities. The United Arab Emirates contains 15.7 billion m^3, or nearly 10%, of the proven oil in the world reserves. The UAE also holds the fifth-largest natural gas reserves in the world and exports significant amounts of liquefied natural gas. Therefore, there is no problem at the moment in providing adequate energy for desalination plants.

2.3. Qatar

Qatar, another oil-rich Arab state, makes up an additional country of the fifth Arabian countries with the least water per capita. In Qatar, water scarcity is identified as the main problem and this is due to the absence of permanent surface water and very low average annual rainfall almost equals to 75 mm. Furthermore, agriculture in Qatar is almost totally dependent on irrigation from pumped groundwater. It is estimated that in 20 to 30 years, Qatar aquifers will be depleted at recent rates of groundwater withdrawal (FAO, 1996). What is more with increasing urban and rural development, groundwater pollution (nitrates) is a clear possibility (UNEP, 1987).

In 1995, total desalination capacity in Qatar was 98.6 million m^3 a year. There are two desalination plants in Qatar. The desalination plant in Ras Abu Aboud, in Doha, has a capacity of 19.0 million m^3 a year. The plant in Ras Abu Fontas, in Doha, has a capacity of 79.6 million m^3 a year. The addition of two new desalination units in Ras Abu Fontas is expected to raise the total desalination capacity of the country in 1996 to 116.1 million m^3/year. Another desalination plant in Qatar, Ras Laffan, located in Ras Laffan, considered the first private desalination plant in Qatar. This plant is designed to produce 227,304.5 m3 a year. According to the topography map of Qatar in figure 3, the main cities are located near the shore and there are no mountains, so there is little difficulty in conveying desalinated water to non-coastal cities. In Qatar, the oil production is 138,261 m3 per day, besides 32.4 billion cubic meters of natural gas (CIA, 2004) which presently provide a good source of energy to run its desalination plants.

Figure 3. Map and topography of Qatar

3. DESALINATION METHODS

Technology for desalination has been established on an industrial scale since the late 18th century. However, it has been utilized for about 50 years (UNEP, 1987). Today, there are two main types of desalination processes available commercially: distillation processes and membrane processes.

In today's middle-eastern market, the MSF (Multi-Stage Flash) process accounts for more than 60%, other thermal desalination process accounts for less than 10% (Ettouney, 2004). Electro-dialysis is not a popular method; its share of capacity is merely 5%, while Reverse Osmosis' market share probably exceeds 25% (UNU, 1995).

3.1. Distillation Processes

Distillation processes are also referred to as thermal processes. These processes correspond to the natural water cycle by heating salt water to produce water vapour and then the water vapour is condensed to produce fresh water. In desalination plant, water is heated to the boiling point and to do this, two conditions must be provided. The first one is to provide the appropriate temperature suitable for the water pressure (the boiling point is reduced by decreasing the atmospheric pressure of the water being boiled) and the second condition is to provide adequate energy. To perform this economically in a desalination plant, three methods are available, Multi Stage Flash, Multi Effect Distillation, without and with thermal vapour compression, and Mechanical Vapour Compression.

3.1.1. Multi stage flash

In the Multi-Stage Flash (MSF) process, a stream of brine is heated in a vessel called the brine heater. This brine is usually heated by condensing steam on a bank of tubes that passes through the brine heater. Then the heated salt water runs at the bottom of a series of stages or chambers (Figure 4). In each stage the ambient pressure is kept at a lower level than the saturation vapour pressure to make the water boil immediately and flash into a steam. A MSF plant usually contains from 4 to 40 stages. The steam produced by flashing is condensed to pure water on tubes of heat exchanger that run through each stage. These tubes contain the feed water going to the brine heater, so during this step the feed water is warmed up thus the thermal energy needed in the brain heater is reduced.

This method is widely used at the large scale (Umm Al Nar station in Abu Dhabi & The Shoaiba plant in Saudi Arabia) and the produced water is usually very pure with less than 30ppm total dissolved solids and a post treatment may be needed to provide drinking water and to protect the distribution system (Dabbagh *et al*., 1993).

The efficiency of MSF plants is affected by the difference in temperature from the brine heater to the condenser on the cold end of the plant. Therefore, operating a plant at the higher temperature limits of 120 degrees C tends to increase the efficiency; however this also increases the potential for accelerated corrosion of metal surfaces and detrimental scale formation (.

