The Cooperation Council for the Arab States of the Gulf (GCC)
General Secretariat

DESALINATION

In the GCC
The History, the Present & the Future

Prepared by Desalination Experts Group,
Originating from the Water Resources Committee

SECOND EDITION
2014

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PREFACE

Their Majesties and Highnesses, the GCC leaders, pay great attention to water issues due to water rareness in the GCC countries and the resulting negative implications in developing the sectors related thereto. This care lead to the establishment of a ministerial committee consisting of the ministers concerned with water in the GCC counties. The main objective of the committee is to develop this vital sector as a part of the Gulf mutual work. The GCC countries have taken serious steps in terms of water cooperation, through adopting a number of water policies and programs, and seeking closely to strengthen the methods, ways and steps that lead to achieving water security, which is the essential foundation within the framework of comprehensive development achievement of the GCC countries.

Due to the accelerating development in the different aspects of the social, construction, industrial and agricultural infrastructure, along with the rapid increase in the demand for water, the GCC countries have made tremendous and continuous efforts to increase their water resources and introducing new resources in this regard.

Due to the importance of the information and details pertaining to and specialized in the water field, the Water Resources Committee, directed by their Excellencies the ministers concerned with the water sector in the GCC countries, have formed a working group for preparing this book to be an important reference for the decision-makers, the researchers and those concerned with desalination, and to include comprehensive information on the desalination sector in the GCC countries, the details of which were submitted by the official authorities in the member countries.

The GCC General Secretariat wishes from this book to be an added value for the Arab libraries, and to be considered as reference guiding the concerned authorities in the GCC countries and an assistant for the researchers and interested in desalination in the GCC countries.

Sincerely,

Abdullatif bin Rashid Al-Zayani
GCC Secretary General

INTRODUCITON

The GCC countries have been witnessing an accelerating development over the last three decades in terms of the social, construction, industrial and agriculture aspects, accompanied by remarkable increase in the demand for water. As a result, the GCC countries have made tremendous continues efforts to increase the utilization of their water resources and introducing new resources by building desalination stations, reusing the sewage water, building dams for reserving the surface water and increasing the utilization of underground water resources.

Their Majesties and Highnesses, the GCC leaders, pay great attention to the water issue due to water rareness in the GCC countries and the resulting challenges facing the sustainable development. This interest resulted in the establishment of a ministerial committee consisting of the ministers concerned with water in the GCC counties. The committee is concerned with developing this vital sector as a part of the Gulf mutual work. The GCC countries have taken serious steps in the field of water cooperation, through adopting policies and programs, and relentless pursuit to strengthen the methods, ways and steps that ensure achieving water security, which is the essential foundation for achieving the comprehensive development of the GCC countries.

This book, which includes comprehensive information on the desalination sector in the GCC countries, is an important part of the efforts made by the GCC and considered as a reference guiding the concerned authorities, researchers and those interested in the water sector in the GCC countries.

Sincerely,

Economic Affairs
Electricity and Water Department

CONTENTS

Part I

Overview of desalination history in the GCC Countries

Traditional Water Resources

Ein Athari in the seventies of 20th century
Kingdom of Bahrain

The GCC countries are located in the south west part of the Asian continent, which is considered as an arid and semi-arid area which suffers from scarcity of fresh water. In this area, the individual share of renewable water does not exceed 500 m^3 /year. The vast majority of GCC land is made up of deserts, in which the surface waters such as rivers and lakes do not exist. The rainfall is rare and irregular with an average of 100 mm/year approximately. Most of it evaporates due to the high rates of evaporation that could go up to more than 3500 mm.

Under these difficult circumstances, the GCC inhabitants' relied on underground water as the primary source of drinking water. Therefore, it is observed that many regions which are having easy access to underground water, such as the Kingdom of Bahrain, the Sultanate of Oman, Eastern and Northern Regions of the Kingdom of Saudi Arabia (KSA) and Al Ain region of the United Arab Emirates (UAE) witnessed a remarkable fast population and agricultural growth. In the State of Qatar, the population used to pump underground water from regions rich in water such Al Mazrouaa, Er Rushaidiyah, Buthailah and Al Thaibiyah to the city of Doha and the .surrounding villages

The population in Sultanate of Oman and UAE, however, used to bring water from the mountains slopes to the populated areas through cleaving, however in the State of Kuwait, the population used to bring water from Shatt Al Arab by Dhows, in addition to the use of underground water.

The rainfall was a limited source of water in valley regions in UAE, KSA and the Sultanate of Oman. With the discovery of Oil in the middle of 20th century, GCC countries experienced an economical, industrial and agricultural development along with population growth which resulted into an evolution in the life style, enhancement in the living standard and easy access to drinking water due to the construction of water transmission pipelines and distribution networks. Increasing demand on underground water resulted in depleted levels of underground water with deteriorated quality.

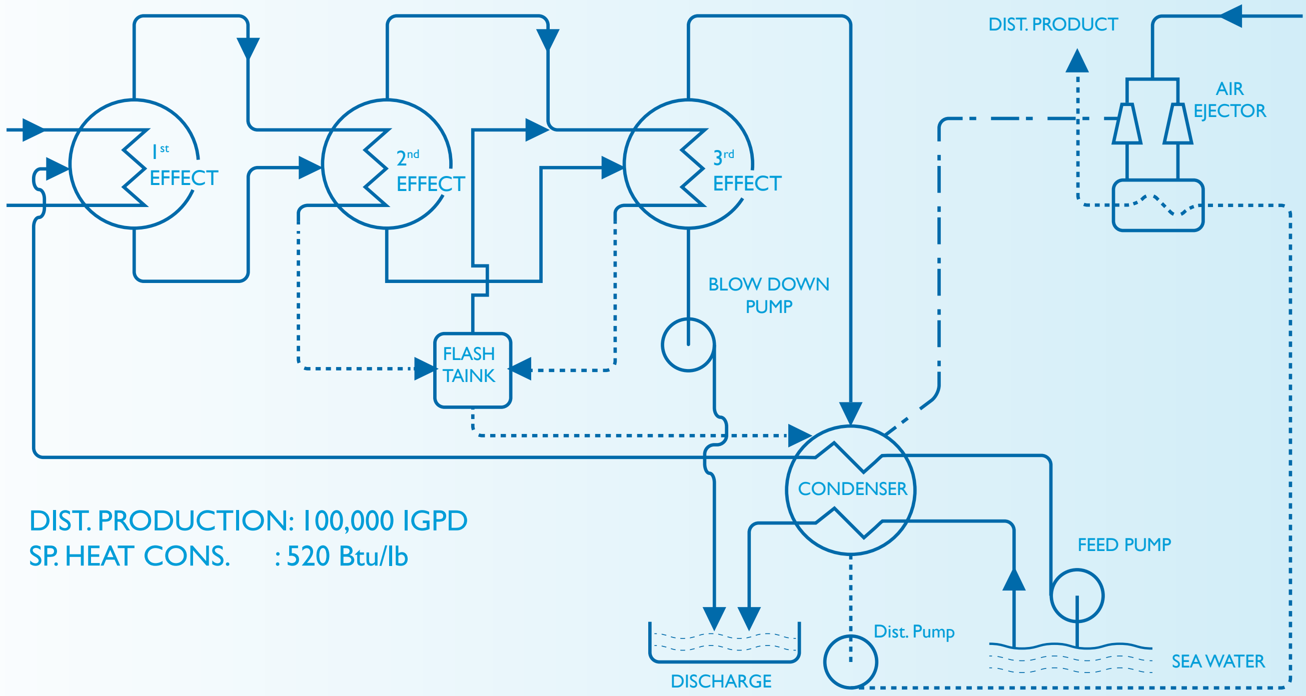
Early desalination attempts in the region

The process of desalinating salt water to produce drinking water was not new to human societies. There are evidences of earlier human successful attempts in this field. In the modern era, particularly in the 18th and 19th centuries, it was very common to produce drinking water through desalinating sea water on board ships using submerged tubes and Multi effect desalination process. Since late 19th century, there are more cases of producing desalinated water on a limited scale onshore for drinking purposes in Egypt, Aden, Chili, Florida and others.

The first desalination use to produce drinking water in the Arabian Gulf countries was in 1907 in the city of Jeddah. A Dutch company installed two distilleries called by the local people "Kendassa" which is apparently derived from the English word "condenser". In 1928, King Abdulaziz Al Saud ordered to replace them by two new units also known as "Kandassa" and works using submerged tube process and they had a total capacity of 135 m3 /day (29700[1] gallon/day) installed by the Scottish company Weir Westgarth.

Falaj Al Khatmayn Procuratorate
Berkat Al moz - Sultanate of Oman

Figure 1. Illustration of A-1 unit of submerged tubes in Shuwaikh plant-State of Kuwait.



In 1953, the states of Qatar and Kuwait built simultaneously a number of units that work using the submerged tubes method which was very common at that time. In the state of Qatar, 5 units were built and their total capacity reached 150040 gallon/day (682 m3/day) while the State of Kuwait built 10 units with a total capacity of 1 MIGD (4545.5 m3/day) in Shuwaikh (figure1) followed by building 10 other units in 1955 which also have a capacity of 1 million gallon/day. The energy consumption of Shuwaikh Plant units was between 420- 520 British thermal units (Btu/Lb) of distilled water and its performance ratio[2] reached about 2.5-3.1 which is low compared to current values.

The low productivity and scaling problems lead to frequent outages for cleaning and descaling as well as high steam consumption and low performance ratio which resulted in significant rise of operation and maintenance costs thus reducing the dependence on this method and limiting its spread. Nevertheless, all units installed of this type in KSA, Qatar and Kuwait were phased out.

1 The gallon used in this book is the imperial gallon (British) equal to 4.545 liter.

2 Performance ratio of distillate is the ratio of the produced water quantity and the quantity of steam used. (Gain Output Ratio GOR).

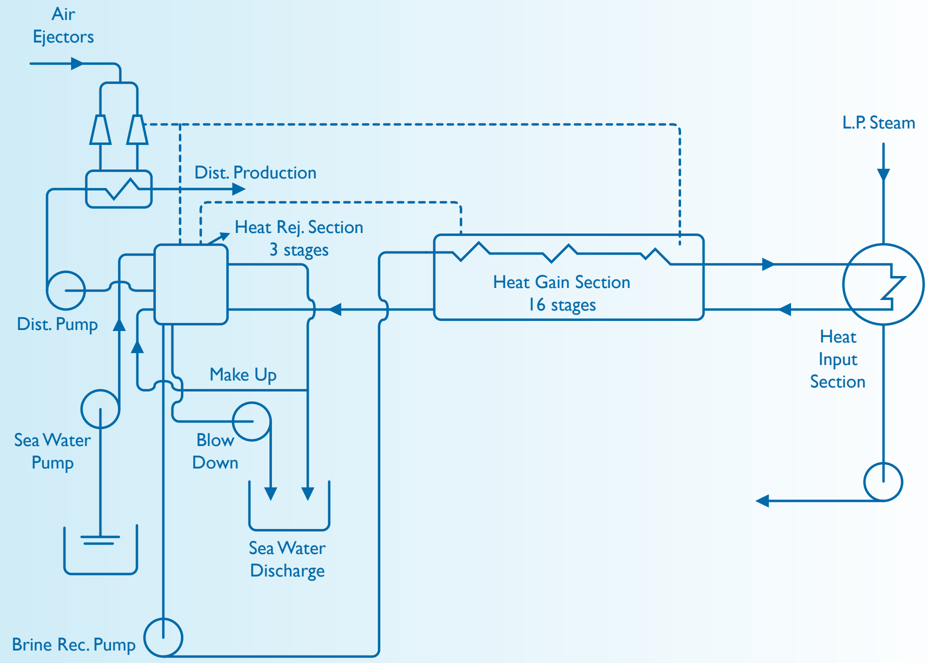
Shifting toward desalination

GCC countries realized the need for alternative sources of drinking water at early stage by observing the rapid growth in demand for drinking water and its desire to provide prosperous life for its population by establishing development where drinking water is its main foundation. Accordingly, they started to think about desalination, which fortunately coincided with important development in this industry where the scientific foundation for new desalination process 'Flash Evaporation' technique was established.

