How water scarcity will effect the growth in the desalination market in the coming 25 years

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Abstract

Desalination technology is finding new outlets in supplying water to meet growing municipal domestic consumption needs in water scarce countries with a per capita availability below 1,000 m^3/y. An expansion of the current municipal water desalination market was related to the population growth and the groundwater scarcity in the coming 25 years in various regions of the world: Europe, The Caribbean, South East and Western Asia, GCC States and North Africa. First, the current impact of desalination on the renewable groundwater resources in these selected areas was determined. Results indicated, that the desalination capacity exceeds 2-10 times the renewable groundwater resources in Qatar, Kuwait, Malta and Saudi Arabia, 10-50% in Libya and Barbados, and less than 0.5% in Jordan, Yemen and Singapore. In the future, a population growth from 51-116 million, 1995-2025, was assumed to be the driving force determining the need for desalination in order to maintain the current urban municipal domestic water consumption (an average of 0.265 m^3/cap/d) in these countries. By 2000, a total sea and brackish water desalination capacity of 7.3 million m^3/d was installed for municipal purposes in these countries. This indicated a growth in the desalination capacity of 1.9 million m^3/d, 35%, between 1995 and 2000. By 2025, the growth in the municipal water desalination market will need to reach 14.8 million m^3/d, 200%, to maintain the current urban municipal domestic water needs and to prevent any decline in renewable groundwater resources in the 10 water scarce countries selected in this study.

Keywords: Water scarcity, Population growth, Municipal water, Desalination, Projections in desalination market.

1. Introduction

Currently, there are 18 countries classified as water scarce (i.e. their per capita yearly fresh water resources are below 1000 m^3/cap/y). The majority of these countries are in the Middle East and northern Africa, however, a few countries are found in Europe, Asia and the Caribbean. By 2025, approximately 29 countries in the world are expected to experience water scarcity, particularly due to the expected increase in population, which will roughly double in regions where severe water shortages already exist, e.g. the Middle East and northern Africa. Future trends in rapid population growth and a significant shift to urban areas will aggravate the existing water shortages in these countries because of increasing fresh water withdrawals for municipal use and agriculture. Desalination, along with wastewater reuse and water importation, can provide a means of increasing the supply of available fresh water in the regions of the world where water is scarce.

Once considered as an expensive last resort solution for marginal municipal domestic and industrial water supply, desalination technology is becoming increasingly affordable. It is finding new outlets in water scarce regions where it was never previously considered as a viable long term resource, e.g. providing alternatives to major water transport schemes, supplying water to meet growing domestic consumption and supplying water to sea resorts. The difference between the cost of desalted water and that of conventional supplies has narrowed dramatically in the past 10 years. Current prices quoted for desalinated brackish water are US$0.2-0.35/$m^3$ and those for seawater are US$0.7-1.2/$m^3$ today. Moreover, the cost is expected to drop below US$0.5/$m^3$ in the near future. A cost comparison of new supplies from non-conventional sources, performed recently in the Middle East region, indicated seawater desalination at a comparable price to water importation by a tanker and cheaper by a factor 2-3 of that to a distance water transportation using pipelines. Desalination of seawater may become an important alternative to increasing the supply of available water in the region of the Middle East, where severe water shortages exist.

In the next decades, a dramatic shift in population from rural to urban areas is expected. By 2025, the number of people living in cities is expected to increase by 1.7 billion new residents, while large housing projects in newly developed urban centres will require additional water supplies. These circumstances may sharply increase the competition between water allocation for municipal use and agriculture irrigation needs, especially in the regions of the world experiencing water scarcity. Currently irrigated agriculture is the leading user of water, accounting for 70% of the world's withdrawals. However, in some countries this share can be even higher and exceeds 90%. In the future, agriculture will undoubtedly remain the largest water user in the light of the rapidly growing population and the concern of food security. However, in the foreseen future, limited use of desalination can be expected in large-scale agriculture irrigation projects due to prohibitively high costs. Use of desalinated water is increasingly seen as a means of additional water supply to meet municipal domestic needs of urban population.

To date projections of the growth potential in desalination currently are based on historical development trends. This study focuses on quantifying the expansion of the desalination market with respect to providing an alternative water supply to municipalities and prevent the worsening of water scarcity due to projected population growth in various regions of the world. The current status of desalination in 10 selected water scarce countries and the potential growth of desalination over the next 25 years is investigated.