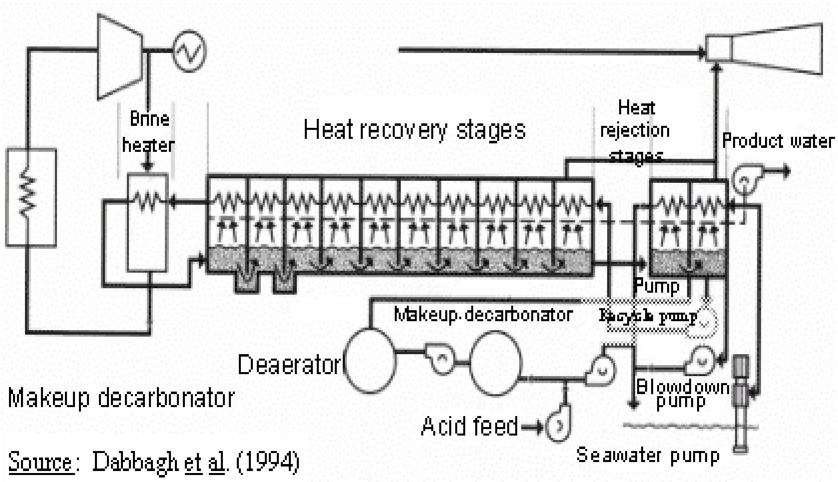


Figure 4. Multi-stage flash process

MSF market share of the capacity of desalting plants in Saudi Arabia is 80.7%. It is 98.3% in UAI and 97.9% in Qatar (UNU, 1995). These numbers show how popular this particular technology is in parts of the Middle-East.

3.1.2. Multi effect evaporation without and with thermal vapour compression

Multi Effect Evaporation (MEE) or Multi Effect Distillation (MED) processes take place in a series of vessels called effects. To allow salt water to undergo multiple boiling without providing additional heat after the first effect, an attempt is made to reduce the ambient pressure in the successive effects. After being pre heated in tubes, seawater enters the first effect either by spraying or by distributing in a thin film onto the surface of evaporator tubes to promote a rapid boiling and evaporation. The tube in the first effect is heated by steam from a boiler and the condensed form from the boiler steam on the other side of the tubes is returned to the boiler again for re-use. The remaining water in the first effect is pumped to the second effect where it is applied to tubes, which are being heated by vapour created in the first effect. This vapour gives up heat to evaporate part of the remaining seawater in the effect while condensing to fresh water. Additional condensation takes place in each effect on the tubes that bring salt water through the plant to the first effect to raise its temperature before it is evaporated in the first effect (Figure 5).

MED processes produce a similar product to that in MSF processes, but it has not been used in large scale as MSF (Dabbagh *et al*., 1993). This method has several advantages. Its processes take place at lower temperature than MSF therefore reducing the probability of corrosion and scale formation. Furthermore, fewer stages are required (from 8 to 16 stages) so smaller plants are required (Dabbagh *et al*., 1993).

It is possible to increase the efficiency of the MEE process by adding a steam ejector for compression of the vapour of the last effect or any other effect. This called Multi Effect Evaporation with Thermal Vapour Compression (MEE-TVC).

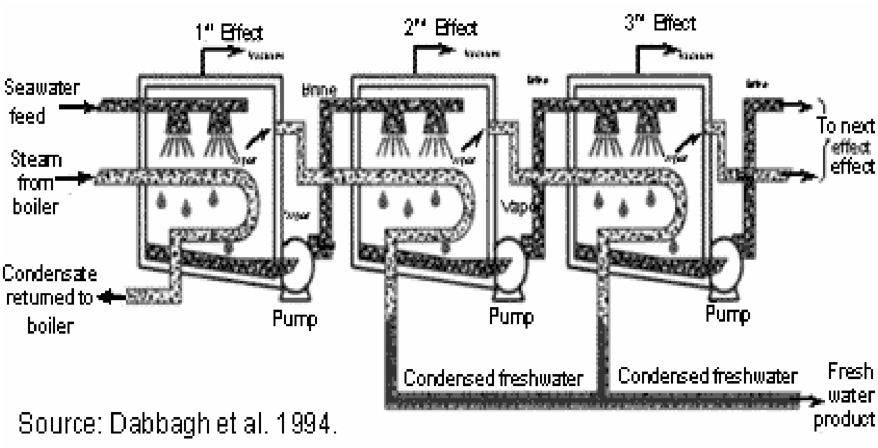


Figure 5. Multiple effect evaporation process

MED process is not in use in Saudi Arabia and in UAS. However, in Qatar, MED'S market share of the capacity of desalting plant is also quasi-inexistent with a mere 0.9% of the market (UNU, 1995).

