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Future of desalination in the context of water security

In September 2022, the Saline Water Conversion Corporation (SWCC) of Saudi Arabia and Global Water Intelligence (GWI) organized an international conference on the future of desalination, in Riyadh. The SWCC was established in 1974 as an autonomous government institution. Since its formation, it has played an increasingly important role in fostering and improving desalination practices and processes not only in Saudi Arabia but also around the entire world. It is now a major force in the world of desalination and is also, by far, the largest global producer of desalinated water.

The conference successfully brought together policymakers, developers, consultants, manufacturers, operators and researchers to discuss the future of desalination in the world.

The conference was timely since the issue of the future of desalination, or the broader issue of the future of the world's waters and the role desalination plays, needs to be discussed much more seriously. It was also very appropriate that SWCC convened this international conference since, as an institution, it probably now has more experience in producing and managing desalinated water than any other institution in the world. Refreshingly, presentations and discussions, for the most part, were based on real problems, issues and solutions in this sector rather than theoretical discussions.

The organizers identified at least three important challenges that desalination will have to resolve by 2030:

- How can the cost of US$0.32/m^3 for seawater desalination become a reality?
- How can carbon emissions from this industry be reduced by half?
- How can the non-water revenue stream of desalination processes be increased to 10% of the total?

Discussions during the conference were rich, varied and, for the most part, application- and solution-oriented. This is rather an exception than the rule for such large international water meetings. Generally, large meetings mostly regurgitate the same old stuff that has been discussed numerous times before in previous meetings. The majority of global meetings very rarely come out with new, meaningful, and applicable solutions to pressing current and future water problems (Biswas, 2006). Based on the discussions in Riyadh, our Keynote Lecture during its Opening Plenary and on further reflections on the entire spectrum of desalination, our views are noted in the rest of this Editorial.

Brief history of desalination

The concept of desalination is not new. The Greek philosopher Aristotle noted some 2360 years ago that 'salt water, when it turns into vapour, becomes sweet, and the vapour does not form salt water again when it condenses. This I know by experiment' (Aristotle, 350 BCE). However, Aristotle was not proposing desalination for human use of water but rather stating a fact that he learned.

The first patent for desalination was granted in the 17th century in England. The first seawater distillation plant was built by the British in Aden (now Yemen), primarily so its ships en route to India could be supplied with freshwater. The first large seawater desalination plant was built in 1930 in Aruba.

When Kuwait constructed its first evaporator-based desalination plant in 1951, large-scale desalination technology was in its infancy. Real interest in the United States in desalination started only when it was facing a prolonged drought in the Southwest during the 1950s. The US government established the Office of Saline Water in 1955. In 1958, this office was given the responsibility to construct five demonstration desalination plants in different parts of the country. The idea was to find the most efficient and cost-effective technology and then replicate it in different parts of the country to alleviate water scarcity problems.

In June 1961, President John F. Kennedy noted that desalination is a 'work that in many ways is more important than any other scientific enterprise in which the country is now engaged'. Unfortunately, however, rains returned to the region around the same time, and unsurprisingly interest in desalination declined. Faced with a high cost of desalination (then around US$1.25/1000 gallons) and the end of the drought, the Office of Saline Water was incorporated into a much larger Office of Water Resources Research. Even this new office was abolished in 1982!

As the United States lost interest in desalination, the Gulf countries picked up the mantle. Currently, Saudi Arabia leads the world in terms of quantity of seawater desalinated. This has made the SWCC a driving force in the world in terms of desalinating seawater in recent years. Furthermore, as water security became an important issue in many parts of the world in recent years, desalination has been progressively viewed as a possible solution.

Current concerns with desalination

At present there are three general concerns with desalination. First, it is expensive because of its high energy requirements. Accordingly, its affordability to users, mainly domestic, becomes an important issue unless desalinated water is subsidized or provided free by governments.

Energy requirements to desalinate one unit of seawater have steadily declined during the past two decades. The current generation of well-planned plants requires about 3 kWh of energy per m^3 of desalinated water. It is likely to fall to around 2.8 kWh/m^3 by 2025. As the process approaches the thermodynamic limit, further reductions in energy will require much higher investments in terms of accelerated research and development activities and may become progressively difficult to achieve.

The second concern is its environmental costs, especially in terms of brine disposal. Current desalination plants produce about 1.5 m^3 of brine for every m^3 of desalinated water. Typically, for all desalination plants near coasts, brine is discharged back into the sea. The Gulf countries now lead the world in terms of desalination. Thus, not surprisingly, waters around the coasts of the Gulf region are now the most saline in the world because of increasing discharges of brine from desalination plants.