2. Materials and methods

2.1. Sources of municipal water supply

Municipal domestic water refers to supply of municipal drinking quality water (TDS 10- <1000mg/l), which is used for drinking and cooking, and needs in households, e.g. washing, swimming pools, flushing of toilets, etc. The water sources used for municipal domestic water supply in Malta (Europe), Barbados (Caribbean), Singapore (South East Asia), Jordan and Yemen (Western Asia), Bahrain, Kuwait, Qatar and Saudi Arabia (GCC States) and Libya (North Africa) include conventional surface and groundwater withdrawals and alternative sources, i.e. desalination. Singapore's municipal water supply is entirely obtained from surface runoffs. This is due to the fact, that groundwater is limited there and is in any case inadequate for municipal use. Countries, like Barbados, Jordan, Yemen and Libya rely almost completely on conventional, groundwater supplies. The situation is very different in Kuwait and Qatar, where alternative water supply, desalination, accounts for all domestic water production. In Malta, Bahrain and Saudi Arabia desalinated water (40-65%) and groundwater (35-60%) are used for their domestic water supply (see Table 1 on the next page).

2.2. Current sea and brackish water desalination capacity in selected countries

The current installed desalination capacity (sea and brackish water desalination plants >500 m^3/d) in each of the selected countries is presented in Table 2. The proportion of desalinated water that is used for municipal domestic purposes is also indicated in Table 2.

2.3. Population growth in 10 selected countries

The total population in 1995 and projected population by 2025, in the 10 selected countries was obtained from the data base: UN Population Projections, Table 3. The current population, by 2000, and the proportion of the population living in urban areas was obtained from the data source: The State of World Population. Currently, a high share, 75-100%, of urban population is in a majority of the selected countries: Malta, Singapore, Jordan, Bahrain, Kuwait, Qatar, Saudi Arabia and Libya, and roughly half, 40-50%, of the population in Yemen and Barbados are living in urban areas. An assumption was made, that the urbanisation trends have stabilised since 2000, and therefore the share of urban population by 2025 in these countries is similar to that in 2000.

2.4. Calculations

Current per capita renewable groundwater resources, m^3/cap/d, in each of the selected countries were calculated from the total groundwater resources in each country attributed to the total current population, N2000, in each country.

Current per capita desalination capacity, Q2000, m^3/cap/d, was calculated from seawater and brackish water desalination for municipal use and attributed to the current urban population in each country according to Eq.(1):

$$Q_{2000} = \frac{(Q_{SW} \cdot Y_{SW} + Q_{BW} \cdot Y_{BW})}{N_{2000} \cdot U} \qquad (1)$$

where Qsw and QBW are seawater and brackish water desalination capacities, m^3/d, Ysw and Ybw is the share of municipal water from sea and brackish water desalination, respectively, N2000 is the current population in each country, and U represents the share of that population that lives in urban centres.

2.5. Projections in desalination growth potential by 2025

In estimating the potential growth in the municipal water desalination market, the following assumptions were made:

- Growth in desalination is determined by the population increase in these countries in the next 25 years.
- Desalination is used to produce water for municipal supply only.
- Only urban population will use desalination to augment their current water supply.
- By 2025, water for municipal (domestic) use in the selected water scarce countries will be completely supplied by alternative sources, desalination.
  No withdrawals of groundwater will be used for this purpose. (In the case of Singapore where no groundwater is available, the assumption is made that no surface water withdrawals will be used for municipal domestic water supply).

The potential growth in desalination in each of the water scarce countries was calculated by the difference between the desalination capacity, Q2025, required to fulfil the domestic water demand in 2025 (refer Table 3, for population growth) and the currently installed desalination capacity, &>2000, of sea and brackish water, Eq. (2):

$$\Delta Q_{2025} = Q_{2025} - Q_{2000} = (N_{2025} \cdot U \cdot WW_{2025}) - (Q_{SW} \cdot Y_{SW} + Q_{BW} \cdot Y_{BW}) \qquad (2)$$

where N2025 is projected population of each country by 2025, U is the share of urban population in that country, WW2025, m^3/cap/d, is the per capita municipal domestic water use by 2025, Qsw and QBW, m^3/d, currently installed sea and brackish water desalination capacity in each country, and Ysw and YBw represent the share of capacity used for municipal water production. The current average per capita municipal domestic water use, WWAVG= 0.265 m^3/cap/d, was calculated from the municipal water withdrawals in each country and distributed over the number of people living in urban centres in that country.

3. Results and discussion

3.1. Current water use practices in water scarce countries

Current water withdrawals in the 10 selected water scarce countries range from 0.5m^3/cap/d in Singapore and Malta to 2.5m^3/cap/d in Libya and Saudi Arabia (Fig. 1). The total water withdrawn includes the share allocated for municipal domestic use and agriculture. In general, the trend indicates the highest water withdrawals in countries where the agrarian activities are directed towards food self-security, because irrigated agriculture require huge amounts of water.