3.1.3. Mechanical Vapour Compression

Mechanical Vapour Compression (MVC) units promote the exchange of heat to evaporate the seawater by using a mechanical compressor together with a separate air removal system. This is done by creating a vacuum in the vessel and after that compressing the vapour taken from the vessel inside a tube bundle. At the same time, saline water is sprayed on the outside of the heated tube bundle. Seawater then boils producing more vapour and at the same time, the vapour inside condenses producing fresh water. The MVC processes are usually used for small and medium-scale units such as units used for resorts and localized industries.

MVC process is not in use in UAS. In Qatar, MED market share of the capacity of desalting plant is 0.7%, and in Saudi Arabia, it is only 0.5% (UNU, 1995). It clearly remains a very restricted method.

3.2. Membrane processes

In membrane processes, salt is filtered out at a molecular level. Since the membrane pores are so small, water is able to pass through, while salt is stopped. To perform this, large amounts of energy and pressure are needed. There are two desalination methods available commercially. Each one uses the ability of membrane to separate salts and water. These techniques are reverse osmosis and Electrodialysis.

3.2.1. Reverse osmosis

In Reverse Osmosis processes (RO), (Figure 6), pressure is used to separate water and salts by allowing water to pass through a membrane leaving the salts behind. In reverse osmosis processes, salt water is forced to flow through a semi permeable membrane; this produces water without dissolved salts and minerals. No energy is needed to heat the water up, but large amount of energy is required to pressurize the salt water. However, this energy has been reduced as the membranes technology had been developed. In RO processes the salt water is pumped into closed vessel where a pressure is applied to press it against the membrane. As a part of the feed water flows through the membrane, the salt is increased in the remaining seawater. This means that the required pressure will increase causing problems such as increased osmosis pressure across the membrane and precipitation of supersaturated salts unless a part of the fed water is discharged without passing through the membrane. The membranes must be able to withstand the pressure applied against it. However, they are fragile and vary in their ability to reject the passage of salts, thus a small amount of salts may be found in the produced water.

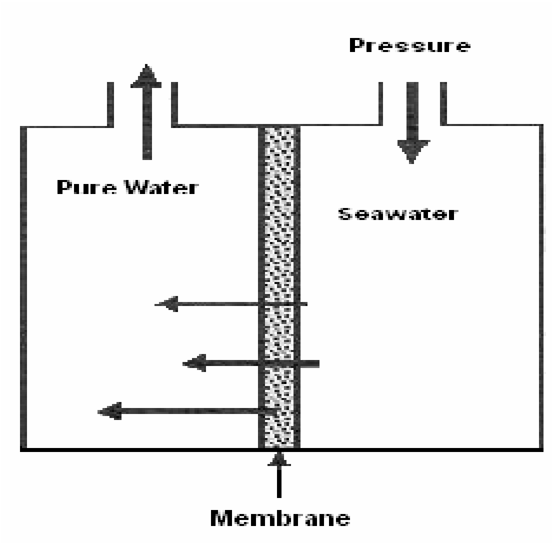


Figure 6. Reverse osmosis

In RO, pre-treatment is required for suspended solids removal in order to avoid salt precipitation and micro-organism growth as the feed water must flow through very narrow passages during the process. Furthermore, post treatment consisting of adjusting the pH, removing gases such as hydrogen sulphide and preparing water for distribution is also necessary (Lafontaine *et al.*, 2004). The improvement that has helped to reduce the operation of RO plants in the past decade is the energy recovery devices. These devices are connected to the concentrate stream as it leaves the pressure vessel, and relatively to the applied pressure from the high-pressure pump, the water in the concentrated steam loses only about 10 to 40 KPa, thus this pressure drop can be converted by these devices to rotating energy. The main disadvantage of this method is the sensitivity of the expensive membrane to fouling and the need for a very careful operation (Dabbagh *et al.*, 1993). Yet it remains very cost effective for low salinity water.

RO market share of the capacity of desalting plant is 16.2% in Saudi Arabia, 0.9% in UAI and it is not in use in Qatar (UNU, 1995).