Hence, the true era of using desalination to produce drinking water in the GCC Countries began with the emergence of Flash Evaporation technique which was first used in the area in the State of Kuwait. Where in 1957 an American company, Westinghouse, built Alshuwaikh desalination plant which consist of two units C1 & C2 with total capacity of 1MIGD (4545.5 m3/day) and works on the concept of once though Flash Evaporation process. In 1958, the same company built two more units D1 & D2 with the same production capacity. These units were the largest Flash Evaporation units for water desalination in the world back then. Each evaporation unit consisted of 4 stages installed one above the other in addition to brine heater which was installed on top of all

Al Kandassa-KSA

Figure 2. Illustration for the first MFS plant - Kuwait



stages which led to minimize the land occupied by the evaporator (distiller). Each stage is composed of a box including evaporation chambers next to condensation chambers as well as brine pipelines to transfer it from one stage to the next, as well as vapor deflection board to direct vapor from flashing chamber to the next condensation chamber.

The state of Qatar built later, in 1959, two units at Ras Abu Aboud, based on the same techniques but with different design, by using Long Tube, which had a capacity of 299860 gallon/day (1363 m3/day).
GCC is proud of being the first to test and implement one of the most important processes for water desalination globally which is Multi Stage Flash Evaporation (MSF)1. That was in Kuwait in the year 1960 where two units were built with a capacity of 1 MIGD (4545.5 m3/day) by The Scottish company Weir Westgarth according to the design innovated by the Scottish Professor Robert Silver as shown in figure2.

Soon after, the State of Qatar built its first Multistage Flash evaporation plant, in 1962 in Ras Abu Aboud located east of the capital Doha which had a production capacity of 1.5 MIGD (6800 m3/day). In 1968, two more units were built with a production capacity of 1.98 MIGD (9000 m3/day). Before the end of sixties in the 20th century, particularly in 1967, KSA had begun to build two plants, Al Wajh and Dhaba, on the western coast using once through MSF process. Those units were built by the American company Aquaquim and had a capacity of 43560 gallon/day (198 m3/day). Both Plants were commissioned in 1969, and it should be noted though that all the above mentioned units were phased out since their designed operational life was completed.

Owing to the success of early sea water desalination attempts using the Multistage Flash distillation process[3], the rest of the council countries started to build similar plants. In 1975, the kingdom of Bahrain built Sitra Plant then, in 1976, Sultanate of Oman constructed Al Ghabra and Massairah Plants followed by construction of Al Bukhariya Plant in Abu Dhabi, UAE, in 1977. Table 1 shows the start date of using Multi Stage Flash Distillation in the Council Countries which is considered as the beginning of modern desalination in GCC countries.

Subsequently, further desalination projects depending on this process were built in the areas such as Shuaiba North and Shuaiba South in the State of Kuwait, Jeddah, Al Khafji and Al Jubail in the Kingdom of Saudi Arabia, Umm Al Nar, Jabal Ali and Al Tawila in the State of United Arab Emirates, Ras Abu Fontas and Ras Laffan (A&B) in the state of Qatar, Al Hidd (Phase 1) in the Kingdom of Bahrain and Barka'a in Sultanate of Oman. It should be noted that the unit's production capacity has been constantly increasing; after it began with a capacity of 1 MIGD (4545.5 m3/day) it reached currently 20 MIGD (90909m3/day) for each unit.

3. It is commonly known that if the number of stages of a distiller is more than the double of its performance ratio, then it is called Multi Stage Flashing Distillation otherwise it is called Flash Distillation.

Table 1 - Date of first use of modern Distillation in GCC countries

State	Date	Plant Name	Process type	Total Capacity
State of Kuwait	1960	Shuwaikh E1 & E2	MSF / Recycle	2
State of Qatar	1962	Ras Abu Aboud	MSF / Long tubes	1.5
KSA	1967	Al Wajh Dhaba	MSF / Once through	0.04356 0.04356
Kingdom of Bahrain	1975	Sitra 1A & 1B	MSF / Recycle	5
Sultanate of Oman	1976	Al Ghabra Massira	MSF / Recycle	5 0.00331
UAE*	1977	Jazirat Abu Mousa	MED	0.02
		Abu Dhabi Vapor Plant	MSF / Recycle	15
		Al Barbarat	RO	1

*the UAE introduced three different processes in one year.

Introducing new desalination processes and technics

Researchers never stopped looking for new desalination processes that could be more effective, less power consumption and have lower costs. As a result, new techniques such as Electrodialysis (ED) and Reverse Osmosis (RO) were invented in the late sixties of the 20th century. Also the old techniques such as Multi Effect Distillation (MED) and Vapor Compression (VC) were redeveloped to overcome their problems and make them more competitive with new processes. Accordingly, desalination industry is having many options that suit every circumstance and need.

Due to the different conditions in GCC countries, and the existence of small communities in remote areas away from sea or important islands for the States, the invention of new techniques and improving old processes helped the GCC countries to supply water to those isolated areas. The new techniques that were introduced to the region are: reverse osmosis (RO), Multi Effect distillation (MED), Vapor Compression (VC) and Electrodialysis (ED).

The first use of RO was in KSA when three plants in Manfouha 2, Al Shumaisi and Al Malz were constructed in the year 1968. These Plants used to produce desalinated water from underground brackish water. UAE was next country to build Al Barbarat Plant in 1977 which had a capacity of 1 MIGD (4545.5 m3/day). In 1982, reverse osmosis (RO) process was introduced in Sultanate of Oman and the state of Qatar where Sultanate of Oman built Ras Al Had and Madraka Plants, each had a capacity of 22000 gallon/day (100 m3/day).

On the other hand , the State of Qatar built Abu Samra Plant with a capacity of 149600 gallon/day (680 m3/day). RO was introduced in 1984 in the Kingdom of Bahrain when the first plant "Ras Abu Jarjur" was built to desalinate salty well water. The Plant had a capacity of 10 MIGD (45454.5 m3/day). In 1979, the state of Kuwait, built Al Doha reverse osmosis (RO) plant for the purpose of research and development. The study of RO process was carried out in order to achieve the lowest production cost and best quality of desalinated water. The trial results concluded that RO process could be used in Kuwait to desalinate sea water with high efficiency and reliability.

Since Kuwait has a natural source of low salinity underground water, it was decided to use this technique to transform a part of it into drinking water in emergency cases. Therefore, in the year 1987 a total of thirteen RO units were installed and operated; each has a capacity of 250000 gallon/day (1136 m3/day) and they were distributed on strategic locations such as hospitals, army camps and social care centers. Further, in the year 1993 an additional 20 similar RO units were built to desalinate low-salinity water and located near water reservoirs and pumping stations.

Most of the RO units in the GCC countries are located in UAE, KSA and Sultanate of Oman. They have varied production capacities and used to desalinate underground salty water and sea water which was found to be the best option to provide drinking water to small and remote villages. Whereas the largest RO plants which have capacity exceeding 10 MIGD are located in UAE, kingdom of Bahrain and KSA.

Riffa Power & Water Station - Kingdom of Bahrain

Observer of the techniques used in the GCC notes that although RO process reached technical maturity stage which makes it approve technology in majority of the world countries, along with many successful trials to use RO technology in most of GCC Countries, the turnout on this technology to desalinate sea water remains limited. Nevertheless, RO process is the second largest process used in the GCC countries after the Multistage Flash Evaporation in terms of production capacity which reached approximately 23%.

Using MED and VC process were not as common as the other thermal processes such as MSF. However, in 1977, UAE was the first country to introduce MED desalination to GCC countries in Jazirat Abu Mousa Plant with a capacity of 20020 gallon/day (91 m3/day). KSA used the same technique with reheating process in fast Amlaj Units in 1981 where two units were installed with a total capacity of 181500 gallon/day (825 m3/day) which then were shifted to Al Wajh city in 1986. In the state of Qatar, Dukhan Plant was built in 1996 with a capacity of 2 MIGD (9091 m3/day). In 2004, the kingdom of Bahrain first used this technique in Alba Plant which has a capacity of 7 MIGD (31818 m3/day). It seems that the largest production opportunity for this technique is in UAE where there are 9 plants some of which have a capacity of more than 50 MIGD (227273 m3/day).

In 1979, Sultanate of Oman used the VC process in Shaisah Plant which has a capacity of 22000 gallon/day (100 m3/day) followed by Hawar Plant in the kingdom of Bahrain in 1985 with a capacity of 31680 gallon/day (144 m3/day). Except for these two plants, no other VC plants were built in GCC countries. Further, since the phase out of Shaisah Plant, the Hawar Plant remains the only one that works according to this technique in the GCC countries.

As for the other process related to membrane water desalination which is Electrodialysis (ED), the only trial was in Sultanate of Oman in Lima Plant which was built in 1983 and had a capacity of 22000 gallon/day (100 m3/day). Table 2 shows dates of introducing different desalination processes in the GCC countries. The processes used with dates for each of the GCC counties are shown in table 3.

If necessity was the mother of invention, the unique circumstances in GCC countries created the necessity of desalinated water not like any other part of the world. Additionally, with the need there was also the capability of funding the construction of a lot of desalination units. We perceive this as a golden opportunity that the desalination industry has received. As a result, huge improvements had been achieved in the past decades in the design, operation and maintenance of desalination plants

Table 2 – Dates of introducing the different desalination processes to GCC

Technique	Year	Plant	State
MSF	1960	Shuwaikh	Kuwait
RO	1968	Manfouha 3, Shamissi and Almaz	KSA
MED	1977	Jazirat Abu Mousa	UAE
VC	1979	Shaisah (Meeko)	Sultanate of Oman
ED	1983	Lima	Sultanate of Oman

Ras Laffan plant- State of Qatar

which allowed this industry to reach to the point of maturity and reliability to become an available option for many of the world countries now days.

Table 3 - Types of desalination techniques used in each country with date of use.