Increasing salinization of coastal waters due to brine disposal has adverse impacts on marine ecosystems, especially on primary producers and benthic communities. If velocities of brine discharges near sea outfalls are high, strong dilutions may occur. However, this may cause hydrodynamic disturbances which, in turn, may result in the development of serious density currents which can carry the discharged brine much longer distances without much additional dilution. This will invariably cause more ecological disturbances.

In recent years, there has been considerable discussion about the possibility of recovering minerals from discharged brine. There are various types of minerals in the brine. These could be of four different types: high concentration but low value (such as salt), very low concentration but high value (gold, silver), low concentration but intermediate value (lithium, copper), and relatively high value and concentration (magnesium, potassium and bromine). If salt is extracted from the brine from all desalination plants that are currently in operation, and this is practiced universally, it would mean that the current global production of salt will rise by over 10 times. This will undoubtedly decimate the global salt market, and its price would encounter a free fall. Lithium and potassium may have a market, but separation technology for recovering them economically is not available at present.

Realistically, mineral recovery and sales of recovered minerals from the brine to reduce the cost of desalination at any significant scale are very unlikely to happen before 2030 at the very earliest.

The third set of constraints is the carbon footprints of the construction and operation of desalination plants. With countries making commitments to be carbon neutral by 2040–70, desalination plants cannot remain to be an exception. Unfortunately, achieving carbon neutrality from the entire desalination process has not received much attention from the proponents of desalination. Current discussions are limited to replacing electricity generated by fossil fuels with renewable sources of energy. However, many techno-economic problems to achieve even this goal still exist. These are unlikely to be resolved any time before 2030.

Even if it is possible to make desalination plants carbon neutral for their operational activities, there has been virtually no discussion or appreciation of making desalination infrastructure to be carbon neutral. Making desalination plants and their operational activities carbon neutral is highly unlikely to be achieved in most countries before 2050 at the very earliest.

Desalination within a water security framework

For most locations, desalination is the most expensive form of producing new sources of water which could contribute to security. Accordingly, the most logical approach to ensure domestic water security for any country that is considering desalination as an option to ensure future water security will be to review objectively and comprehensively all the processes and practices of current systems of water supply and wastewater management and improve their efficiencies in all stages as much as possible.

It should start with a very fundamental question that the water profession has not really asked during the past century, let alone answered. It is: How much water does a person need to lead a healthy and productive life? Consider Riyadh. According to official data, daily per capita water consumption has progressively increased from 289 litres in 2009 to 357 litres in 2017, an increase of 98 litres in only eight years (General Authority for Statistics, 2018). Citizens of some cities in the Gulf region, one of the most water-stressed regions of the world, currently use more than 500 litres of water per person each day. This is nearly five times the water consumption of an average Danish citizen.

Over the past 50 years, most Gulf cities have transformed their living and cultural conditions from one where water was used very carefully and sparingly to one where water use has become one of the highest in the world. Current water-use patterns are clearly unsustainable over the long term.

Thus, the fundamental question that needs to be asked and answered is how much water a citizen of a Gulf country, or any other country, needs to lead a healthy and productive life. This would be very critical information for efficient water management. Unfortunately, no such studies have been carried out in the Gulf countries or in also almost in any other country of the world. The only such study was carried out in Singapore, between 1960 and 1970 (Biswas, 1981). It correlated domestic water use in relation to waterborne diseases reported in Singapore hospitals and showed that as domestic water use rose, disease rates fell. However, there were no perceptible health improvements beyond water use of 75 litres per capita per day. This level could be considered to be a social minimum.

There is now increasing evidence that per capita daily water use of around 75–80 litres may be enough for nearly all countries for their citizens to lead healthy and productive lives. Spanish cities such as Barcelona and Zaragoza in arid and high-temperature climates now have reduced their daily per capita consumption to less than 100 litres, and this rate is still continuing to decline.

The Singapore study and other recent data from various urban centres of developed countries show that per capita daily water use of 75–80 litres may be adequate for average people to lead a healthy and productive life. Any amount of water used beyond this quantity, in most countries, is very likely to be aesthetic and thus a lifestyle choice primarily because extra water is available, either free or at a subsidized rate.

Thus, a fundamental policy dialogue that needs to be carried out before any new desalination plants are constructed is: Can the current water-use patterns be significantly reduced so that additional desalination capacities are not needed because of the high cost and environmental damages of such processes?

Another related important issue that came up for discussion during the Riyadh Conference was the high rate of unaccounted-for water in many countries, often around 20–35% of the total water supply. The idea was: Would it not be a better policy decision to reduce this high unaccounted-for water to around 5–8% before expensive desalination plants are considered? It is worth noting that Tokyo now has unaccounted-for water at 3.9%, and Singapore at 5%. Even Phnom Penh, a Third World country, has had its unaccounted-for water during much of the past decade at 8% or less (Biswas et al., 2021).