3.2.2. Electro-dialysis

In Electro-dialysis (ED) processes, an electrical current is used to force salts to move selectively through a membrane leaving pure water behind. Dissolved salts are separated into positive and negative ions by applying a direct electrical current through seawater. These ions tend to move toward the electrode with opposite charge (Figure 7). To operate there processes, membranes are chosen to allow either positive or negative ions to pass through but not both of them. These membranes are placed alternately with a positive ions selective membrane, followed by a negative ions selective membrane. Then the negative ions pass through the negative selective membrane but cannot pass any more membranes because the next one is a positive selective ions membrane so the negative ions are trapped in what is called brine channels. Similarly, the negative ions move in the opposite direction through the positive ions selective membrane and then trapped. This means that there is a succession of channels, some carrying concentrated brine in alternans with others carrying desalinated water. Thus a spacer is provided to allow water to flow between the membranes.

This method is most valid for low to medium brackish waters (Dabbagh *et al.*, 1993). However, a pre treatment must be provided to the feed water to prevent narrow channels from being clogged and to avoid causing damage to the membranes, and a post treatment is needed to adjust the pH and to stabilize the water before being distributed (Lafontaine *et al.*, 2004). During the operations, a low-pressure circulating pump is needed to avoid the resistance of water while it flows through the narrow channels (Lafontaine *et al.*, 2004).

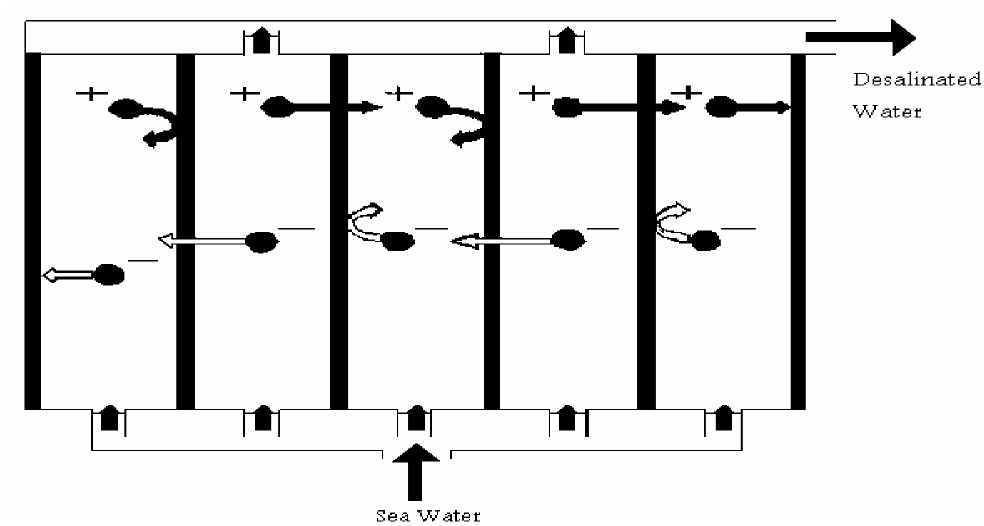


Figure 7. Electro-dialysis

As it mentioned before, ED is not as popular as RO and this is not because of its costs, which are similar to the costs of RO, but because that the ED units require a reliable source of electricity and its process will only remove ions or charged particulates from the source water. Furthermore, there is only one main supplier for ED units worldwide while for RO units are sold by numerous companies which keep the price of RO units in check (UNEP, 1998 a). As a result ED market share of the capacity of desalting plant is 2.6% in Saudi Arabia, 0.5% in UAI and it is not in use in Qater (UNU, 1995).

3.3. Summary

It is clear from the previous overview that there are two dominant technologies implemented in the Middle-East: Multi-Stage Flash (MSF) and Reverse Osmosis (RO). The seemingly dominant role of MSF should not convey the idea that it is the ultimate solution for that region, but is rather indicative of the natural characteristics of the countries that have implemented desalination so far. These are dominantly coastal countries treating sea water, an essential factor to be born in mind when analyzing the situation of other desalination candidates such as Syria.