Table 1
Current sources of municipal, domestic, water supply in water scarce countries

Country	Region	Source water for municipal use		
		Surface, %	Groundwater, %	Desalination, %
Malta	Europe	0	35	65
Barbados	Caribbean	0	100	0
Singapore	South-East Asia	100	0	0
Jordan	Western Asia	0	100	0
Yemen		0	100	<1
Bahrain	GCC states	0	60	40
Kuwait		0	For dilution	~100
Qatar		0	0	~100
Saudi Arabia		0	50	50
Libya	North Africa	0	98	2

Table 2
The current installed desalination capacity, sea and brackish water desalination plants >500 m^3/d, in the selected water scarce countries

Country	Region	Desalination (2000)			
		Seawater		Brackish water	
		Capacity, Q_{SW}, million m^3/d	Municipal (domestic), Y_{SW}	Capacity, Q_{BW}, million m^3/d	Municipal (domestic), Y_{BW}
Malta	Europe	0.140	0.97	0.007	0.92
Barbados	Caribbean	0.005	0	0.030	1.00
Singapore	SE Asia	0.014	0	0.004	0
Jordan	W Asia	0.004	0	0.004	0
Yemen		0.062	0.92	0.004	0
Bahrain	GCC states	0.402	0.64	0.071	0.75
Kuwait		1.491	0.98	0.045	0.94
Qatar		0.561	0.93	0.004	0.16
Saudi Arabia		4.015	0.88	1.065	0.73
Libya	North Africa	0.577	0.71	0.106	0.44

Table 3
Population in selected water scarce countries

Country	Region	Population, millions					
		1995		Current 2000		Projected 2025	
		N_{1995}	Urban U_{1995}, %	N_{2000}	Urban U_{2000}, %	Projected N_{2025}	Assumed U_{2025}, %
Malta	Europe	0.37	89	0.39	90	0.42	90
Barbados	Caribbean	0.26	48	0.27	51	0.30	51
Singapore	SE Asia	3.3	100	3.5	100	4.2	100
Jordan	W Asia	5.4	71	6.5	75	11.9	75
Yemen		15.0	34	17.5	41	39.6	41
Bahrain	GCC States	0.56	90	0.61	98	0.86	98
Kuwait		1.7	97	1.9	100	2.9	100
Qatar		0.54	91	0.59	95	0.78	95
Saudi Arabia		18.2	80	20.9	87	42.4	87
Libya	N Africa	5.4	86	5.5	94	12.9	94

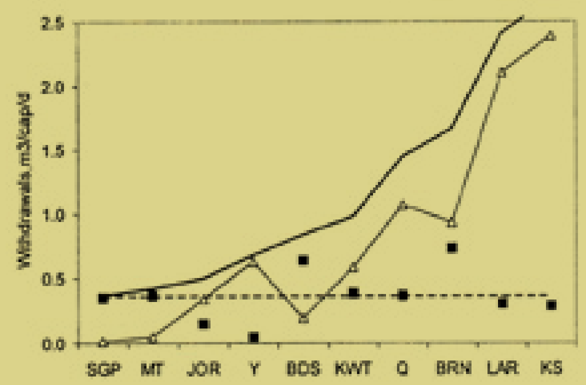

Fig. 1. Per capita water withdrawals: total, solid line, for agriculture, open triangle, and municipal use, solid square, in water scarce countries: Singapore (SGP), Malta (MT), Jordan (JOR), Yemen (Y), Barbados (BDS), Kuwait (KWT), Qatar (Q), Bahrain (BRN), Libya (LAR), and Saudi Arabia (KS).

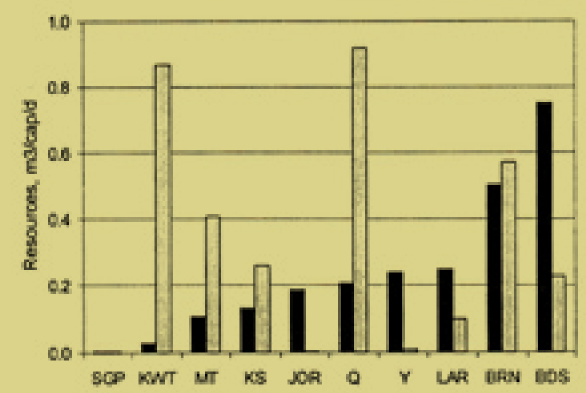

Fig. 2. Per capita renewable groundwater resources, dark bars, and per capita desalination capacity, light bars, in selected water scarce countries: Singapore (SGP), Kuwait (KWT), Malta (MT), Saudi Arabia (KS), Jordan (JOR), Qatar (Q), Yemen (Y), Libya (LAR), Bahrain (BRN) and Barbados (BDS).