State	MSF	RO	VC	MED	ED
UAE	1977	1977	-	1977	-
Kingdom of Bahrain	1975	1984	1985	2004	-
KSA	1967	1968	-	1981	-
Sultanate of Oman	1976	1982	1979	-	1983
Qatar	1962	1982	-	1996	-
Kuwait	1960	1987	-	-	-

Sitra Power & Water Station - Kingdom of Bahrain

Part II

Desalination techniques used in the GCC Countries

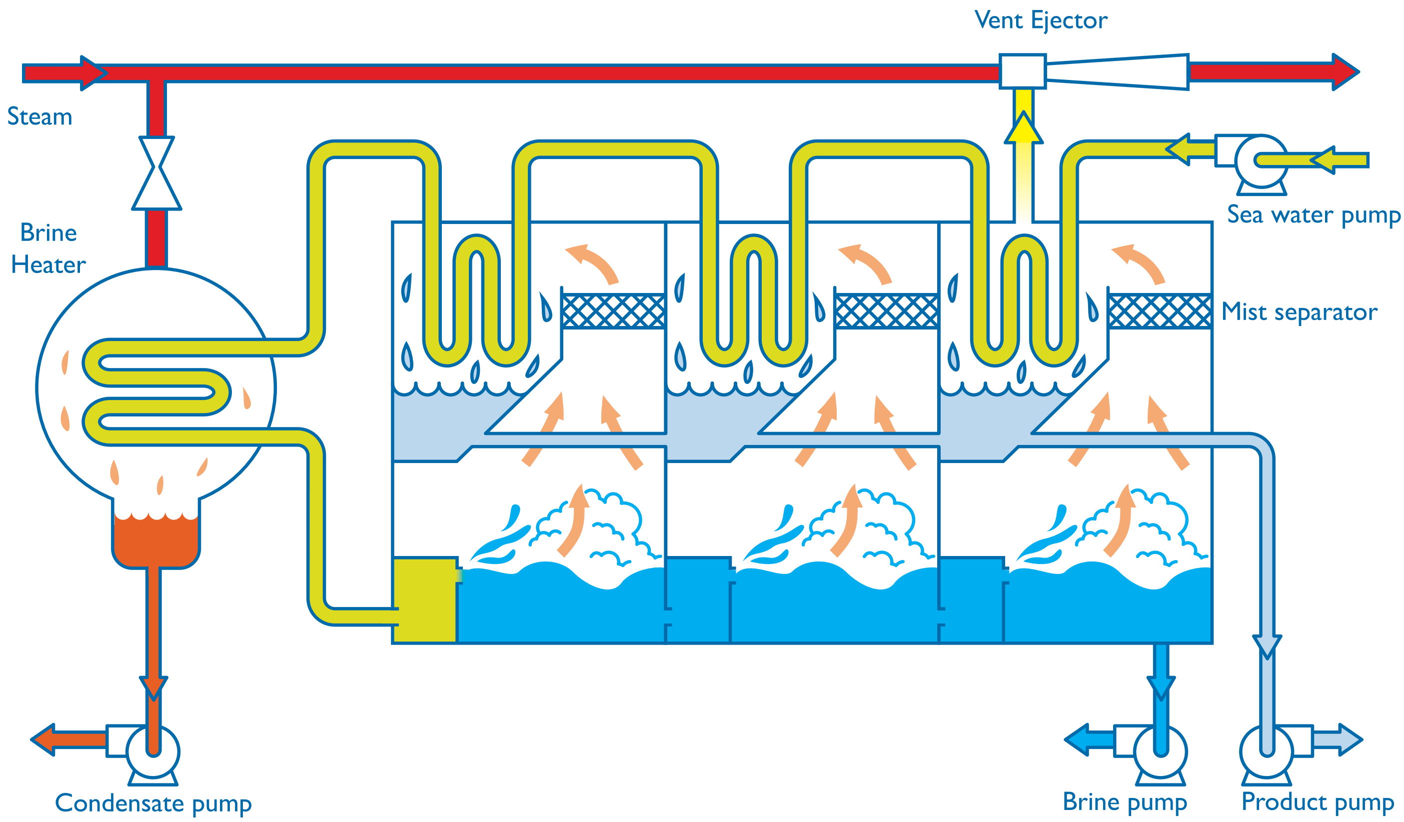
There are many water desalination processes used in GCC and they are divided into two categories, the first category is based on thermal processes while the second category is based on membranes processes.
The following is an explanation on water desalination processes used to produce desalinated water in GCC countries' plants:

Suhar desalination plant - Sultanate of Oman

I. Thermal processes

1- Multi Stage Flashing (MSF)

Figure 3 - MSF illustration



MSF method is used in all the council countries to desalinate sea water and it is usually connected to power plants. The process depends on heating salt water up to a certain temperature between 90 and 120 C in brine heaters. Then the water is pumped to a series of consecutive low-pressure chambers (which are under vacuum), the water flashes as it enters each chamber and produce water vapor at entering temperature of each chamber. Salt water temperature reduces as it passes through the different chambers and hence the vacuum pressure keeps reducing to ensure flash evaporation in all the chambers. The rising water vapor from the chambers gets condensed on outer surface of feed water tube bundle producing desalinated water and also results in preheating the feed water before entering the brine heater which will reduce the energy required for heating.

2- Multiple Effect Distillation (MED)

Similar to MSF, MED is made of multiple stages (or effect chambers) using the principle of reducing the vacuum in different chambers which enables the salt water to boil repeatedly without adding additional heat after the first effect chamber. It is sufficient to use the vapor produced from the first effect as heating source in the second effect when the vapor condenses releasing its latent heat and boiling sea water in the second effect. Hence, the second effect works as condenser for the vapors coming from the first effect. Accordingly, the third effect works as condenser for the vapors produced from the second effect and the process continues. Therefore, each chamber in that series is called effect. Figure 4 illustrate the main principle of Multi Effect Desalination process which takes place when hot steam is supplied to the first effect tube bundle and latent heat transfer to the thin film of salt water falling by gravity on the outer surface of the tube bundle causing it evaporate and produce water vapor. The produced vapor in the first effect is forced to flow inside the tube bundle of the second effect through demister pads and the process continues in all effects. Water vapor produced in the last stage gets condensed in final condenser which is cooled by sea water and works also as heat reject section for the unit. Part of the sea water at the final condenser outlet is filtered and used as feed water for the different effects by spraying it equally over the tube bundles.

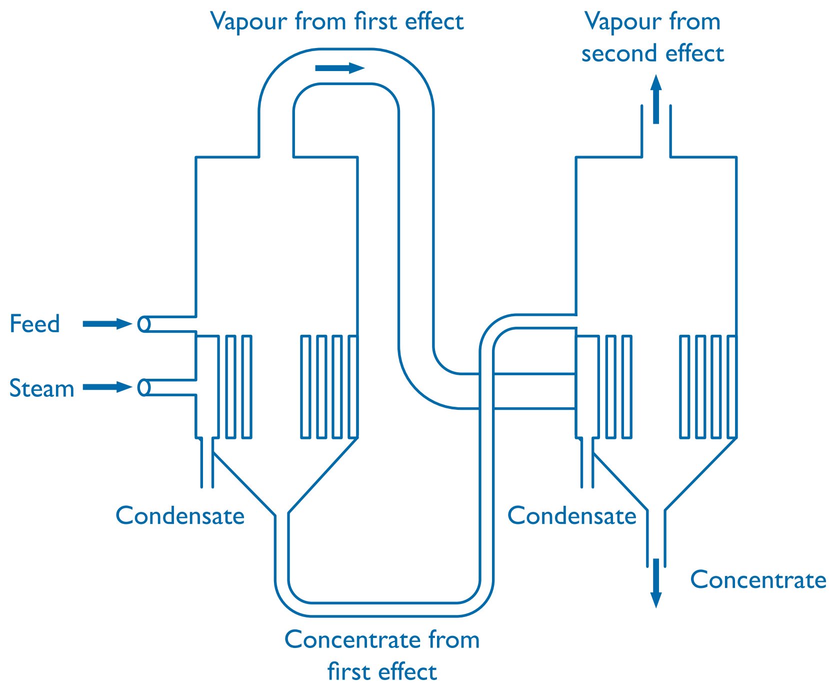


Figure 4 - MED Illustration

3- Vapor compression (VC)

The Vapor compressor VC distillation process is used in small and medium capacity units to desalinate sea water. In general, the capacity of desalination units using compressed vapor process varies between 20-2000 m3/day (4400-440000 gallon/day). This process is often used in tourist resorts, industries and well excavation sites. The heat required for evaporation comes from compressing the vapor instead of direct heat transfer from steam produced in boilers.

In this process, a mechanical compressor driven by electric motor or a steam ejector is used to create vacuum inside evaporation chamber, which will cause the water to evaporate at the feed water temperature. The produced vapor is compressed till its temperature increase and subsequently becoming the source of heat required to evaporate another part of feed water. The pressurized vapor is pumped to the shell side of tubes containing salt water causing the vapor to condense on the outer surface of tubes and also heating the salt inside the tubes producing additional quantities of water vapor which will be compressed again so the cycle will continue to produce condensed water as product water.

Figure 5 – Mechanical VC process schematic

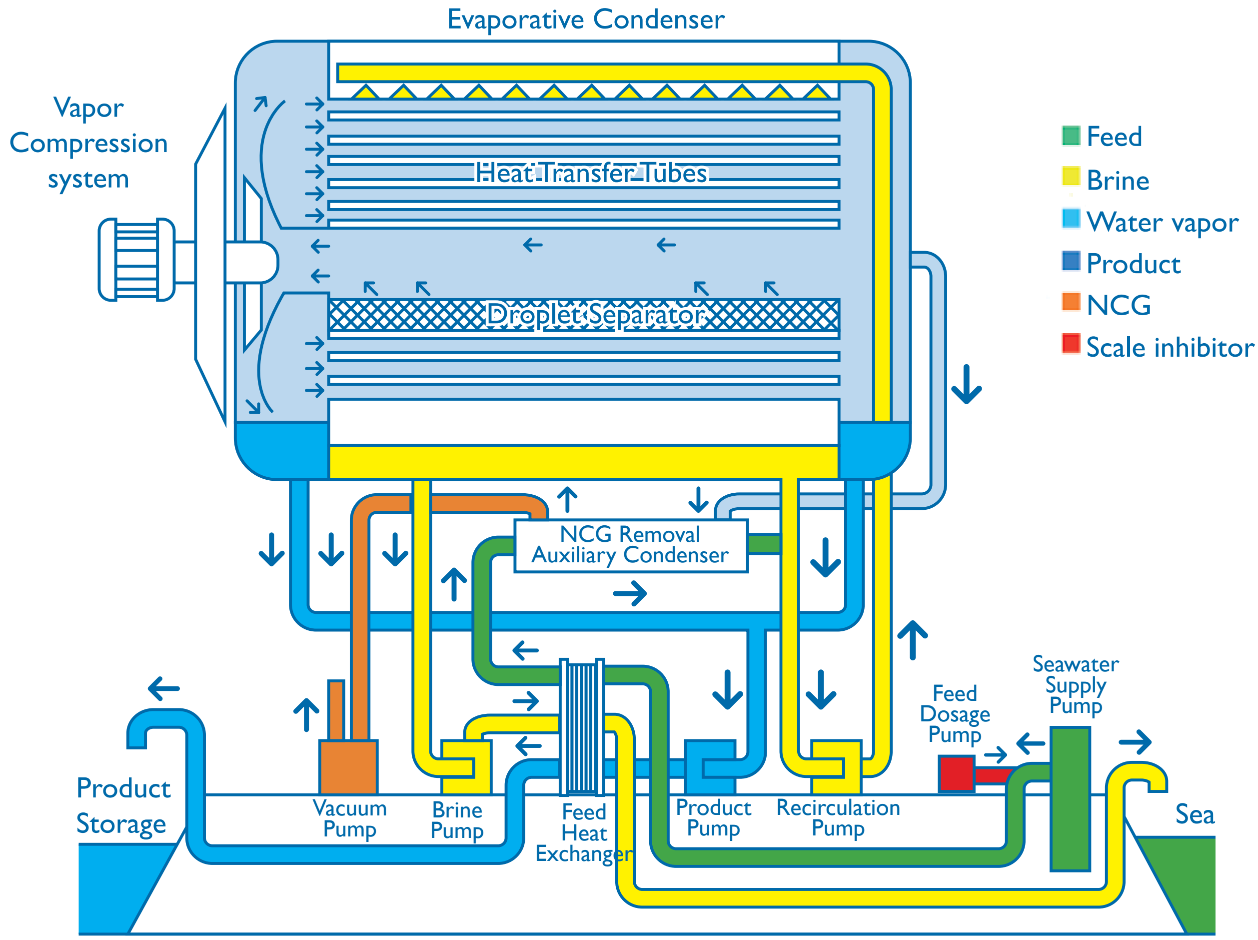
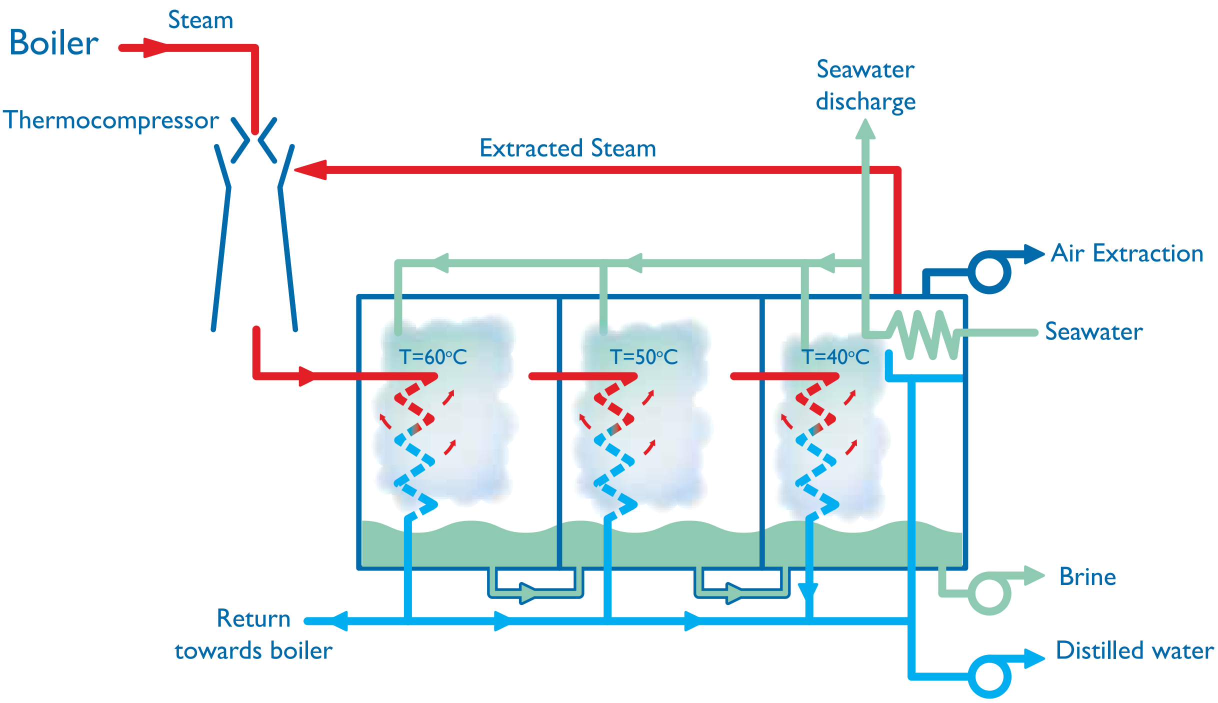