4. SYRIA

Water shortages have also affected many regions in Syria as a result of the fast depletion of natural fresh water resources. This is owing to several factors. First of all, the decrease of underground water level besides the increase of the salt concentration as a result of the over pumping of aquifers for irrigation and other purposes. Further, the population growth with an actual rate equals to 3.3%. Forecasts expected that within the next 20 years, the Syrian population will increase from 18 millions in 2001 to 28 millions in 2020. Additionally, the damage to the Euphrates, Oronte and Barrada river basins because of the disposal of sanitary sewage in addition to the increasing damping of the industrial wastes as well as the industrial development. Available water resources in 2000 were 16.5 billion m3, and there are already water shortages in all water basins with the exception of the coastal region and the Euphrates.

It is clear that a solution should be found to increase the water resources in the country, and in fact the Syrian government has made several attempts to find solutions, such as building dams and creating multipurpose reservoirs such as Lake Assad and the Tabaqah Dam. The development of non-conventional water resources including water desalination technologies would form an essential source which means the increasing of the national water budget. Desalination will allow Syria to invest the seawater and its brackish water in the eastern regions in order to obtain industrial and drinking water.

The Syrian government has already showed an interest in desalination and, as a result, formed a Scientific National Commission (MedAqua, 2001) to perform three things: Firstly, to evaluate the actual Syrian needs for desalinated water and this includes evaluating surface and groundwater resources, water distribution and water demand; secondly, to perform a technical study to choose the most suitable techniques of water desalination in Syria which means quality of treated water, production capacity, energy consumption and cost of both investment and production; finally, to suggest an integrated programme to enable Syria to perform brackish and seawater desalination and this contains a detailed plan of work and an executive measure to start national industry. Initial work is going in Syria but the authors are currently involved in a parallel, albeit technical, effort and are drawing some of their conclusions below.

Syria's topography is like no other of the major middle-eastern actors (figure 8). Its costal region is narrow, and mountain ranges extend from north to south parallel to the Mediterranean coast. Unlike none of the others, its topography and borders severely impair its access to sea water. The interior region located east of the mountains, and the Badiah and the desert plains in the south eastern part of the country. The main cities, Damascus and Aleppo, are non-costal cities and large populations in need of fresh water are located away from a direct source. Pipelines would need to be constructed to convey desalinated water from the costal region. In order to supply Damascus the water would have to run across the mountain, which would involve costly infrastructures. Syria's situation is also different in the sense that some regions have large reserves in underground brackish water. Desalination of available brackish water in the eastern region could offer a reasonable source of water supply to some inland cities. This would be a more reasonable approach and would give a different orientation to Syria's deployment of infrastructure and technologies.

It seems that the Scientific National Commission has reached similar conclusions and favours brackish water desalination East of Hamah, Al-Badia and Al-Jezirah and would want to deploy several smaller scales, low cost plants to provide water needs in various regions. Seawater desalination in medium scale for industrial property, resorts, and complexes would be implemented in coastal industrial regions. To alleviate the severe water crises in overpopulated Damascus, a solution to the water shortages in Barada and Awaj basin should thus be found. In addition, better management of the basin renewable water resources is another clear key factor for the future, providing a solution to the region's problem until around 2027.

Total oil production in Syria is 83,625.4 m3 per day, and the total quantity of natural gas production is 312 million in cubic meters (FAO, 1997 b). Therefore, Syria has an adequate source of medium term energy to pursue a desalination strategy when compared to other countries using desalination in the region.