Accordingly, one fundamental question that policymakers and water professionals need to ask and find an appropriate answer: Is it morally, economically and environmentally justified for any city to consider desalination when its citizens use water profligately and unaccounted-for water rates are above 10%?

In fact, during the Riyadh Conference, some participants advocated that multinational development banks should not provide funding support for desalination projects in developing countries until they first reduce their unaccounted-for water rates significantly.

There are fundamental questions that need to be seriously discussed and appropriate policy options need to be found in each country, to ensure their water security during the coming decades, including desalination considerations.

Expanding water supply but not managing water demand

Throughout history, balancing water supply and demand has mostly focused on increasing water supply but neglecting policy options to reduce demand. There are claims that many parts of the world are facing water scarcity that is unprecedented in human history. Even then, cities do not consider how demands for water for domestic, industrial and agricultural uses can be very significantly reduced to the extent that there may not be any water scarcity not only now but also in 2100 (Biswas & Tortajada, 2019). The so-called water crisis in most countries is not because of the lack of this resource but because the available resources are being managed very poorly.

Policymakers and politicians find that expanding water supply is primarily a techno-economic and thus much easier option to focus on. This is because if technology and funding are available to increase water supply to meet higher demands, no societal mindset changes are necessary. In contrast, if demand management options are to be considered, water should be priced at its marginal cost, and water awareness and conservation ethos have to be installed among all citizens. Unfortunately, for decades, people have become used to receiving subsidized, or even, free water. To wean them from this centuries-old practice will not be an easy task. However, it is a doable task, as countries such as Denmark have shown. Per capita daily water use in Denmark in 2020 was 101 litres per capita per day (DANVA, 2020). This figure has been steadily declining over recent years.

An important constraint that the water profession has faced historically is that it is dominated by engineers: social scientists have been missing from these discussions. Not only in Riyadh but also at major water fora such as World Water Forums, and various national and international Water Weeks, social scientists have been conspicuous by their absence. Yet, how to change human behaviour, including installing a resource conservation ethos in all citizens, is in the preview of social scientists and not engineers. Thus, unless the water profession makes a sustained attempt to get social scientists actively involved in water management on a long-term basis, supply-side management will continue to be the only non-flexible solution. This, for sure, will contribute to a global water crisis over the medium term.

Future of desalination

The International Conference on desalination that the SWCC and GWI organized is an excellent first step. The future of desalination contains many complex issues which are changing or evolving with time. It is hoped that the SWCC considers making this a biennial event.

There is no question that this meeting was a remarkable success. However, special efforts should be made in the coming years to bring social and political scientists into the discussion.

Nearly all over the world, conflicts between various freshwater users are not only becoming commonplace but also more intense with time. This is because allocating limited freshwater available in any country is a zero-sum game. In contrast, seawater is unlimited, and its volume has been steadily increasing in recent years due to global warming. This is contributing to the melting of glaciers and sea-level rise. Thus, desalination could be an important source of water in the coming decades in specific locations.

It is, however, important to note that mechanical desalination, as it is practiced currently, may give way as more research is done in the area of biomimicry. It could become a very appropriate cost-effective and environmentally friendly solution in the post-2040 world. Increasing research is being done by biologists as to how anadromous species of fish desalinate water in their own bodies. These types of fish spawn in freshwater, migrate to the oceans and mature there, and then return to freshwater to spawn. Common anadromous fish include salmon, smelt, sturgeon and lamprey. Catadromous fish do the reverse. They spawn in marine water, mature in freshwater and then return to ocean for spawning. Examples are eels. Similarly, mangroves have a built-in unique ultrafiltration system that removes more than 99% of salt ions of seawater through their roots.

Research is accelerating now on how nature does desalination so effectively in the case of certain species of fish as well as in plants such as mangroves. Our estimate is that biomimicry could become a viable cost-effective and environmentally safe form of desalination in the post-2040 world. At the Riyadh Conference, except for our Keynote Plenary lecture, the biomimicry possibility was not even mentioned, let alone discussed.

Should the SWCC decide to make the future of desalination a biennial event, as suggested above, it would be desirable to bring in prominent biologists working in biomimicry to discuss and review progress in this area.

Papers in this issue

As usual, the current issue of the journal contains several important papers on a wide variety of subjects. These include hedging the risk of hydrological drought in irrigated agriculture (Gómez-Limón et al., 2021), local empowerment and irrigation devolution in Ethiopia (Bekele & Mekonnen, 2021), the value of groundwater to public supply in west-central Florida (Van Beynen, 2021), delivering multipurpose hydropower under water and energy risks (Wyrwoll & Grafton, 2021), perceived versus measured water supply service in New Zealand (Robak, 2021), comparative assessment of an alternative water supply: contributions across five data-scarce cities (Sušnik et al., 2021), discourse analysis of water diplomacy aspirations by the Netherlands (Mukhtarov et al., 2021), and a study of the transmission of SARS-Cov-2 associated with wastewater treatment (Muñoz-Palazon et al., 2021). Together, these papers provide a wealth of new information on different aspects of water management.