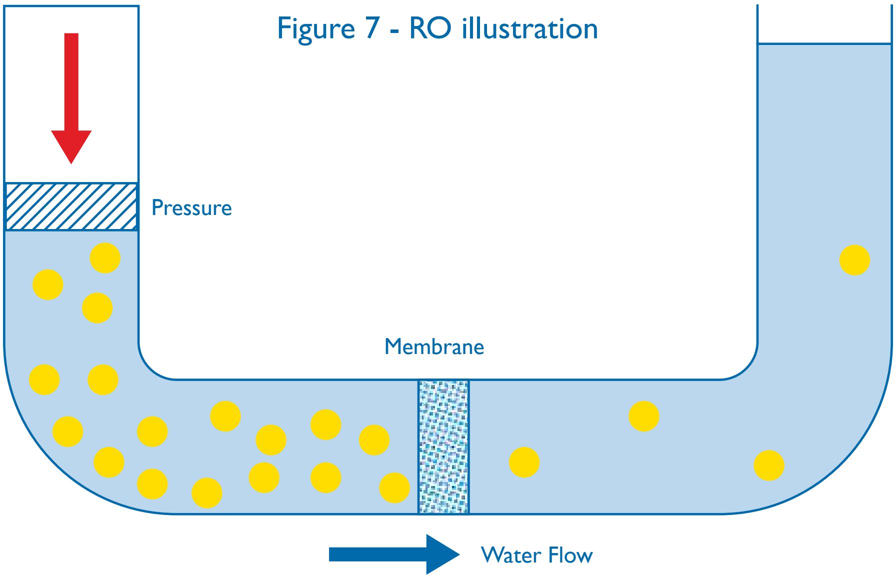
Figure 6 – Reheating Process Schematic



II. Membrane Processes

RO is the process of reverse transfer of water from a high concentration solution to a low concentration solution through semi porous or permeable membrane under the effect of pressure higher than the osmotic pressure applied in the high concentrated solution as shown in figure 7. The membrane made of special polymers is called semi permeable because it allows water molecules to pass through and prevents the passage of salt molecules. The required pressure is obtained by high-pressure pumps. Several factors control the value of required pressure; the most important factors are temperature and salinity of feed water and required production.

Figure 7 - RO illustration



The membranes of RO are made of several types, but there are two widely used types which are Spiral Wound and Hollow Fine Fiber. These two types are used to desalinate both brackish water and sea water.

2- Electrodialysis (ED)

Voltage is used as driving force to move and attract salt through a special membrane that only allows the passage of one type of ions to one electric pole and thus removing the salt and getting fresh water.

It may also be used by applying a certain voltage on two poles one positive and the other negative; so the feed water passes between the poles. Negative and positive ion gets attracted to positive and negative poles respectively while the water passes outside the unit with reduced salinity to an acceptable limit. ED effectively purify water with low salinity (up to 2000 ppm).

Figure 8 - ED illustration

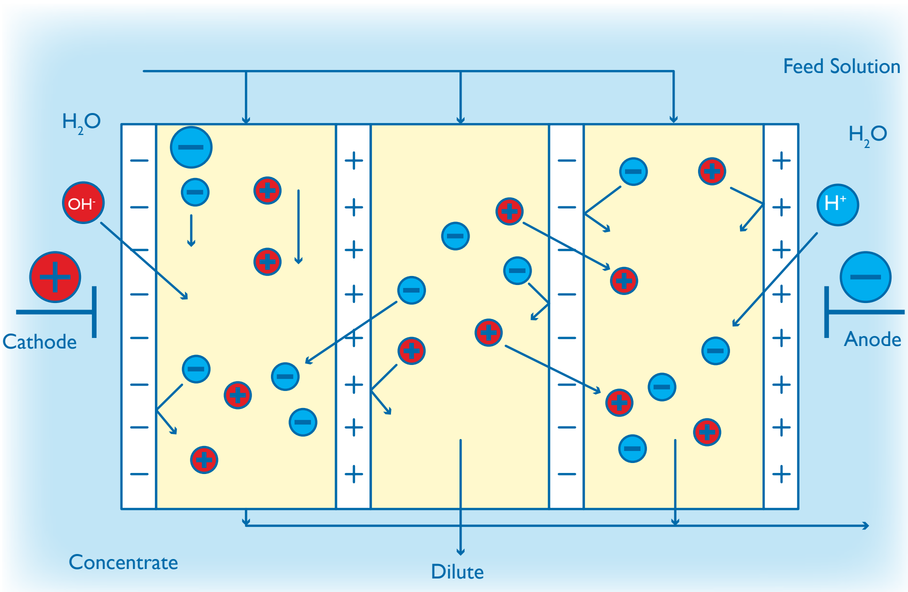


Figure 8 - Forms of ED membranes

Part III

Current status of Desalination in the GCC countries

GCC countries currently depend on desalination as a main source of drinking water as the desalinated water represents 80% of total drinking water whereas the rest of the quantity comes from underground waters. Rainfalls considered as a limited source of water in KSA. As on year 2008, the total desalination capacity in GCC countries was 14.84 million m^2 /day (3265 MIGD), and it is distributed as follows: 39.4 % in KSA followed by 32.8% in UAE, then 13% in the State of Kuwait, followed by 7.2% in the State of Qatar, then 4.5% in the Kingdom of Bahrain followed by 3.1% in Sultanate of Oman (see figure 9).

The desalinated water is produced from 199* desalination plants distributed on the coast of the Arabian Gulf, the Red Sea, and the Arabian Sea as well as numerous locations away from sea. Most of which have smaller production capacity not exceeding 10 MIGD and forms 63% of the overall desalination plants. However, there are 6 stations which represent 3% of the total number of desalination stations but can be described as giant stations as their production exceeds 100 MIGD. These are Al Shuwaihat and New Qadfa'a in UAE, Al Jubail 2 in KSA, Doha West, Az-zour South and Sabiya in Kuwait. The total productaion of those stations represents 23 % of total desalinated water in GCC countries. Annex 2 contains the list of desalination plants in GCC countries. Annex 3 shows the most important plant sites on map.
Desalination processes used in the GCC countries varies. MSF process is widely used and has the highest contribution

Figure 9 - Percentage of desalinated water production of the GCC Countries for year 2008

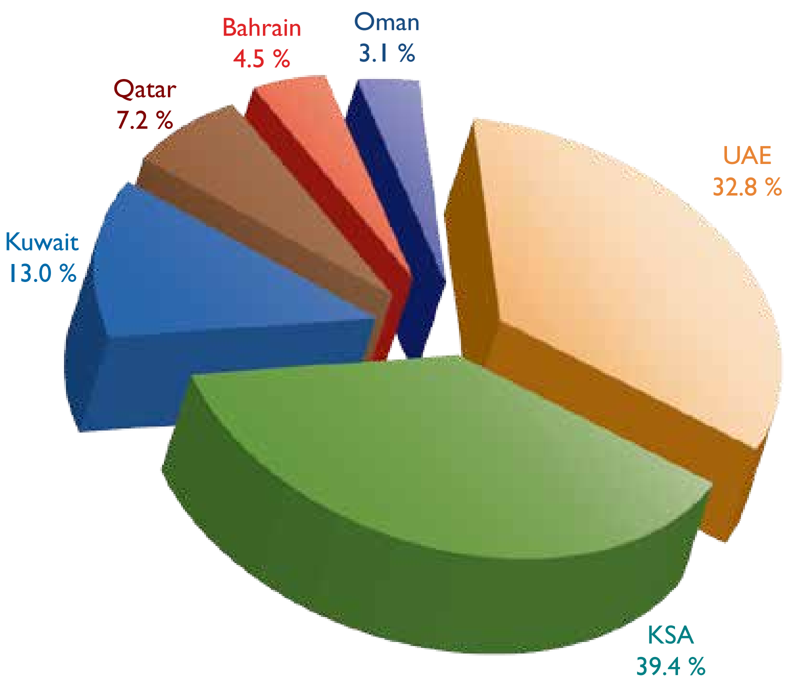
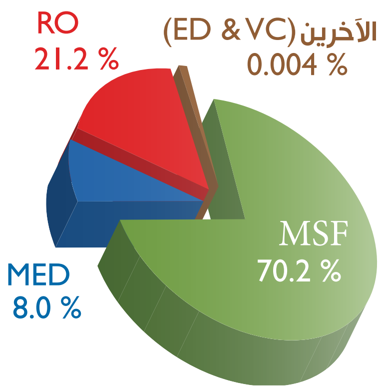


Figure 10 : Percentage contribution of desalination processes used in GCC countries (2012)



rate based on production capacity, 68.8%, among other processes used followed by 23.2% produced by RO process, and 8% produced by MED process. Other processes such as ED and VC are also used and produce less than 0.004% as shown in figure 10. Since year 2000, the new projects in GCC countries showed an increasing confidence in RO and MED processes which may increase their contribution rates to the total desalinated water capacity in the coming years. Table 4 below shows the number of desalination plants and its production capacity for each process in the GCC countries.