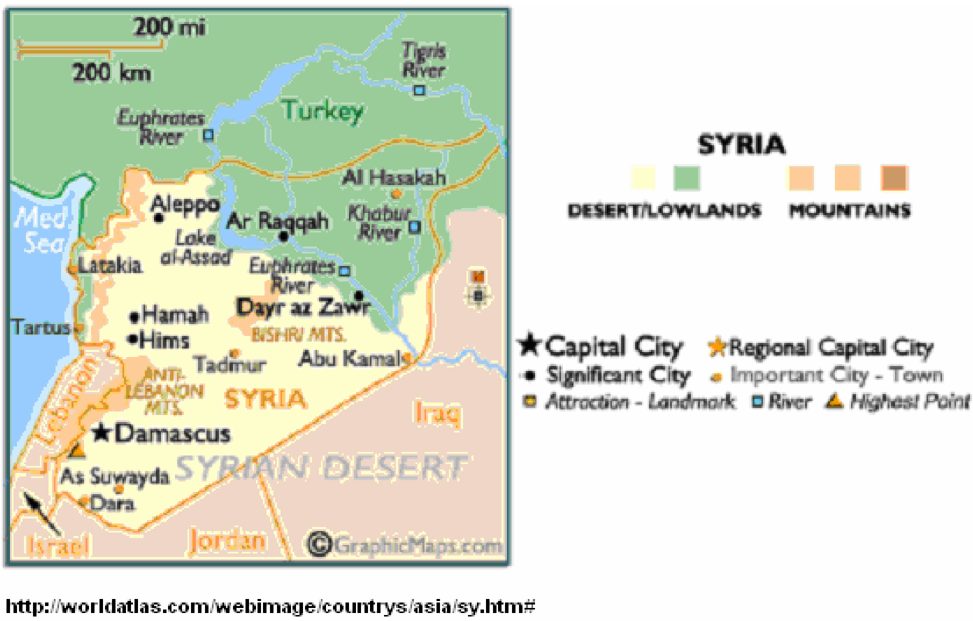


Figure 8. Map and topography of Syria

5. WHICH DESALINATION FOR SYRIA?

Based on the previous considerations and on the conclusions of the Syrian Commission (MedAqua, 2001) a suitable policy should involve the deployment of:

- Small scale units using RO technology for small villages near brackish water sources with the aim to improve the quality of water, the quality of life as well in these regions and reduce the immigration toward the main cities. These units should be coupled to electricity network and to renewable energy sources.
- Medium scale units using thermal compression in presence of vapour and mechanical compression in presence of electricity coupled. These units will serve industrial complexes or tourist resorts with the aim to encourage industrial and tourist activity in new areas on the coast.
- Large scale units using RO with pressure recovery and thermal with energy recovery technologies, to be coupled to water transportation project to provide new, independent and stable water resource and to create an integrated long-term programme to resolve water scarcity in Syria.

However, as a first stage, the Desalination Commission has decided to build a RO plant for brackish water desalination in the eastern region and another plant based on thermal technology for seawater desalination (MedAqua, 2001).

To estimate the expected cost of applying desalination technology in Syria, three factors must be taken into account:

- The direct capital cost such as land cost, water supply, brine disposal, process equipment, building and membrane cost.
- The indirect capital cost which may includes freight, insurance, construction overhead and contingency.
- The annual operating cost including electricity, labour, membrane replacement and chemicals, etc.

Taking these into account, the desalination commission in Syria has estimated that the total cost of desalination processes should vary between 0.44 USD/m^3 to 1.40 USD/m^3 depending on the chosen desalination technology (MedAqua, 2001). The construction cost of the first stage of the desalination programme should indeed be less than USD180 millions. By contrast the construction cost of existing desalination plants in Saudi Arabia, is estimated to be USD 2.1 billion (USTI, 2003). For Syria however, further costs should be considered for laying conveyance pipeline and for improved water distribution to large cities such as Damascus and Aleppo. For villages with brackish water resources, small, low maintenance RO units should be used. These units should be solar powered with backup via the electrical network and automatic switch from one mode to the other. This has been implemented quite successfully in regions of Jordan (USBR, 2004).

6. SUMMARY AND CONCLUSION

- Many countries in the Middle East are using desalination.
- Most of them, including Syria have an adequate energy source to power desalination plants, which make them vital medium term solution to the water shortage crisis in the region.
- The Multi Stage Flash process accounts for more than 60% in the market today, the Reverse Osmosis for 30%, while other thermal desalination process accounts for less than 10%. However, in the Arabian Gulf country, the Multi Stage Flash process accounts for 86.7%, reverse osmosis for 10.7, Electrodialysis for 1.8%, vapour compression for 0.65% and finally the Multi Effect Distillation for 0.15%.
- It is clear from the Scientific National Commission’s suggestions however that Syria will rely on the Reverse Osmosis process mostly, for brackish water desalination. Reverse Osmosis has indeed proved to be a very effective technique for brackish water desalination (UNEP, 1998 b). Personal communications between the authors and Dr. S. AlAyoubi (Personal Communication, 2004) have confirmed that Syria should favour RO. This implies that the numbers given above for the market shares of the various solutions, worldwide and for the Arabian Gulf, are mere statistics. Desalination technology is very dependent on resources and geographic situation.

- Syria may rely, locally, for seawater desalination, on other thermal techniques rather than Multi Stage Flash process which has proved to be the most expensive technique among other thermal technique (OSA, 1997).

A wise mix of these technologies should be used in Syria to meet some of its attributes and needs

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