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Towards sustainable desalination

David Lloyd Owen

Envisager Ltd., Trewindsor Farm, Cardigan, Ceredigion SA43 2LN, UK
Tel. +44 1239 615505; email: david@envisager.co.uk

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ABSTRACT

As the role of desalination in providing water is broadened, it has come under increasing scrutiny due to its perceived impact on the marine environment and its energy intensity. Desalination's increasing popularity is due to lower cost technologies such as reverse osmosis along with the need to supply water to populations are moving towards the coast. Sustainable desalination is feasible when desalination projects are combined with demand management to ensure that the water is effectively used. There is appreciable scope to lower its energy demand through new technologies and approaches and by adopting desalination techniques wastewater can be recovered for potable and non potable use. Desalination can also play a positive role in relieving pressure on low flow rivers.

Keywords: Energy; Demand management; Environmental impact; Demographics

1. Introduction

The deployment of membranes in mobilising sea and brackish water resources to complement surface and groundwater supplies has transformed desalination into a globally significant water resource. This paper proposes that a policy overview weighing the environmental impacts of desalination against its humanitarian and developmental benefits is needed as a matter of some urgency to ensure a proper appreciation of the sector's role in water management after the conclusion of the United Nations' water and sanitation Millennium Development Goals in 2015.

2. Desalination in context

2.1. Desalination and demographics

In 2010, the majority of the world's population lived in urban areas for the first time. In 1950, 28.8% lived in urban areas and the proportion is forecast to grow to 68.7% by 2050 [1]. At the same time, there is a shift in populations towards coastal areas. Data is inconsistent both in terms of defining coastal areas and the proportion of people living within them. According to Columbia University's Centre for Climate Systems Research the number of people living within 60 miles of the coast will rise by 35% between 1995 and 2025 to 2.75 billion [2]. In addition, 20 of the world's 30 largest cities are defined as coastal. Water scarcity is also pronounced in coastal areas which are experiencing rapid population growth with the total number of people living in areas experiencing water stress set to rise from 2.8 billion in 2005 to 3.9 billion by 2030 [3].

2.2. Membranes have transformed desalination

According to the Global Water Intelligence/IDA database, Reverse Osmosis accounts for 61.1% of the current global installed desalination capacity of 59.9 million M^3 per day [4]. This reflects their appreciably lower costs (the typical cost for Multi Stage Flash distillation systems being \$2.00–6.00/M^3 over their operating life, against \$0.45–0.80/M^3 for a Reverse Osmosis membrane facility) and since circa 2000, they have delivered comparable performance in terms of water quality and reliability.

3. Challenges facing desalination

3.1. Ethics and desalination

There are three areas of concern regarding the ethics of desalination: [1] Where does desalination fit in the current debates about the politics and economics of water provision? [2] Should investment be in mobilising new resources or in ensuring current resources are used more efficiently? [3] Is desalination environmentally sustainable?

3.2. Desalination as a political proxy

Water as an 'uncooperative commodity' has been adopted as a proxy for wider political and social dissent in recent decades. Desalination has inevitably been drawn into this, often because of its relatively high profile. Thames Water (then owned by RWE AG) sought to build a 140,000 m^3/d brackish water RO facility for 900,000 people at Beckton in East London. This was subjected to a court challenge in 2005 by the Mayor of London on the basis of the project's carbon emissions and arguing that it ignored leakage management (915,000 m^3 of distribution losses per day in 2004–05). After the election of a new Mayor in 2008, the legal challenge was withdrawn in return for the facility being powered by recycled biofuels.

3.3. Economics and desalination

Most Reverse Osmosis desalination and reclamation plants are financed on a project basis, with the membrane company working with other bidders in a consortium of specialist systems and services companies. Private sector participation has become the norm for contract awards, with the project company providing a fixed volume of water to the industrial customer, municipality or government at an agreed volumetric fee via a 20–30 y Build Operate Transfer contract. Selling the desalinated water to a third party for a commercial rate means that full cost recovery (all operating costs plus part of the capital spending costs are paid each year) is used either at the utility or customer level.