* The number does not include all purification (desalination) plants in KSA.

Table 4. Number and types of desalination plants in the GCC countries – 2008.

Process	UAE	Bahrain	KSA	Oman	Qatar	Kuwait	Total
MSF	20	1	18	3	5	6	53
RO	18	2	76	31	2	-	129
MED	8	1	3	-	1	-	13
VC	-	1	-	-	-	-	1
ED	-	-	-	-	-	-	-
Mixed	1MED+RO	1MSF+MED	-	1ED+RO	-	-	3
Total	47	6	97	35	8	6	199

Note: The table does not include small purification (desalination) plants in KSA.

Table 5. Installed Desalination capacity (MIDG) according to the process used - 2008

Process	UAE	Bahrain	KSA	Oman	Qatar	Kuwait	Total
MSF	788	55	649.7	95	233	423.1	2243.8
RO	92.16	26.5	635.5	6.1	0.4	-	760.7
MED	190.02	67	1.61	-	2	-	260.6
VC	-	0.014	-	-	-	-	0.014
ED	-	-	-	0.022	-	-	0.022
Total	1070.18	148.51	1286.8	101.12	235.4	423.1	3265.1

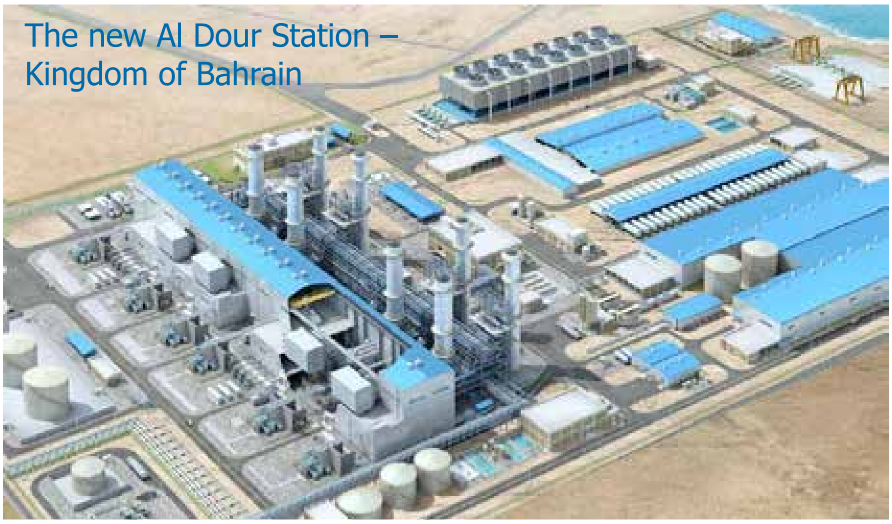

Al Shoaibiya 3 - KSA

It is to be note that most of the desalination stations in the GCC countries use one type of process. Few stations, however, use two different processes which we may call mix Plant as shown in table 4. There is only one plant in the council countries which works with Hybrid process which is the New Qadfa'a in UAE which implies MED and RO processes.

Part IV

Growth of Production Capacities of Desalinated Water in the GCC countries

Under the continuous economic prosperity that has been taking place in the GCC countries during the recent decades, the demand for water, regardless of the great efforts made to rationalize consumption, was increasing rapidly. Therefore, the expansion of desalinated water production through new projects or expanding the existing stations was inevitable due to the continuous shortage in the traditional resources. If we look, for instance, at the desalination projects during the past ten years, we would find that in each year a new station was built in one of the GCC countries, which resulted in a rapid growth of the installed capacity of desalinated water production in those countries (see table 6). The growth rate of desalinated stations production capacity reached 64% from 2000 to 2009, with an annual average growth of 6%. Diagram (11) shows the annual growth of the installed capacity for the desalinated water production in the GCC countries. The diagram also shows that the growth was increasing until year 2006 but slightly decreased in the following years. However, it is expected to increase again according to the desalination projects under construction.

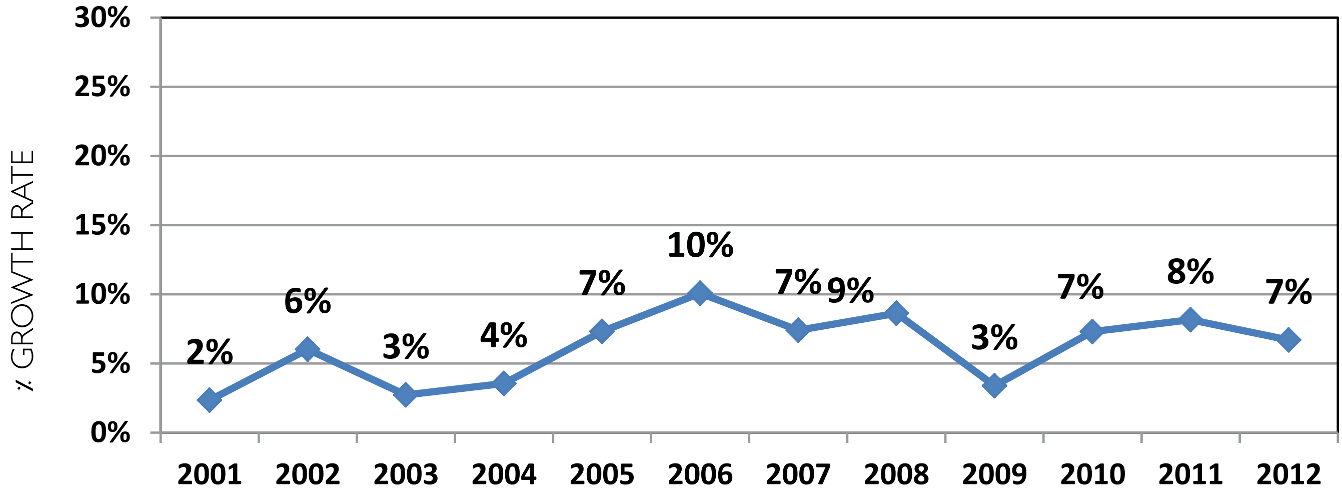


Considering each of the GCC countries separately, the growth (see diagram 7) was not similar. For instance, the UAE has witnessed a clear annual growth of an approximate average of 10% and peaking in 2008 at 20.2%. The case in Qatar was similar as starting from 2004 to 2008, the production capacity was increasing at an average of 17% annually and the maximum growth was in 2008 which reached 28%. Sultanate of Oman, however, witnessed a slight annual growth in most of the years, ranging between 0.004% and 0.4% due to the installation of small capacity RO plants alongside three surges in growth in 2002, 2007 and 2009 at 47%, 52.6% and 47.5% respectively. The State of Kuwait witnessed a slight annual growth of 1% in few years as a result of increasing the capacity of some operating units alongside three surges in 2001, 2006 and 2007 at the rate of 10%, 16.4% and 13.5% respectively. In the Kingdom of Bahrain, the growth increased slightly in 2005 followed by a tremendous increase of 68% in 2006. Finally, the maximum growth witnessed in the KSA was in 2005 at the rate of 7.8%, whereas in the remaining years, the annual growth was approximately 1%.

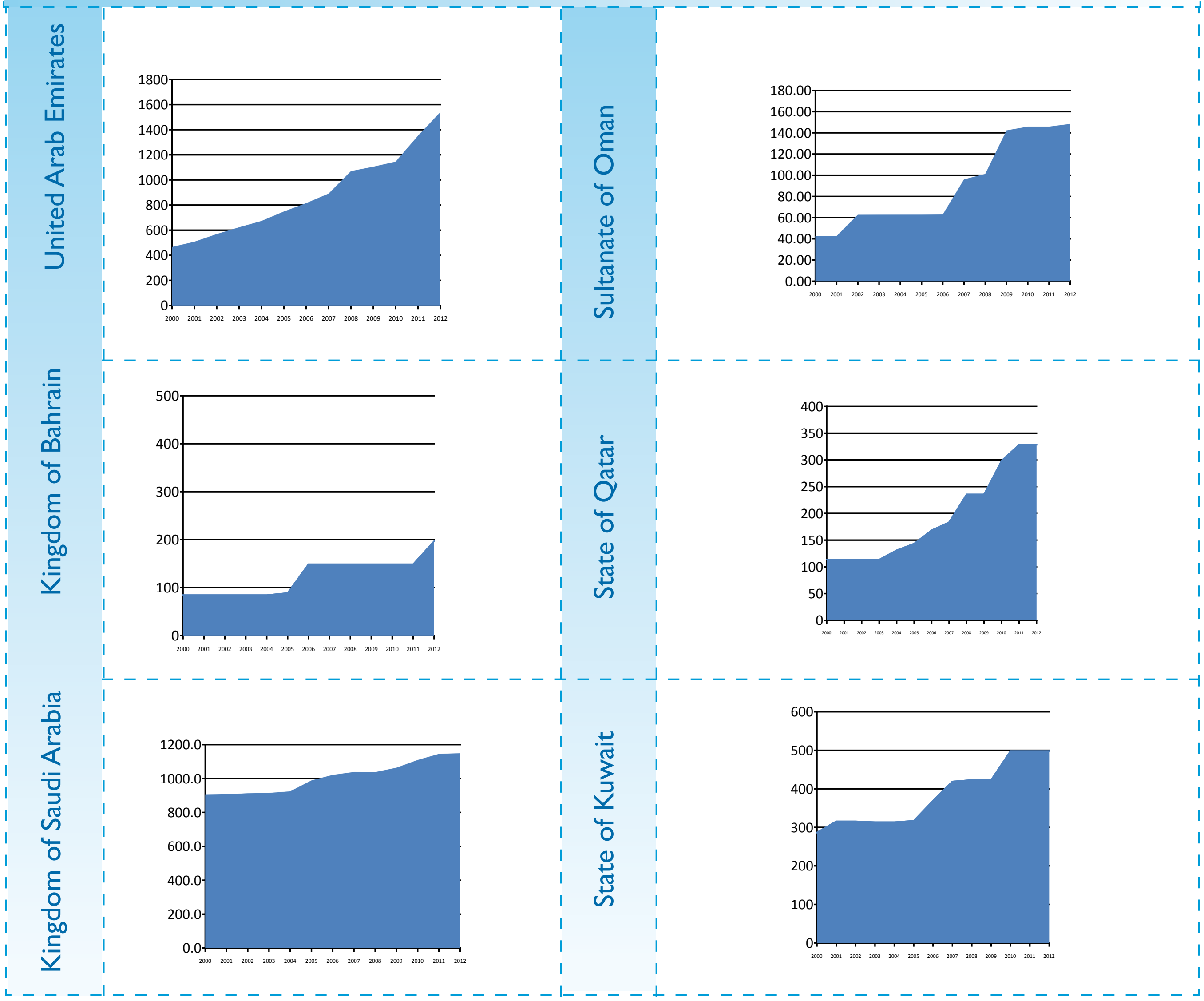
Table 6. Growth of the Installed Capacity for the Desalinated Water Production in the GCC Countries (MIGD)

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
UAE	465.7	507.3	568.6	622.7	672.8	748.1	815.1	890.9	1070	1105
Bahrain	84.1	84.1	84.1	84.1	84.1	88.5	148.5	148.5	148.5	148.5
KSA	903.9	906.4	913.0	914.9	924.2	979.0	1011.6	1028.8	1037.6	1050.2
Oman	42.43	42.56	62.70	62.76	62.78	62.80	62.93	96.06	101.2	142.26
Qatar	113.4	113.4	113.4	113.4	131.0	143.4	168.4	183.4	235.5	235.5
Kuwait	286.8	315.6	315.6	313.5	313.5	317.1	369.1	419.1	423.1	423.1
Total	1896	1941	2057	2113	2188	2339	2576	2767	3016	3105