Table 4
Projection of desalination growth in 10 water scarce countries

Selected 10 water scarce countries	Past situation 1995	Current situation 2000	Projection for 2025
Population:			
Rural population, millions	16.2	15.2	32.9
Urban population, millions	34.5	42.5	83.3
Total population in these countries, millions	50.7	57.7	116.2
Renewable groundwater resources:			
Average per capita renewable groundwater resources, m^3/cap/d	0.202	0.178	0.088
Municipal (domestic) water supply:			
Average per capita municipal domestic water use m^3/cap/d	0.265	0.265	0.265
Average per capita ground water withdrawal for domestic use, m^3/cap/d	0.108	0.092	0
Average per capita ground water resource compensation by desalination, m^3/cap/d	0.157	0.173	0.265
Desalination for municipal use:			
Existing installed desalination capacity, million m^3/d	5.4	7.3	7.3
Projected extra desalination to compensate ground water resources, million m^3/d	0	0	14.8
Total desalinated municipal water, million m^3/d:	5.4	7.3	22.1
Growth in desalination market: million m^3/d	0	1.9	14.8

Very little, 0.1 m^3/cap/d, water is allocated for agriculture in Singapore and Malta, while ca. 2m^3/cap/d are currently used in Libya and Saudi Arabia, Fig. 1. In fact, these high withdrawals for agriculture exceed the renewable fresh (ground and surface) water resources in these countries and thus intensive over-exploitation of fossil water resources are occurring there. Measures against water overuse would include more efficient water use in agriculture, water reuse and food importation (virtual water). However, in the foreseen future, limited use of desalination can be expected in large-scale agriculture irrigation projects due to prohibitively high costs.
Water withdrawals for municipal use in Fig. 1 range from 0.05-0.75 m^3/cap/d in the selected water scarce countries. The lowest per capita municipal water withdrawals are in Yemen and Jordan (W. Asia), while the highest are in Bahrain (GCC State) and Barbados (Caribbean). An average daily municipal, domestic, water consumption of 0.30m^3/cap/d has been quoted in the GCC States, however, considerably higher amounts of water may also be needed in modern housing and large villas in these countries.

Currently, in many of the selected water scarce countries the share of conventional groundwater supply in their municipal domestic water needs is high. On the other hand, available groundwater resources are intensively exploited by agriculture for irrigation needs, e.g. Libya and Saudi Arabia use 6-8 times more water for agriculture than for municipal purposes. In the future, rapid population growth in many of these selected water scarce countries is expected, Table 3. As a result, the need for municipal water supply in cities and also for irrigated agriculture will sharply increase. Hence an alternative water supply, e.g. desalination is likely to compensate the withdrawals of groundwater for municipal domestic use by urban centres. The growth in desalination market for municipal use would also alleviate pressure to divert water resources away from irrigation to meet municipal needs.

3.2. Current status of desalination in water scarce countries

A comparison of the current per capita desalination capacity and the renewable groundwater resources in 10 selected water scarce countries is presented in Fig. 2. The installed per capita seawater and brackish water desalination capacity, m^3/cap/d, is compared to the per capita renewable ground water resources, m^3/cap/d, currently available for abstraction. Countries, like Qatar, Kuwait, Malta and Saudi Arabia rely heavily on desalination and the per capita capacity of desalinated water exceeds their renewable groundwater resources 2-10 times. In Libya and Barbados, desalinated water accounts for 10-50% of their renewable groundwater resources. The situation is very different in Jordan and Yemen, where desalination currently contributes less than 0.5% to their renewable groundwater resources. In Singapore, the situation is very oppressive due to the very limited groundwater resources and poorly developed desalination there. However, some improvement is expected in the near future because of the recently announced project for a seawater desalination plant to be built in Singapore.
Future trends indicate rapid population growth in many of these water scarce countries and this will result in substantial reduction in per capita renewable groundwater resources and worsen the existing fresh water scarcity in each country. On the other hand, desalination capacity is expected to increase in the future. Seawater desalination will develop in Singapore where a desalination plant, 136,000m^3/d, is expected to be built by 2005. New seawater desalination plants are contracted in Kuwait, ~110,000 m^3/d, Qatar, ~240,000 m3/d, and Bahrain, ~270,000 m^3/d. Brackish water desalination is considered as a future option of supply augmentation for Jordan, where otherwise a potable water crisis is expected to emerge by 2010.