Due to political and operational challenges, over the past decade private sector operators have tended to favour treatment contracts rather than those directly dealing with the customer such as water provision and sewerage. This means that most identified water recovery from treated wastewater projects are being outsourced to the private sector as well.

3.4. Policy considerations

While desalination is concerned with bulk water provision and is therefore not directly linked with the United Nations water and sanitation Millennium Development Goals, the environmental aspect of desalination means it is falling within the remit of integrated water resource management initiatives such as the EU's Marine Strategy Framework Directive (2008/56/EC).

The World Bank sees desalination as a last resort and not to be used where a utility is poorly managed [5]. The WWF calls for desalination to have the equivalent of the World Commission on Dams in effect calling for a moratorium on major projects [6].

3.5. Priorities over resource development

The conflict between supply and demand management has been highlighted in Saudi Arabia, where access to cheap oil means that desalination has been used irrespective of context. 60–70% of Riyadh's water comes 450 km from desalination plants (273 out of 415 million m^3 per day in 1999) in Jubail and there are 31% distribution losses in the city (1.1 million m^3 per day lost in 2006) along with a relatively low household water (85%) and sewerage (56%) connection rate. The Saudi government estimated in 2008 that \$0.4 billion on leakage repairs will save \$2.1 billion in avoided new desalination capacity. The low level of sewerage and sewage treatment means that wastewater reuse has yet to be used.

3.6. Environmental impacts

Environmental impacts are well recorded, principally being energy intensity (with a recent focus on its carbon contribution), the potential for damage to aquatic life at the inlet, surface water disposal concerns (brine discharge typically twice the salt level of seawater and lower dissolved oxygen levels), and the discharge of treatment and scale control chemicals.

4. Responses

4.1. Amelioration – inlet & outlet

Excepting energy, progress has been made on many of these concerns. Inlet flow management and speed can minimise the potential for taking up aquatic life, while brine discharge can either be avoided (discharge to surface sites, but this in turn had land/groundwater contamination concerns or more usefully, brine recovery) and the use of diffuse discharge or brine blending/mixing zones – can minimise discharge impact, provided suitable locating and monitoring is carried out from the outset.

4.2. The climate change conundrum

The role desalination has to play in countering the effects of climate change is somewhat overlooked. By supplementing stretched water resources it can prevent river over-abstraction (the EU's Water Framework Directive restricts abstraction from low flow rivers from 2015–27) and can be mobilised to respond to greater seasonal change (drier summers in SE England, for example) as well as addressing episodic droughts. It also provides planners with an increase in responsiveness to population change. The modular nature of RO desalination allows capacity to be altered to circumstances and for the facility to be used only when required.

4.3. Towards carbon neutrality

Improving the efficiency of membranes, allied with new technologies (membrane-condensation, waste heat, forward osmosis, aquaporins and nanotubes) and energy recovery systems indicate that there is more scope to minimise their impact, but RO is an intrinsically energy intensive approach.

Using renewable energy sources offers the potential for carbon neutrality. To date, examples include cooking waste biofuels (Beckton, UK) and photovoltaic energy (Perth, Australia). The scope for wind power is limited to areas where there is a suitable wind profile. Tide and wave energy may offer potential, especially for smaller plants, but these are at the early development stage. Finally, where wastewater is being treated in the vicinity, sludge to energy can be a significant energy source.

4.4. Desalination and good management

Due to common technologies and techniques, along with a significant record of publicly tendered contracts, there is a high level of understanding about the various cost elements in RO desalination projects. This reduces the headroom for corruption and financial mismanagement in the contract award and procurement stages.

The high relative cost means of water production means that water economics are usually taken into full consideration. Treated water is sold by the operator to the municipality on a commercial basis and the municipality is in turn more likely to seek to minimise distribution losses and encourage water efficiency in order to optimise the use of a costly resource.

