Desalination, a neglected option for the sweet water supply

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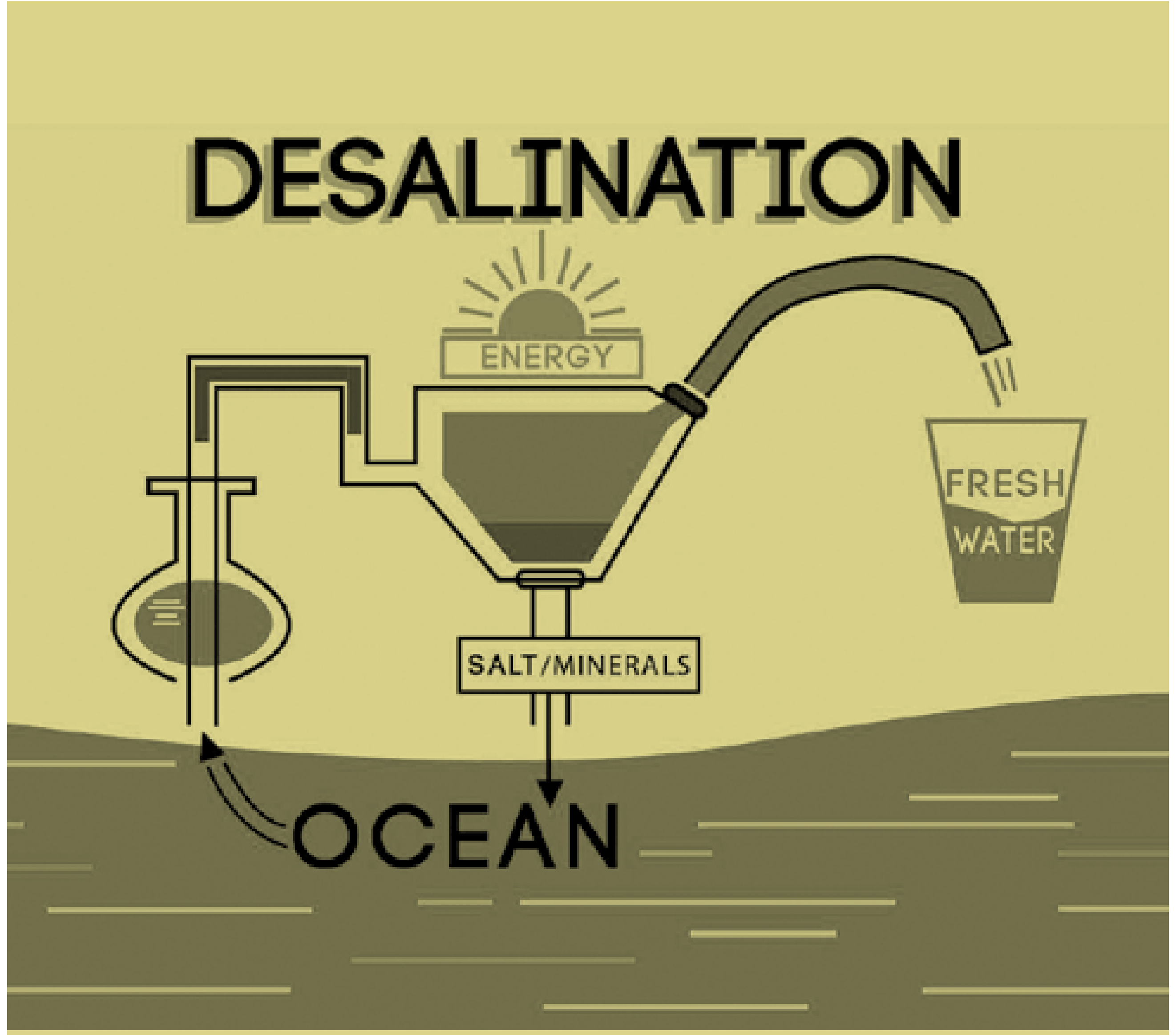

Desalination will become an important option for relieving water scarcity in coastal areas, because of growing populations along the many coastal regions of the world. Another reason are the breakthroughs in the reduced energy requirement and investment costs for desalination processes.

By 2025 mega cities in the coastal areas may very well be home to some 5 billion people. Providing this population with desalinated seawater would avoid putting undue pressure on the amount of water available for agriculture and for the minimal water needs of ecosystems, all of which is a subject of great concern at world water seminars. There are major breakthroughs in the reduced energy requirement and investment costs for desalination processes, resulting in cost levels of US \$0.40 to \$0.80/m^3 before distribution. This is much lower than its level of 10 years ago of approximately \$3.00 to \$5.00, and of \$1.50 to \$2.50/m^3 only 3 to 5 years ago. At the same time, the real costs of traditional water supplies are on the increase, and in many cases have already surpassed the present cost figures of \$0.40 to \$0.80.