Diagram 11 - Growth rate in the Desalinated Water Production in the GCC Countries (2000 – 2009)

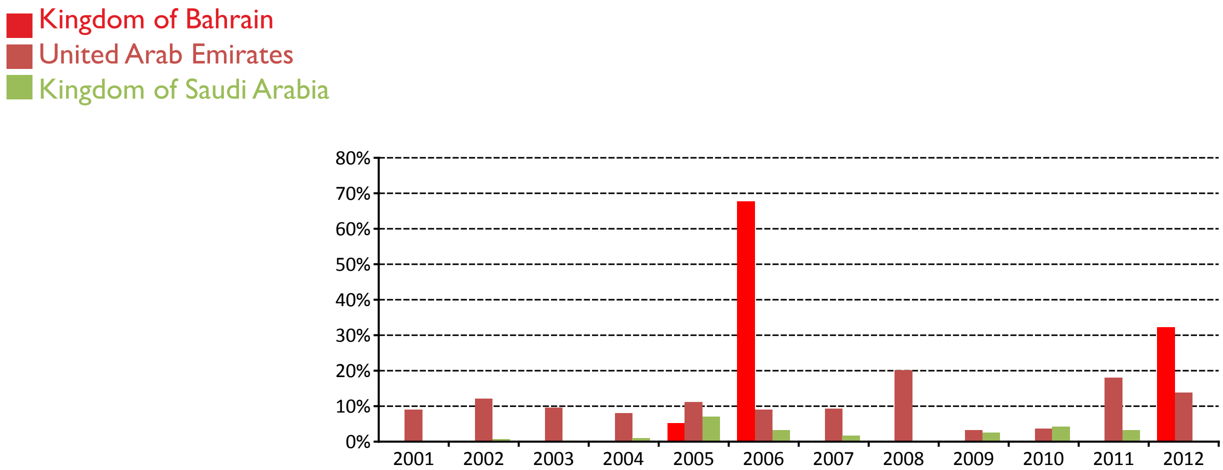


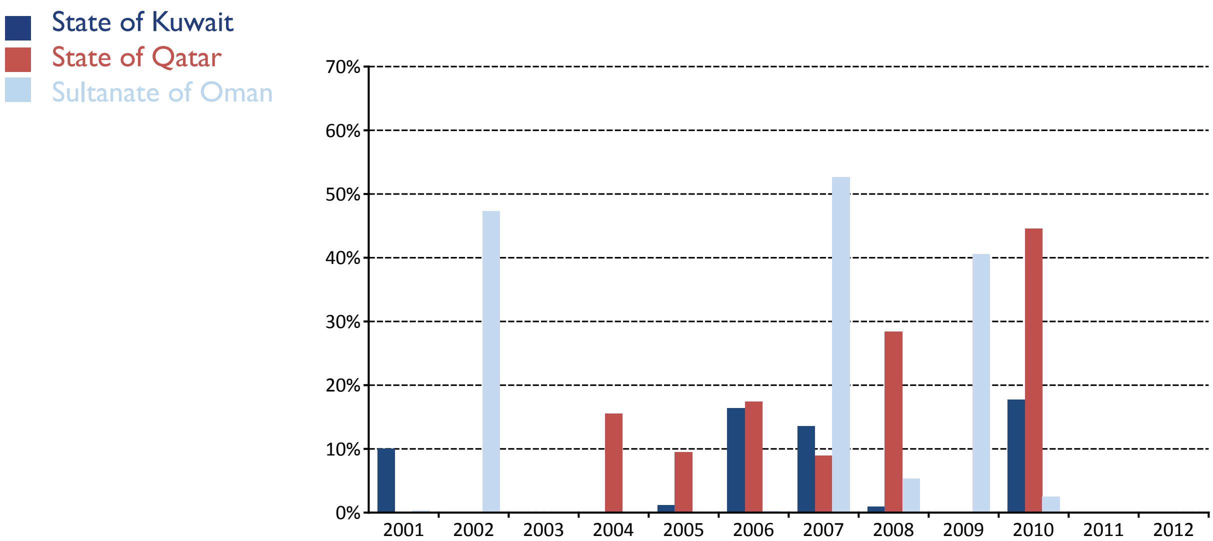
Installed Capacity MIGD



Ras Abu Fontas Station – State of Qatar

Annual Growth Rate





Part V

Future Prediction for the Desalination Stations in the GCC countries

Based on the instructions of their Majesties and Highnesses leaders of the GCC countries and the millennium objectives set by the UN for improving the living standards, availability of drinking water and its accessibility to all citizens and residents are required for implementing the luxury for citizens. In addition, achieving development demands abundance in water supply, which is enough to ensure the trust of the GCC countries infrastructure and to support its economic growth. Therefore, all of the GCC countries currently own a slight surplus in the production of desalinated water, which could be sufficient for some years compared to the demand. The anticipations for the coming twenty years indicate the continuous growth of demand in all the GCC countries, which contributed in setting the mid and long term plans for installing more desalination stations as one of the main possible options alongside the other options, such as utilizing treated sewage and rationalizing consumption, etc.

Table (8) shows the main desalination projects under construction in the GCC countries as on year 2008, which are expected to boost the production capacity in the GCC by around 1103 MIGD (5 million m3 per day) and percentage of 37%. According to the table, only 12% of the new capacity will be produced from MSF and 55% of it will be produced from RO while the remaining 32% will be produced from MED which shows clearly increase usage of RO and MED technics. Also, it can be noted that at least 60% of the new production capacity will be through private projects. There are many future projects at different stages of study and design as shown in table (9).

Liya Station – UAE

Treatment plant (Limestone Filters) – Ras Abu Fontas - The State of Qatar

Equipment & valves – Ras Abu Fontas - The State of Qatar

Table 8 - Desalination stations under construction in GCC countries.

State	Station Name	Capacity (MIGD)	Type of Technology	No. of Units	Operator
UAE	Fujairah (the second)	100	MED + RO		
	Shuweihat (Phase two)	100	MED		
	Al-Leila – Sharjah	8	RO		
	Al-Leila – Sharjah	5	RO		
	Al-hamriya al Jadida	80	RO		
	Sirbonair Island	0.15	RO		
	Khorfakkan – Sharjah	5	RO		
	Kalba'a	3	RO		
	Abu Mousa Island	0.15	RO		
Kingdome of Bahrain	Al dur	48.9	RO		Private
KSA	Al-Wajh- 3	1.98	MED	2	Governmental
	Amlaj- 2	1.98	MED	2	Governmental
	Rabegh - 2	3.96	MED	2	Governmental
	Fersan -2	1.98	MED	2	Governmental
	Al-Qunfuthah	1.98	MED	2	Governmental
	Al-Laith	1.98	MED	2	Governmental
	Jeddah - 3	52.8	RO	16	Governmental
	Al- Shaqiq for water and electricity company	46.64	RO	16	Private
	Al – Shuaibah for water and energy company	193.6	MSF		Private
	Al – Shuaibah for water and energy company	33	RO		Private
	Marafeq company	176	MSF		Private
Sultanate of Oman	Barka'a 2	26	RO	1	Private
	Central Sour	17.6	RO	1	Private
	Al-Ghabra – 2	5	RO	24	Governmental
	Aldaqm	1.32	RO	1	Private
	Sour	0.5	RO	1	Governmental
	Tiwi	0.5	RO	1	Governmental
	Quryat	1	RO	1	Governmental
	Alsifa – 2	0.022	RO	1	Governmental
	Adam – 3	0.099	RO	1	Governmental
	Hima – 3	0.088	RO	1	Governmental
	Alnajda	0.022	RO	1	Governmental
	Deba -2	0.44	RO	1	Governmental
	Hitam – 3	0.055	RO	1	Governmental
	Al-Dhahr	0.088	RO	1	Governmental

Sabiya Station - Kuwait

Tawila Station - UAE

Table 8 - Desalination stations under construction in GCC countries.

State	Station Name	Capacity (MIGD)	Type of Technology	No. of Units	Operator
Sultanate of Oman	Madraqa	0.66	RO	1	Governmental
	Al-khalouf	0.022	RO	1	Private
	Dhalkout	0.11	RO	1	Governmental
	Sadh	0.11	RO	1	Governmental
	Al-mazyouniya	0.132	RO	1	Governmental
	Ben nawatesh	0.44	RO	1	Governmental
	Sharabthat	0.044	RO	1	Governmental
	Mandar al-Dhebyan	0.0088	RO	1	Governmental
	Al-mashash	0.0044	RO	1	Governmental
	Maqshen	0.022	RO	1	Governmental
	Mitn	0.011	RO	1	Governmental
	Bithnah	0.011	RO	1	Governmental
	Al-hashman	0.011	RO	1	Governmental
	Dimit	0.011	RO	1	Governmental
	Rabkout	0.022	RO	1	Governmental
	Rakhaiwit	0.11	RO	1	Governmental
	Al-Shuwaimiya	0.011	RO	1	Governmental
	Barbazoum	0.011	RO	1	Governmental
	Thahboun	0.033	RO	1	Governmental
Qatar	Ras Abo Fontas A-1	45	MSF	3	Private
	Ras Laffan 3	63	MED	10	Private
Kuwait	Shuaiba North	45	MSF		Governmental
	Shuwaikh	30	RO		Governmental
Total		1103			

*these data includes stations executed after 2008 until the issue of this book in 2010, therefore some of the stations have entered into production.

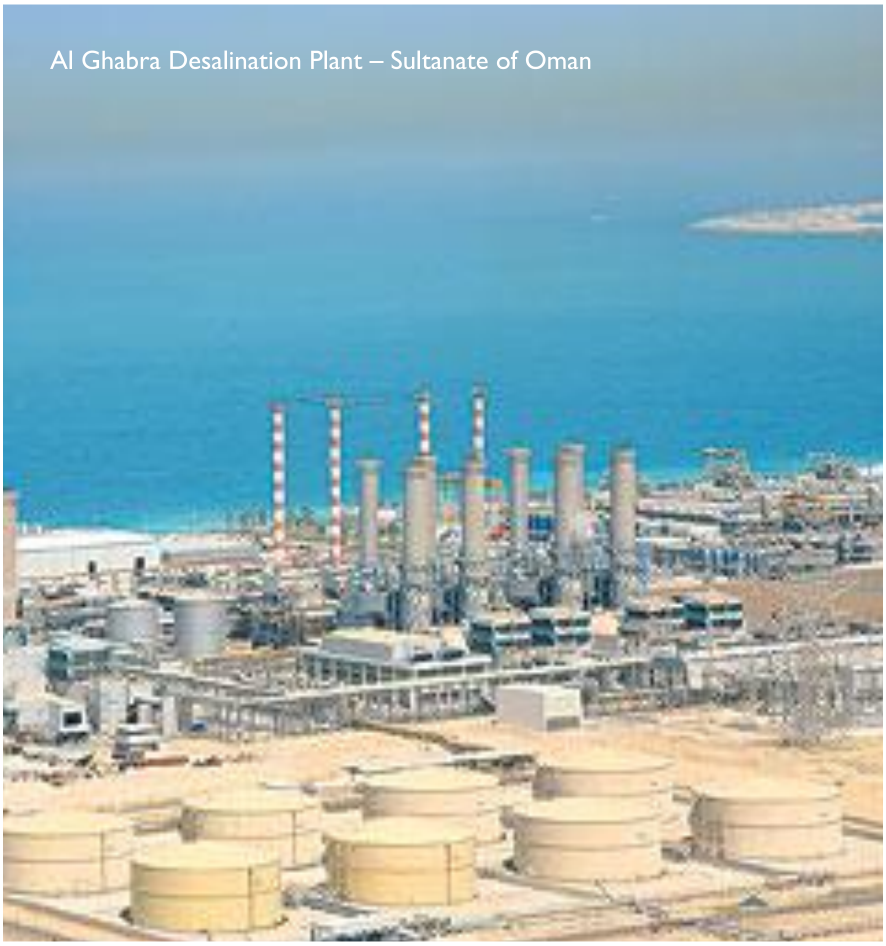
Table 9 – Future projects in GCC countries