References

Aristotle. (350 BCE). *Meteorology. Book 2*. Translated by E. W. Webster. Provided by The Internet Classics Archive. http://classics.mit.edu/Aristotle/meteorology.2.ii.html

Bekele, R. D., & Mekonnen, D. (2021). Local empowerment and irrigation devolution in Ethiopia. *International Journal of Water Resources Development*, *38*(6). https://doi.org/10.1080/07900627.2021.1936465

Biswas, A. K. (1981). Water for the Third World. *Foreign Affairs*, *60*(1), 148–166. https://doi.org/10.2307/20040994

Biswas, A. K. (2006). *Challenging prevailing wisdoms: 2006 Stockholm water prize laureate lecture*. Third World Centre for Water Management, Mexico. https://thirdworldcentre.org/2006/08/challenging-prevailing-wisdoms-2006-stockholm-water-prize-laureate-lecture/

Biswas, A. K., Sachdeva, P., & Tortajada, C. (2021). *Phnom Penh water story: Remarkable transformation of an urban water utility*. Springer.

Biswas, A. K., & Tortajada, C. (2019). Water crisis and water wars: Myths and realities. *International Journal of Water Resources Development*, *35*(5), 727–731. https://doi.org/10.1080/07900627.2019.1636502

DANVA. (2020). *Water in figures 2020*. Benchmarking & Statistics. Denmark. https://www.eureau.org/resources/publications/members-reports/5482-danva-2020-water-in-figures/file

General Authority for Statistics. (2018). *Per capita water consumption in Saudi regions during the period 2009–2017*. https://www.stats.gov.sa/sites/default/files/per_capita_water_consumption_in_saudi_regions_en_0.pdf

Gómez-Limón, J. A., Guerrero-Baena, M. D., & Fernández-Gallardo, J. A. (2021). Hedging the risk of hydrological drought in irrigated agriculture: The role of precautionary savings. *International Journal of Water Resources Development*, *38*(6). https://doi.org/10.1080/07900627.2021.1949699

Mukhtarov, F., Gasper, D., Alta, A., Gautam, N., Duhita, M. S., & Hernández-Morales, D. (2021). From 'merchants and ministers' to 'neutral brokers'? Water diplomacy aspirations by the Netherlands – A discourse analysis of the 2011 commissioned advisory report. *International Journal of Water Resources Development*, *38*(6). https://doi.org/10.1080/07900627.2021.1929086

Muñoz-Palazon, B., Bouzas, P. R., González-López, J., & Manzanera, M. (2021). Transmission of SARS-CoV-2 associated with wastewater treatment: A seroprevalence study. *International Journal of Water Resources Development*, *38*(6). https://doi.org/10.1080/07900627.2021.1910935

Robak, A. (2021). Perceived vs measured water supply service: Evidence from New Zealand. *International Journal of Water Resources Development*, *38*(6). https://doi.org/10.1080/07900627.2021.1940105

Sušnik, J., Jussah, O., Orabi, M. O. M., Abubakar, M. C., Quansah, R. F., Yahaya, W., Adonadaga, J. A., Cossa, C., Ferrato, J., Cossa, C. A., Hadi, W., Yuniarto, A., Marsono, B. D., Purnomo, A., Bichai, F., & Zevenbergen, C. (2021). Comparative assessment of alternative water supply contributions across five data-scarce cities. *International Journal of Water Resources Development*, *38*(6). https://doi.org/10.1080/07900627.2021.1964449

Van Beynen, P. E. (2021). Value of groundwater to public supply in west-central Florida. *International Journal of Water Resources Development*, *38*(6). https://doi.org/10.1080/07900627.2021.1931051

Wyrwoll, P. R., & Grafton, R. Q. (2021). Reforming for resilience: Delivering 'multipurpose hydropower' under water and energy risks. *International Journal of Water Resources Development*, *38*(6). https://doi.org/10.1080/07900627.2021.1944844

Asit K. Biswas
International Journal of Water Resources Development, Third World Centre for Water Management, and Water Management International Pvt. Ltd, Singapore
http://orcid.org/0000-0001-9332-4298

Cecilia Tortajada
International Journal of Water Resources Development, School of Interdisciplinary, Studies, University of Glasgow, Glasgow, UK
cecilia.tortajada@gmail.com http://orcid.org/0000-0001-6308-4924