Currently only about one percent of the world's potable water is derived from desalination plants, due to a long-standing strong and emotional opposition to large-scale introduction of desalination. The percentage for industrial use is even lower, while the percentage of irrigation water is practically zero. Historically, desalination has been considered:

- merely a 'technical fix'
- as requiring an unacceptable level of fossil fuels
- too costly, too large in scale, and too technical for universal solutions
- an impediment to awareness raising and efficient water management. In addition, it does not fit in the traditional water supplier's culture.

Thus, the total capacity in 2000 was about 26 million cubic meters per day, up from 20.3 million cubic meters per day in 1995. Of this total capacity, about 60% comes from seawater and 40% from brackish water. However, as an imminent shortage of drinking water in many coastal regions and mega cities quickly emerges as a major natural resource issue of this century, the abundance of salt water presents an obvious opportunity for reassessing desalination as a solution to providing an adequate, sustainable drinking water supply. Furthermore, major breakthroughs in desalination technologies are and will continue to be so substantial that its contribution to solving major worldwide water issues, including water for food production, drinking, industrial use and natural ecosystems, can no longer be ignored by policy makers.

Desalination technology should no longer be considered some kind of forbidden fruit. In fact, the desalination market has already become an annual billion-dollar business, which will continue to grow to at least five billion dollars per year in the coming decade. Recent and potential desalination developments indicate that there will be a substantial increase in the use of these technologies to produce pure and fresh water from seawater and brackish water, but also from wastewater. It is difficult to predict the precise future shares of desalination and recycling in the water market, but the strategic opportunities are impressive.

Desalination technologies

Among the numerous existing desalination technologies there are currently five major applications. Three apply to the evaporation method - Multi-Stage Flash (MSF), Multi-Effect Distillation (MED), and Vapor Compression (VC) - while membrane separation processes have two applications - Reverse Osmosis (RO) and Electrodialysis Reversal Process (EDR). In just the past three years, all of these technologies have developed energy recovery systems, higher process efficiencies, new or improved construction materials, dramatic decreases in membrane prices, high-tech ultra- or micro-filtration for pretreatment, the use of waste energy from other processes, and the use of low-grade energy from electricity generating plants, all contributing to substantially decreased energy use. A new application of membrane distillation called Memstill, is being developed by TNO in the Netherlands and can substantially further improve energy efficiency and cost price levels. In the days when energy was cheap and desalination applications limited, little attention was paid to the energy consumption involved in the process. Energy use for evaporation methods like MSF, including pumping work, could be as high as 400 MJ/m^3 for desalinating seawater containing 3.5% salt. It can now be as low as 200 MJ/m^3 using MED and co-generation with adjacent power plants. The reverse osmosis method requires significantly less energy than the evaporation method. In the early days, maximum consumption was about 12 kWh/m^3 from seawater containing 3.5% salt. However, by introducing energy recovery systems, this was reduced to 7 kWh/m^3. In the newest RO plants, the energy requirement has been reduced to between 4 and 5 kWh/m^3 and further reductions to 3 kWh/m^3 are foreseen with additional technical improvements. If one wants to compare these kWh/m^3 data for RO with the caloric requirements for evaporation, MSF operates in an equivalent of the range between 15 and 25 kWh/m^3 and MED at around to 10 kWh/m^3, depending on process temperatures. Overall, it is clear that energy consumption for desalination has declined substantially in the last 5 years. For very large units, when used in conjunction with power generation, MSF still has cost advantages for seawater desalination. MED has an advantage over MSF for medium- to large-sized plants, because of its up to 25% lower power requirements, while RO has the advantage of being competitive in all sizes, but still remains dependent on the availability of electricity from fossil fuels. For brackish water, RO consumes even less energy in direct proportion to the salt content. For the evaporation methods, consumption remains at about the same level as for seawater conversion, effectively ruling out this desalination method for brackish water.

Although the eyes of the world are focused on the energy equation of the improved desalination technologies, the investment and operating costs constitute a second major factor in the successful introduction of these technologies on a broader scale. Through upgraded designs investment costs per cubic meter/day/capacity have been reduced to present levels of $500 - 1000, down from at least double that amount in the past. In combination with the improved energy efficiencies, the various desalination technologies can currently deliver fresh water from the sea at costs that range from $0.40 to $0.80/m^3, whilst freshwater from brackish water can now be produced at the rate of $0.10 to $0.20/m^3, depending on the salt content. An important factor in the expansion of desalination plants is the combination of water and power generation, the so-called IWPP (Independent Water and Power Projects), where large-scale evaporation (MSF) has become competitive with RO, leading to water prices of $0.50 to $0.70/ m^3 and energy prices of $0.025/kWh.