Country	Station	Capacity (MIGD)	Technique	Project status
UAE	Al-Shuwaihat Station extension	240 (After extension)	-	Under Study
	Al-Hesyan	140		Under Study
Kingdome of Bahrain	Al-Dur(Phase two)	52		Under Study
KSA	Ras Al-Zour (Phase one)	225.5	MSF	Under Study
	Yanbua'a – Almadena (Phase three)	0.088	MSF	Under Study
	Jeddah RO (Phase three)	0.0528	RO	Under Study
	Al-Shuaibah (Phase three)	226.6		Under Construction
	Al-Shaqiq (Phase two)	0.04664		Under Construction
	Marafiq Company	0.176		Under Design
	Haqil (Phase three)	1.98	MED	Under Design
	Dhaba(Phase four)	1.98	MED	Under Design
	Rabegh expansion (Phase two)	1.98	MED	Under Design
Sultanat Ouman	Al-Ghabra 3	40 TO 30	RO	Under Study
	Al-Jazer	-	-	Under Study
	Al-Daqem 2	1.32	RO	Under Study
	Al-Daqem 2	1.32	RO	Under Study
	Mhout	-	-	Under Study
	Al-kahel 2	0.11	RO	Under Design
	Al-lakbi 2	0.11	RO	Under Design
	Kuhaid	0.011	RO	Under Design
	Al-Khuwaimah	0.066	RO	Under Design
	Lima 2	0.044	RO	Under Design
	Qarn Al Alam	0.022	RO	Under Design
	Al-ouwaifah	0.044	RO	Under Design
	Bakha	0.022	RO	Under Design
	Hima 4	0.044	RO	Under Design
	Al-sail	0.066	RO	Under Design
	Film 2	0.055	RO	Under Design
	Al-najda 2	0.044	RO	Under Design
	Hajj	0.308	RO	Under Design
	Khasab	0.066	RO	Under Design
	Manathef	0.11	RO	Under Design
	Kebout	0.044	RO	Under Design
	Andat	0.011	RO	Under Design
	Tosnat	0.011	RO	Under Design
	Houlouf and Meshailah	0.011	RO	Under Design
	Hasek	0.011	RO	Under Design
Qatar	Existing stations extension	60		Under Study
Kuwait	Az-zour South	30	RO	Under Tendering
	Az-zour North Phase one	102	MSF	Contractors prequalification
	Az-zour North Phase two	102	MSF	Under Study
	Az-zour North Phase three	25	RO	Under Study

Part VI

Privatization of Desalination projects in the GCC countries

This part highlights privatization of desalination projects in general in order to put the reader to the progress of desalination industry in GCC countries. Due to the challenges and difficulties imposed by the funding of water desalination projects, the GCC governments headed towards involving the private sector in building desalination stations financed and owned completely or partially by the privet sector. Privatization in GCC countries started in Qatar through establishing Qatar Electricity and Water Company in 1990 A.D.; with its first project of Ras Abu Fontas – B station in the same year. In 2003, two more stations were privatized, Ras Abu Fontas - A and Dukhan stations. It is worth mentioning that all desalination stations built in Qatar after 1990 are established by the private sector. On the other hand, Privatization projects in the UAE and the Sultanate of Oman, were running in parallel with the development of the public sectors projects. So that, although some of the new water desalination projects were awarded to the privet sector, the governments, however, continued to execute its own projects. The first private sector project in the UAE was in 1998 through CMC the Emirati Company, while Barka'a in the Sultanate of Oman was the first private water desalination station established in 2003 by AES Company. The Kingdom of Bahrain privatization experience, however, falls between the experiences of Qatar from one side and the Emirati and Sultanate of Oman from the other side. While the State retained the ownership and operation of the existing stations, construction of new stations were assigned to the privet sector. The first privatization experience in the



Al Ghabra Desalination Plant – Sultanate of Oman

Kingdom of Bahrain started with the transfer of ownership of Al-Had station to the private sector in 2006 as part of constructing the third phase in the station with a capacity of 90 MIGD. The construction of facility was completed in 2008 and called Al-Had power company after privatization.

Based on the resolution number (2/92), KSA converted in the Year 2008 (1429 H) the Saline Water Conversion Corporation (SWCC) into a holding joint-stock company fully owned by the state. The purpose of this new company is to regulate production companies of existing and proposed stations which will be opened for privet sector investors and developers for not less than 60% ownership by the privet sector for each company.

Al Shuaibah Water and Power Company was the first private project which is currently constructing desalination plant with a capacity of 226.6 MIGD. Whereas in the state of Kuwait and according to the law number 37 for the year 2010 concerning the organization of privatization programs and operations, the Ministry of Electricity and Water presented the project of Az-zour North (1500 MW, 100 MIGD) to the private sector through establishing a joint stock company. Therefore, it is considered as the first privatization project in water desalination field. The Ministry has also a plan for further projects in this field which will lead to the transfer of ownership of the existing Power and Water Stations to the private sector after evaluating the capital value of each station and selecting the suitable station to privatize.

Appendices

Appendix 1: Chronology of water desalination admission to the GCC Countries and important events

1900 | 1910 | 1920 | 1930 | 1940 | 1950

1907
KSA
Al Kandassa - Jeddah
Establishment of Al kandassa desalination units using submerged pipeline technique.

1928
KSA
Al Kandassa - Jeddah
Updating and Replacing of the units.

1953
Kuwait & Qatar
Construction of Stations working on the principle of submerged pipe in Ras Aboabboud and Shuwaikh

1957
Kuwait
Shuwaikh Station
Establishment of the first Flash Evaporation station in the GCC.

1960
Kuwait
Shuwaikh E1 & E2
First experience for a Multi Stage Flash desalination technique.

1968
KSA
Manfouha 2, Al Shumaisi and Al Milz
Establishment of first station working through RO technique in GCC countries.

1977
UAE
Abu Mousa Island
Establishment of first station working through multi effect evaporation technique in GCC countries.

1979
Sultanate of Oman
Shaisa
First station working on steaming pressure in GCC countries (phased out).

1983
Sultanate of Oman
Lima station
Establishment of the first and only station operating on electro dialysis in GCC countries.

1985
Kingdom of Bahrain
Hiwar
The only station operating on steaming pressure technique in GCC countries.

1990
Qatar
Ras Abu Fontas B
First private station in the GCC countries.

1960	1970	1980	1990	2000

Appendix 2: List of desalination stations in GCC countries (2008 AC)

Operating Stations in United Arab Emirates

Plant	Capacity		Technology	Units No.	Commissioning year
	MGPD	m3/day			
Abu Dhabi Steam Station	15	68182	MSF	4	1977
Abu Moussa Island	0.05	227	MED		1977
AJMAN	9	40909	MED	5	2000
AJMAN-	3.2	14545	RO	4	1994
Al Hamariah	1.15	5227	RO		1995
Al Hlyow	0.07	318	RO	3	1994
Al Layyah	63.5	288636	MSF+MED	10	1981
Al Mirfa	39	177273	MSF	3	1996
Al Saja'a	5.5	25000	RO	5	2000
Al Zawra1	6	27273	RO		2008
Al Zawra2	3	13636	RO		2012
Al Zawra3	7	31818	RO		2012
ALqoua	0.15	682	RO		
ALwajan	0.35	1591	RO		
Al-Zibair	0.11	500	RO		2004
Burairat	1.2	5455	RO	2	1977
Fujairah F1	102	463636	RO +MSF		2005
Fujairah F2	132	600000	MED+ RO		2010
Ghalilah	3	13636	RO	3	2005
Jebel Ali (RO) G	25	113636	RO	9	2007

Plant	Capacity		Technology	Units No.	Commissioning year
	MGPD	m3/day			
Jebel Ali D	35	159091	MSF	8	1979
Jebel Ali E	25	113636	MSF	4	1989
Jebel Ali G	60	272727	MSF	9	1993
Jebel Ali K	60	272727	MSF		2000
Jebel Ali L	125	568182	MSF		2005
Jebel Ali M	140	636364	MSF		2011
Kalba plant	7.3	33182	MED+RO	3	1995
KFK plant	5	22727	RO	1	2009
NAKHEEL	16	72727	MED	6	1998
S1-SHUWEIHAT	101	459091	MSF	6	2004
S2-SHUWEIHAT	101	459091	MSF		2011
Seir BuNeir Island	0.015	68	RO		2002
Taweelah A1	85	386364	MSF +MED		2001
Taweelah A2	51	231818	MSF	4	2002
Taweelah B 1	70	318182	MSF	6	1995
Taweelah B2	23	104545	MSF	3	2000
Taweelah NEW EXTENSION	69	313636	MSF		2008
UAQ- A	2.5	11364	RO	5	1985
UAQ- B	2.5	11364	RO	5	2005
UM ALzmoul	0.25	1136	RO		
Umm Al Nar	145	659091	MSF+MED		1979
Total	1539.85	6999295			

Appendix 2: List of desalination stations in GCC countries (2008 AC)

Operating Stations in Sultanate of Oman

Plant	Capacity		Technology	Units No.	Commissioning year
	MGPD	m3/day			
Abu Mudhabi	0.055	250	RO	2	1985-2012
Adam	0.372	1691	RO	3	1997-2009
Al Ghubrah-1	42	190909	MSF	7	1976-2001
Al Ghubrah-2	5	22727	RO	24	2010
Al Najdah-1	0.022	100	RO	1	2008
Al Najdah-2	0.044	200	FO	1	2012
Alkahal	0.017	77	RO	1	2006
AlKhalouf	0.022	100	FO	1	2010
Alkhiran	0.033	150	RO	1	2003
Alkhulouf	0.022	100	RO	1	2007
Alkhuwaiymah	0.088	400	RO	2	2001-2012
Allakbi	0.022	100	RO	1	2005
Alsa'adanat	0.033	150	RO	2	1985-2001
Alsail & Al Ramlah	0.022	100	RO	1	2004
Alsifah	0.022	100	RO	1	2003
Alzahiya	0.022	100	RO	1	2001
Bamah	0.132	600	RO	2	2002-2012
Barka ACWA	20	90909	MSF	3	2003
Barka SMN	26	118182	RO	1	2009
Dibba	0.88	4000	RO	2	2008-2012
Eshairgah	0.022	100	RO	1	1995

Plant	Capacity		Technology	Units No.	Commissioning year
	MGPD	m3/day			
Film	0.055	250	RO	1	2012
Fins	0.022	100	RO	1	2002
Haima	0.132	600	RO	1	1995-2009
Hamra'a Al dorou'	0.264	1200	RO	1	2008
Hijj	0.396	1800	RO	2	1995-2012
Hitam	0.044	200	RO	1	2012
Khumkham	0.022	100	RO	1	1995
Kumzar	0.077	350	RO	2	1996-2012
Lima	0.066	300	RO+ED	2	1983-2008
Madraka	0.11	500	RO	2	2007-2010
Musairah	0.726	3300	RO	3	2001-2008
Qarn Alalam	0.044	200	RO	1	2001-2012
Qurayat	1.5	6818	RO	2	2010-2012
Ras Alhad	0.11	500	RO	1	2006
Sarab	0.066	300	RO	1	2012
Sheesa	0.044	200	RO	3	2008
Sohar	33	150000	MSF	4	2007
Soqrah	0.066	300	RO	2	1998-2012
Sur	16.7	75909	RO	1	2010
Zahar	0.121	550	RO	3	1985-2010
Total	148.395	674522.7			