3.3. Trends and projections in the growth in the desalination market

The development of desalination for municipal use between 1995 and 2000, and the projected growth in desalination capacity in the selected water scarce countries for the coming 25 years is summarized in Table 4. The driving force determining the need for desalination development is assumed to be the increasing population, which has grown from 51 million in 1995-58 million in 2000 and is projected to reach 116 million by 2025 in countries selected in this study. Due to continuously growing population, the average per capita renewable groundwater resources have dropped from 0.202-0.178 m^3/cap/d between 1995 and 2000, and will decrease to 0.088 m^3/cap/d in 2025 as the population will roughly double in these countries. Results indicate that these limited renewable groundwater resources alone would be sufficient to cover 75% in 1995, 67% in 2000, and only 33% by 2025 of the current municipal domestic water consumption (an average of 0.265m^3/cap/d) at the projected rate of population growth in the coming 25 years.
Desalination of sea and brackish water is used to compensate for groundwater resources in municipal domestic water supply in the selected water scarce countries. The role of desalination in municipal water supply is assumed effective for urban areas, where the concentration of people is high 75-100% in Malta, Singapore, Jordan, Bahrain, Kuwait, Qatar, Saudi Arabia and Libya, and 40-50% in Yemen and Barbados. In 1995, an average installed municipal water desalination capacity, 0.157 m^3/cap/d, was sufficient to compensate for 60% of the average urban municipal domestic water use leaving the remaining 40% to be covered by conventional groundwater supply. By 2000, the share of desalinated water had increased to 65% and reduced the conventional groundwater share to 35%. An assumption is made that by 2025, water for municipal domestic use in these countries will completely, 100%, be supplied by desalination and no withdrawals of groundwater will be used for this purpose.

In 1995, a total sea and brackish water desalination capacity for municipal use of 5.4 million m^3/d was installed in the selected 10 water scarce countries. By 2000, the installed desalination capacity increased to 7.3 million m^3/d indicating a growth of 1.9 million m^3/d, 35%, in the municipal water desalination market between 1995 and 2000. By 2025, a desalination capacity of 22.1 million m^3/d is needed to maintain the current per capita urban municipal domestic water supply and to compensate for groundwater withdrawals. This indicates a growth in the municipal domestic water desalination market of 14.8 million m^3/d, 200%, in the next 25 years. Recently contracted desalination projects already indicate that municipal water desalination capacity will increase by 0.85 million m^3/d by 2006. On the other hand, the use of sea and brackish water desalination started in the sixties-seventies, and many plants built at that time are still in operation today producing desalted water, i.e. ca. 4 million m^3/d of municipal domestic water is produced by systems built between 1960-1985. Replacement of these old desalination plants by newer and more efficient processes can be expected in the near future, next 5 years, due to technology improvements in the field. Longterm considerations take into account gradual aging of plants built between 1985 and 1995. The replaceable desalination capacity for the next 25 years may increase to 5.4 million m^3/d which was produced by sea and brackish water desalination in 1995, as depreciation and replacement of plants built in the eighties and beginning of the nineties will gradually occur. The capacity of gradual desalination plant upgrading will add to the projected growth in the municipal domestic water desalination market due to population growth and prevention of groundwater withdrawals for municipal purposes.

Expanding desalination capacity will be possible by building new plants or upgrading the existing facilities in each of the selected water scarce countries. This process, however, will require huge economic investments, which will vary considerably among the selected water scarce countries. The highest desalination market growth may be expected in Saudi Arabia and Libya due to high population growth rate there in the next 25 years. In Singapore and Jordan, desalination for municipal use yet has to be developed. Little extra desalination capacity will be needed in Malta and Barbados, although rapidly developing tourism in these countries may require an additional desalination capacity to be installed.

4. Conclusions

- The current impact of desalination varies greatly among the 10 water scarce countries selected in this study. The current installed desalination capacity exceeds the renewable groundwater resources by a factor 2-10 in Qatar, Kuwait, Malta and Saudi Arabia, while it accounts for 10-50% in Libya and Barbados and less than 0.5% in Jordan, Yemen and Singapore.
- The driving force determining the need for desalination development in municipal domestic water supply is assumed to be the population growth from 51 million in 1995 to the projected 116 million by 2025. This will cause continuous decline in the renewable groundwater resource availability in the 10 selected water scarce countries.
- A growth in desalination capacity of ca. 15 million m^3/d will be needed to supply the urban population in the 10 water scarce countries and to prevent groundwater withdrawals for municipal purposes in the next 25 years.

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