4.5. Integrated water management in Singapore and Masdar city

Singapore Public Utilities Board 'Water for All' strategy launched in 2010 nenvisages the country being self-sufficient in water by 2060 through 'Four National Taps' including NEWater (water reuse) for 50% of consumption and Sing Spring (desalination) for at least 30% of consumption [7]. This is allied with demand management (cut water consumption from 165 l/c/d in 2000 to 147 l/c/d by 2020) and a 4% leakage rate.

Masdar City is a proposed $22 billion 'Eco City' for 45–50,000 people in Abu Dhabi, UAE. All of the city's primary water will come via solar powered desalination. A proposed 60% reduction in water usage against the norm in the region equates to residential usage to 180 l/c/d, which is high by European standards, especially given the scarcity of water in the region. Though further demand management and water recycling and recovery, the developers aim to reduce net water usage to 70 l/cap/d.

The 'eco/sustainable city' concept is based on no net depletion of local water resources, nor any appreciable nutrient loading downstream. Solar powered desalination and effluent powered water reuse form part of their criteria, integrated with demand management and greywater reuse. It is an attractive concept, but with an implied cost of $0.45–0.50 million per capita for the Masdar City concept, there remains a gap between theory and practice. Since the term was coined in 1987, a number of housing projects and cities have adopted the term, but none has met all the criteria for water, energy and waste management.

4.6. Closing the loop

Considering desalination in isolation ignores the potential for reverse osmosis as a tool for optimising water usage and maintaining the integrity of the water cycle. Combining the two approaches as seen in Singapore's NEWater and Sing Spring projects, using membranes at the beginning and the end of the water cycle maximises the beneficial use of water obtained by desalination. Political and public acceptance of reused water requires extensive consultation, as demonstrated in Singapore. Likewise, to get the greatest benefit from combining desalination and wastewater recovery and to minimise their impact requires planning and integration at the utility, rather than the project level.

Management initiatives to optimise the utility of desalinated water include full cost recovery pricing at the customer rather than the utility level, along with water metering and progressive (rising block) tariff structures with affordability support where appropriate. Considering the relative cost of desalination, demand management tools such as supporting the use of dual-flush lavatories and other household goods with minimised water consumption ought to be deployed, demonstrating the need to look beyond desalination as an isolated water provision project.

4.7. Engaging desalination

At the global level, policy is being set by a triennial cycle of World Water Development Reports (WWDR) and World Water Forums. The fourth WWDR and the 6th World Water Forum will both be launched in March 2012 where it is anticipated that the World Water Vision of 2000 for universal access to safe water and improved sanitation by 2025 will be revived. Desalination and its cousin wastewater reuse can play a significant local role and even regional role in ensuring these are attained. In terms of new technologies, this is already a short period of time, as the lead time from the development to operation is at least five to ten years, but that does not understand the need for continuing innovation to optimise the sustainability of membrane based desalination.

5. Conclusions: towards sustainable desalination

The necessity for desalination, where and when it is needed remains undeniable. Controversy about its applicability is often based upon information about its economic and environmental impact that has been divorced from its operational context.

There is a need to integrate desalination projects into a utility's water management. This reflects a shift from pure supply management towards integrated supply-demand management, allying investment in new desal capacity with optimised water efficiency and leakage reduction (demand management) along with grey-water recovery and reuse (supply management). Treating water as a commodity encourages its sustainable management through ensuring its optimal beneficial use at the lowest achievable cost. This in turn may become a tool for regulation led demand management, whereby utilities are incentivised to encourage lower water demand.

The challenge for the sector lies in its need and ability to engage with the various debates, and to be able to set its benefits and impacts into their applicable social, political and environmental contexts so that it remains, where applicable, a valid policy option and that suitable incentives exist for encouraging the sector to further optimise its sustainability.

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