While exact cost figures for the various types of desalination vary according to location, saline levels and available types of energy, the cost per cubic meter is today approaching the cost level of producing freshwater from ground and/or surface water, which in western countries is in the order of $0.50/m^3. However, the costs of traditional methods of extracting and purifying surface water and ground water are increasing around the world. The reasons? Increased scarcity, ground water depletion, deeper wells, higher purification costs, increasing distances from natural water resources, increased energy costs, increased ground water taxes, and increasing distances to transport the water. If the ecological costs of deeper wells and depleting surface water resources were taken into account, the cost picture would look worse. In many areas of the world, subsidized consumer prices do not reveal the true costs necessary to produce fresh water from traditional sources, but my guess is that true costs will be applied more and more frequently in the future, especially for municipalities and mega-cities. As desalination costs progressively undercut the level of the real costs of traditional methods of producing fresh water, this will contribute to increased investments in desalination plants, especially in coastal areas with mega-cities. In the future, the price ceiling for water will probably be determined by the desalination technologies with the overall lowest costs.

The Market Place

As scarcity and costs increase, the marketplace will begin searching for alternatives to rising costs. These include shifting from supply to demand management, increased efficiency, seasonal storage, reuse of sewage effluent, distributing various qualities of water based on its utilization, additional renewable water resources, transfer of water from region to region, importation of water and desalination of seawater. Until quite recently, desalination was always last on the list. However the evolving state of the art, as we noted earlier, will propel it upwards, at least in the coastal regions. And we must not forget that 70% of the world population lives within 50 miles of the world's seas and oceans. The following is an interesting illustration of the growing competitiveness of desalination technology near the coastlines. Recently, details were published about negotiations between Turkey and Israel concerning the shipping of water from the Manavgat River in Anatolia to the port of Ashkelon. They agreed on a price of $0.15/m^3, but shipping costs of between $0.80 to $0.90/m^3, prevented the deal from going through. Meanwhile, the bids for the Build-Own-Operate-Transfer desalination project at Ashkelon have set the price at below $0.60/m^3, thus providing a cheaper, safer source. In the meantime, both projects have been approved. Other recent decisions on desalination plants near coastlines and with capacities of between 100.000 and 150.000 m^3/day and water cost prices of between $0.50 and $0.70/m^3 have been made in Singapore, Shandong Province in China, Carboneras in Spain, Shuheiwat in UAE, Batmah Coast in Oman, Perth in Western Australia and on the island of Taiwan. In 1990, the Gulf States had more large-scale desalination plants than the rest of the world combined. Saudi Arabia, for example, currently has 20% of the world's large-scale plants and will place further orders for more plants for the next twenty years, to the tune of $50 billion. But in fact, the majority of existing and projected desalination capacity today is of the very large-scale variety. According to recent market projections, with the increase in experience and improved techniques, this trend will increase, spreading to other coastal regions in Asia and Africa.

Memstill technology

Recent market projections show that new desalination plants could be supplying up to 120 million m^3/day by 2025 in the 18 driest countries in the world, where water supply per capita falls well short of daily demand. The main features of the Memstill technology are:

- compact, easily operated modules that require much less space than conventional units
- built to any specifications, from household to large-scale industrial applications
- operational on renewable and conventional energy, especially waste energy where it becomes very competitive with existing technologies
- an ingenious module design that reduces heat transfer-losses to an absolute minimum, resulting in an energy requirement for seawater desalination of 100 to 200 MJ/m^3 of (waste) heat, or the equivalent of 3 to 6 kW/m^3 in exergy
- limited fouling and scaling, minimum pretreatment and maintenance using synthetic components
- targeted specific investment costs of less than $500 per m^3/day
- targeted cost price of less than $0.50 per m^3.

The flexibility of this technology with respect to the use of various kinds of waste energy is an essential asset, as there is an abundance of waste energy available in industrialized coastal area's.

Environmental effects

The large-scale introduction of desalination applications raises the question of how this technology will affect the environment and the quality of the water produced. A country that has done a considerable amount of work on the environmental aspect is Cyprus. Before making the decisions to substantially expand their RO desalination capacity to cope with increasing water demand on the island in the face of decreasing availability, extensive Environmental Assessment Studies were and are currently still being carried out, monitoring the marine environment at regular intervals. The brine that results from desalination typically contains two times the salt content of the feed water and usually has a higher temperature and a lower pH than the seawater. By dumping the brine into the sea at a depth of 10 to 15 meters, and by imposing limitations on the chemicals used in the pretreatment and membrane maintenance processes, only negligible and temporary effects on the benthos life were discovered. In Cyprus, the affected area was limited to a radius of 200 meters. Other studies are done by the Electric Power Research Institute in the US and the California Coastal Commission. Obviously, environmental regulation must be implemented to avoid the negative effects of coastal desalination installations, but it seems that the problem is manageable.