



# Desalination

Price  
30p

Though water covers over 70% of the Earth's surface less than 1% by volume is available in rivers, lakes and underground aquifers and not all of that is 'fresh' enough to be drunk or used to irrigate crops, or even in a useful place. As the options of taking more water from rivers and lakes, or building reservoirs to store water at times of surplus for use in drier times, become increasingly limited, it is not surprising that water suppliers are looking more seriously at taking water from the sea or tidal reaches of rivers and making it useable by removing the salt.

There are thousands of large and small desalination plants in the world, 60% by number in the Middle East producing about half the global desalinated drinking water. 10% of Israel's water is desalinated and two thirds of Malta's drinking water. There are many desalination plants on the Californian coast but only one currently producing water in the UK - a 6000 cubic metre a day ( $m^3/d$ ) plant in Jersey - though a large plant for London is on its way.

It is possible to produce pure water by boiling it and condensing the steam\* or freezing it and melting the ice, though only the 'boiling' route is in commercial use. It is also possible to use a membrane (a kind of filter) and force pure water through it leaving the salt behind in a process called reverse osmosis (RO) explained below. Other processes

*\*At a small scale one can simply allow water vapour to rise from a tank of sea or brackish water, condense on a cool surface and run down via collecting channels to a separate tank as is done with solar 'stills'. The old dew ponds, though not dealing with salt water, used the same principle. They were designed to collect water vapour which condensed as the temperature dropped overnight and prevent it evaporating again when the sun rose.*

such as electrodialysis are in commercial use but historically sea water has generally been de-salted by 'boiling' and less salty, or so called 'brackish', water by RO though, because RO can be done at any scale, it is the standard method on board ship and, indeed, is gaining ground in the global desalination market.

Both of these desalination processes use large amounts of energy which has inhibited development due to cost and is now causing anxiety on environmental grounds - unless the energy can come from renewable or nuclear sources.

## The Multi- Stage Flash process

Boiling or 'distilling' water and condensing the steam is a very expensive way to produce pure water but engineers exploit a neat trick to save energy and money. One cannot brew a good cup of tea high on Mount Everest because the atmospheric pressure is too low and the water 'boils' at too low a temperature. So, in what is called the 'multi-stage flash' (MSF) process, the water is boiled at normal pressure driving off some steam and then pumped into a second chamber where the pressure is below atmospheric pressure. Here more water immediately converts or 'flashes' to 'steam' before it is drawn off again to another chamber at even lower pressure. And so on. The 'steam' removed at each stage condenses and its heat is transferred back to the incoming water to reduce the energy required. The number of chambers depends on the efficiency of the pumps and quality of the fittings but will typically be 20 or so.

Sea water contains about 35,000 milligrams per litre (mg/l) of various salts, mostly sodium chloride. A little salt water, typically less than 500 mg/l, will be blended back into the pure desalinated water to render it palatable but the waste stream will end up very salty and corrosive and will need careful disposal if it cannot be dumped back in the sea and be dispersed by the tides. The cost of MSF desalination is independent of the saltiness of the water. An alternative process, Multiple Effect Distillation (MED), applies the same physical properties, though with different routing of sea water and steam. MED was in fact invented first, back



*A bank of some of the 38,000 cylinders containing spirally coiled membranes in the largest sea water reverse osmosis plant in the world at Ashkelon on Israel's Mediterranean coast. The plant produces 100M  $m^3$ /year, 5+% of Israel's total water need.*

## An ALDES Briefing Note

New, August 2008

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in 1840. It fell out of favour due to the difficulty of removing deposits in the chambers but is making a come back.

### The Reverse Osmosis process

Tidal reaches of rivers such as the Thames will be less salty than sea water especially at low tide when the proportion of river water to sea water is highest. Thames Water were given planning permission in June 2007 for a plant at Beckton which will take water with about 25% of the saltiness of sea water and will employ the RO process. Scientists found that when liquids of different saltiness were stored either side of an acetate, semi-permeable, membrane water would move from the less to the more salty side until the pressure either side was equal. The process was known as osmosis and is critical to many plants' ability to 'suck up' water from the soil. Reverse osmosis, as its name implies, reverses this process. It uses very high pressure to force pure water through the membrane leaving the salt behind. Because the pressure needed (and hence the cost) is related to the saltiness of the incoming water RO is more economic the less salty the source water is.

### Energy used

The great drawback of desalination is that all of the different processes use energy. Figures for the pressures needed for RO range from 2 to 17 bar (atmospheres) for fresh to brackish water and up to 70 bar for sea water with the energy needed rising pro-rata to the salt concentration. Other figures suggest a typical RO plant will use from one unit (kilowatt hour) of electricity to produce a cubic metre of water from mildly brackish water rising to around 6 units for sea water. This compares to MSF plants which use at least 25 units for a cubic metre and often much more. Very roughly, a family would more than *double* the electricity it currently uses if it relied exclusively on MSF desalination plants for its water.

Unsurprisingly engineers are looking intently for ways to bring the energy needed down. Many RO plants, including the one at Ashkelon, are nowadays built with their own on-site power stations to provide the electricity to drive the pumps. Power stations, including nuclear ones, are also built alongside MSF plants so that their low grade heat, which would otherwise be wasted, can be used to heat the incoming sea water.

Because water, unlike electricity, can be stored, joint facilities allow some conjunctive working whereby the quantity desalinated can vary during the day to balance out periods of peak and off peak electricity demand. Indeed, though more storage capacity would be required, desalination could help balance out the variable electricity supplied by renewable sources such as wind, tidal and solar. Solar energy particularly, though still very expensive, would tend to be available when

extra water was most needed – in hot dry summers.

### Costs and other factors

It is not easy to compare the costs of desalination and conventional supplies. Some conventional water is taken from reservoirs in the hills where the water is very clean and needs little more than a dose of disinfecting chlorine, and where it flows to households most of the way by gravity. On the other hand much water is taken from rivers where both treatment and pumping costs are significant, or from a borehole where treatment is simple but much more pumping has to be done. Borehole water in the Middle East can emerge at 80°C and contain all kinds of nasty trace elements including sulphides and mercury so has to be cooled first and then treated extensively which adds more to the costs.

One advantage of desalination is that many consumers live near the coast and a works can be sited close to them. Even so a proposed desalination plant at Newhaven, Sussex was rejected because the cost would have been around 10 times that from a conventional river or borehole source. On the other hand desalination is often only installed to meet demand in dry summers so that whereas the capital cost may be high, the operating cost and energy used will be relatively low.

A good test of the economics of desalination is to note where plants are actually being installed. Newhaven was too expensive but in Australia Perth commissioned its first desalination plant in 2008, Adelaide is building a pilot, Melbourne is planning a £1.4 bn plant to provide 150 Mm<sup>3</sup>/year (a third of present supplies) and Sydney is building a 90 Mm<sup>3</sup>/yr plant costing £826M which will use 400,000 MWh of energy/year (that is about 4.5kW/m<sup>3</sup>). New plants continue to be built all round the Middle East, of course, where energy costs remain low.

In this country Thames Water have been forced to commit to powering their Beckton plant with 100% renewable energy but it seems they are actually counting bio-diesel generation as wholly renewable (which it is not) with no apparent intention of utilising dedicated wind power when this is available.

### Conclusion

Despite all the potential to reduce leakage from pipes and use more efficient showers and other water using appliances, the prospect is for more desalination plants worldwide. Unless they can be powered by renewable or nuclear energy this will not help the world to reduce CO<sub>2</sub> emissions so it is critical that more attention be paid to the power source. Until then desalination should be seen as a 'last resort'.

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