Appendix 2: List of desalination stations in GCC countries (2008 AC)

Operating Stations in KSA

Plant	Capacity		Technology	Units No.	Commissioning year
	MGPD	m3/day			
ALJubail 1	30.30	137727	MSF	6	1982
ALJubail 2	208.536	947891	MSF	40	1983
ALJubail RO	20	90909	RO	15	2000
AL- Khobar 2	49.060	223000	MSF	10	1983
AL- Khobar 3	61.600	280000	MSF	8	2000
AL- Khafji 2	5.035	22886	MSF	2	1986
Hagl 2	0.968	4400	RO	4	1990
Duba 3	0.968	4400	RO	4	1989
AL- Wajih 3	1.980	9000	MED	2	2009
Umlujj 2	0.968	4400	RO	2	1986
Umlujj 3	1.980	9000	MED	2	2009
Rabigh 2	3.960	18000	MED	2	2009
AL- Azizia	0.990	4500	MED	3	1987
Jeddah 3	19.439	88359	MSF	4	1997
Jeddah 4	48.747	221577	MSF	10	1982
Jeddah RO1	12.496	56800	RO		1989
Jeddah RO2	12.496	56800	RO		1994
Yanbu 1	23.776	108073	MSF	5	1981
Yanbu 2	31.680	144000	MSF	4	1998
Yanbu	28.200	128182	RO	15	1998
AL- Shuaiba 1	49.060	223000	MSF	10	1989
AL- Shuaiba 2	100.000	454545	MSF	10	2001
Farasan 2	1.980	9000	MED	2	2009
AL- Qunfutha	1.980	9000	MED	2	2008
AL- Lith	1.980	9000	MED	2	2009
AL- Shuqaiq	21.343	97014	MSF	4	1989
SWCC Total	740	3361463.636			

Operating Stations in State of Qatar

Plant	Capacity		Technology	Units No.	Commissioning year
	MGPD	m3/day			
Ras abufentas A	55	250000	MSF	12	(1977-1983) (1994)
Ras abufentas B	33	150000	MSF	5	1997-1998
Ras laffan A	40	181818	MSF	4	2003-2004
Ras laffan B Qatar Power	60	272727	MSF	4	2006-2008
Abu samra	0.2	909	RO	1	1982
Qaeedat alshamal	0.2	909	MSF	1	1993
Ras abufentas A1	45	204545	MSF	3	2010
Ras abufentas B2	30	136364	MSF	2	2008
Ras Qertas	63	286364	MED	10	2010-2011
Dukhan	2	9091	MED	2	1997
Total	328.4	1483636.364			

Appendix 2: List of desalination stations in GCC countries (2008 AC)

Operating Stations in Kuwait

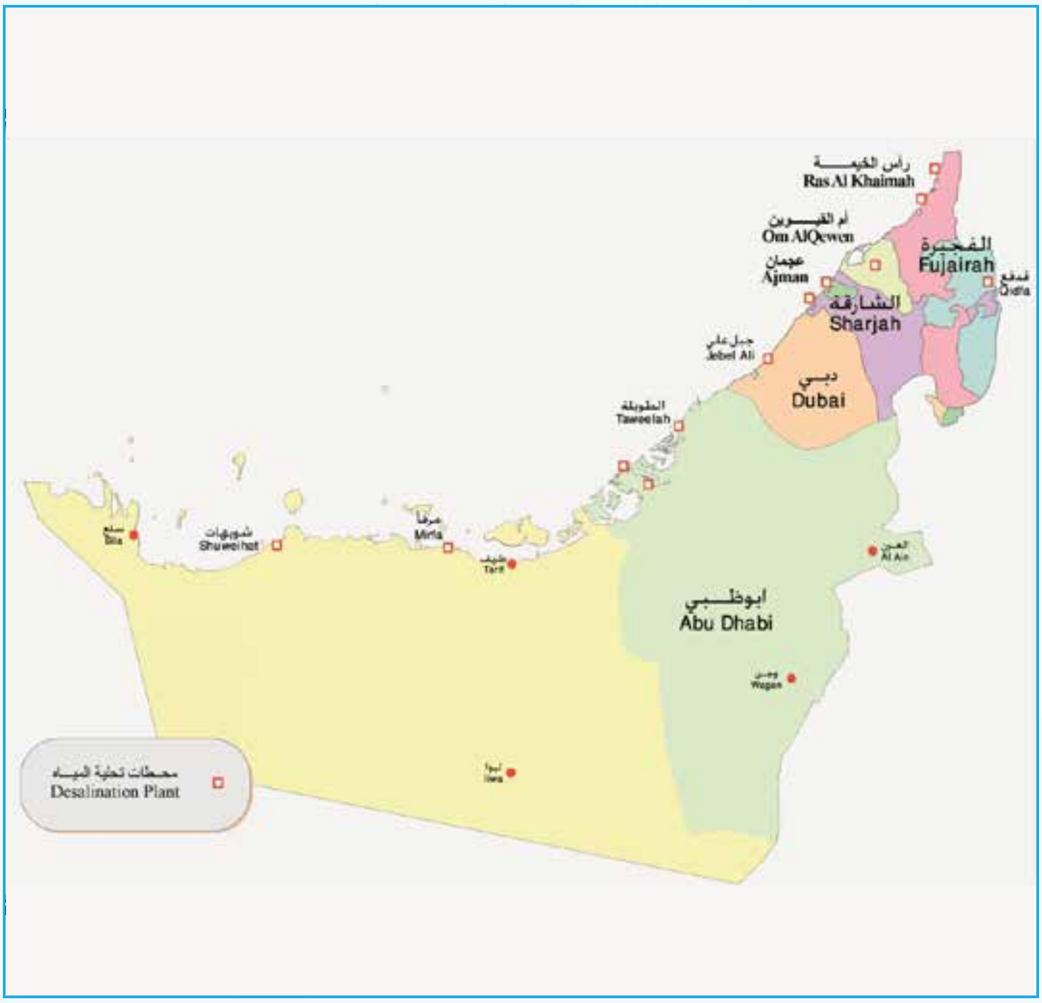
Plant	Capacity		Technology	Units No.	Commissioning year
	MGPD	m3/day			
Shuaiba South	36	163636	MSF	6	1971-1975
Doha East	42	190909	MSF	7	1978-1979
Doha West	110.4	501818	MSF	16	1983-1985
Al showiakh	49.5	225000	MSF+RO	3	1982-2011
Shuaiba North	45	204545	MSF	3	2011
Az Zour South	115.2	523636	MSF	16	1988-2001
Sabiya	100	454545	MSF	8	2006-2007
Total	498.1	2,264,091			

Operating Stations in Kingdom of Bahrain

Plant	Capacity		Technology	Units No.	Commissioning year
	MGPD	m3/day			
Sitra	25	113636	MSF	5	1975-1985
Ras Abujarjur	16.5	75000	RO	10	1984
Addur	10	45455	RO	8	1989
Alhid	90	409091	MSF+MED	4+10	2000-2005
Alba	7	31818	MED	4	2004
Hawar	0.01368	62	VC	2	1985
Addur PWC	48	218182	RO		2011
Total	196.51	893244			

Appendix 3: Location of the main desalination stations on the map

United Arab Emirates



Kingdom of Bahrain

Appendices

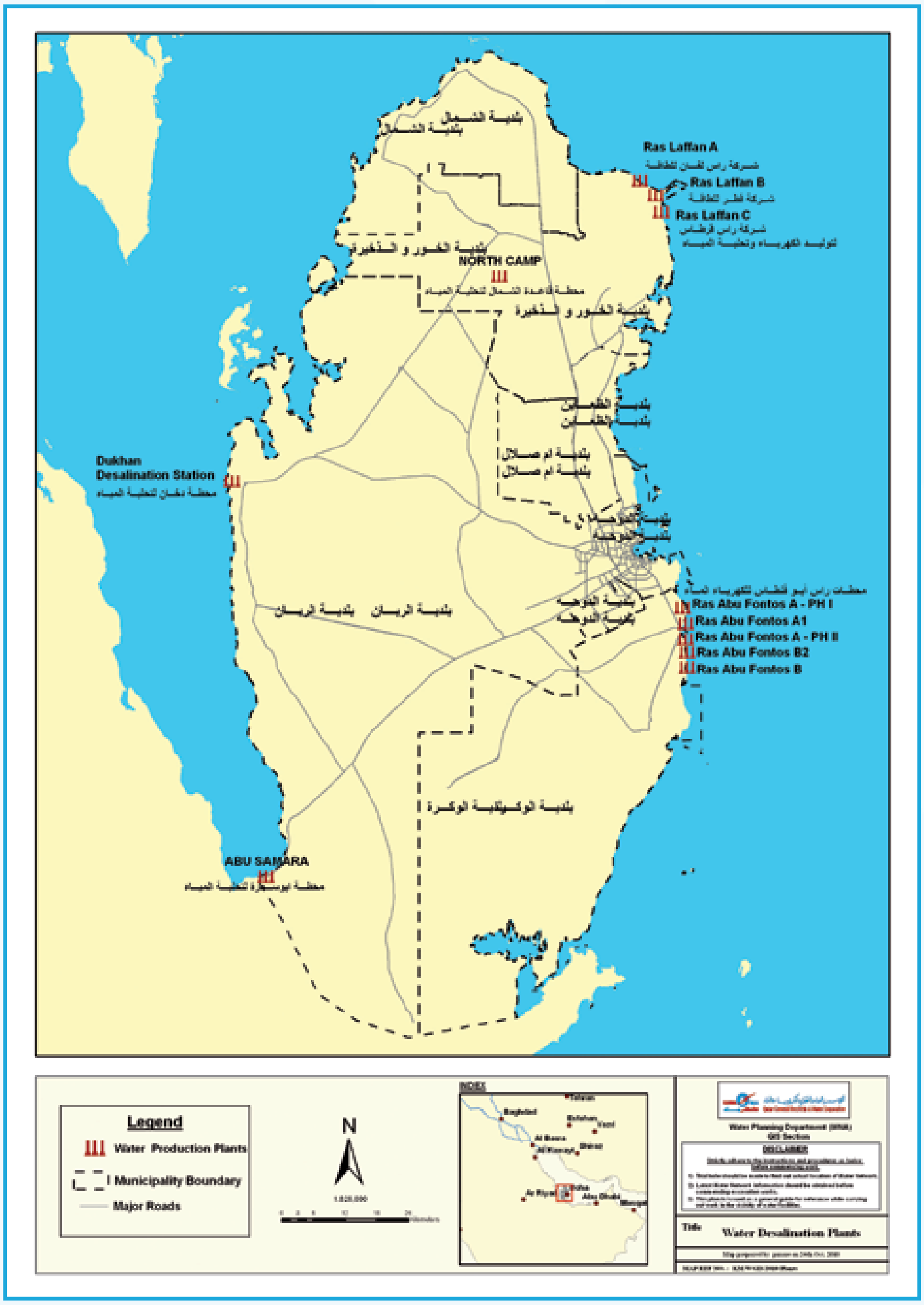
Appendix 3: Location of the main desalination stations on the map

Kingdom of Saudi Arabia

Sultanate of Oman

Appendix 3: Location of the main desalination stations on the map

State of Qatar



State of Kuwait