The Challenge for Membrane Materials in Water Separations

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Membranes are a human technology; water is life. Before we can discuss challenges for membrane technology in water separations we need to discuss a much larger issue. What are the challenges for humans and water? We have come to the point of accepting that, despite the cause, we are experiencing changes in our weather patterns. Communities that could always count on snowmelt are gazing up at dry winter mountaintops. Those who were certain spring rains would water their crops are still gazing out at dusty dry fields when June comes along. Other areas are being deluged in torrents of rain such that soil and crops are washed away. What is the role of the membrane industry in such a world?

Over the past year we have been working with Texas Water Development Board and Texas Division of Emergency Management, and meeting with Texas Commission on Environmental Quality and small towns in severe drought situations to try to understand what technology can do to help in the event of a drought emergency. We were surprised by the answer: Not much.

Some of the key roadblocks to membrane applications in drought emergency are

1. Traditional concepts of water supply and ownership,
2. Competition for water between municipal use, agriculture, power, industry, and energy extraction,
3. Utility managers unfamiliar with membrane processes, there cost, and operational issues,
4. Overworked regulators unfamiliar with membrane processes and how they should be handled within outdated regulations, and
5. Static system design.

Traditional Concepts of Water Supply

United States View of Water: Inexpensive, plentiful, out of mind. If it is in our pipe, it is ours. If it is under our land it is ours. When it leaves our house, we never want to see it again. This kind of thinking is not conducive to increasing use of membrane systems to improve our water supply. It is also illogical, unrealistic, and unsustainable. “The Big Thirst: The Secret Life and Turbulent Future of Water” by Charles Fishman (2011) is the best water book I’ve read yet. It eloquently describes our idiosyncratic mythology of

water in a way that hopefully even the water blind will begin to see their folly. Water is the most wonderful thing in the world, yet we take it for granted. We demand utmost purity and then use it to flush the toilet, wash the dishes, and water the grass. We pay more than $100/per month for TV, phone, and Internet yet complain bitterly if our monthly bill for unlimited pure water in a desert goes above $50. People who receive ultra-filtered snow melt right from their tap purchase glossy electronic devices for thousands of dollars to "increase the alkalinity" because they don't trust the healthfulness of their water. Others buy water shipped in plastic bottles from around the world because they think it will be better for them.

Application to Membrane Separations: This type of thinking drives investment into membrane systems for bottled water. But is it the best use of the technology? We ought to be recycling industrial and municipal water or at least treating it to a high level before releasing it to the environment to ensure that the next user has clean water.

Water footprint? After the Carbon Footprint became a popular metric, Professor Arjen Y. Hoekstra created the Water Footprint concept to show the linkage between consumption of goods and water resources (www.waterfootprint.org). This is a difficult and misleading concept geared toward developing a societal decision-making process to allocate water resources. Unfortunately in the United States, society doesn't make water resource allocation decisions. They are made through economics.

Another problem with the water footprint concept is that unlike fossil fuel; water is not destroyed with use and there is little global impact associated with using water in a sustainable manner. With the exception that mining water stored deep underground may be adding to the total water in circulation and contributing to the rise in ocean levels a bit. Whatever the use, water is still water.

Water is local. If a city has abundant fresh water, why conserve? Conservation needs to be promoted where water is scarce and where the water requires significant treatment or pumping cost. In those places a higher price that actually reflects the cost of delivery and treatment will promote appropriate conservation. Otherwise, conservation just cuts revenue for supporting the water system and leads to higher rates.

Application to Membrane Separations: If the cost of water was directly tied to the cost to treat and deliver it, and if people were given an accurate message about their own water supply, then there may be enough capital and public support to invest in better treatment systems – which may be membrane systems.

<u>Competition for Water</u>

The concept behind the Water Footprint is that if we knew the impact of water use behind the products we use, we would make better/different decisions about which products we use. As mentioned above, in the United States, water resource decisions are not made from an area wide perspective. For instance, in Texas, during our drought planning interviews with communities we found rampant competition for water between small

rural towns and agricultural and energy extraction industries. In Texas the High Plains Underground Water Conservation District limits pumping from that aquifer to 1.75 acre ft/contiguous acre per year for 2013 to be reduced to 1.5 in 2014. Beginning in 2013, municipalities are limited to the maximum documented pumping per year from the past three years (http://hpwd.com/rules-and-management-plan/district-rules/ Rule 5). Oil and gas wells are exempt from pumping limits (same link, Rule 7c).

The past three years have been serious drought years with farmers pumping as much as they could to make up for rain that did not fall. Green irrigated fields surround each of the four towns we visited while the city wells were declining in productivity. Municipal wells need to be constructed according to AWWA standards to include sufficient packing and screen mesh to provide filtration. Irrigation wells do not have that requirement. As a result, a municipal well is far less productive than irrigation wells in the same formation. Irrigators pump as much as they can, drawing down the water levels in the aquifer, leaving nearby municipal wells high and dry. As a result the towns will be limited to what they were able to secure during a very difficult time for municipal pumping.

In Texas groundwater rights come with the land. One of the communities we interviewed had lost a bidding completion for a productive well in the vicinity to an energy company. That town had to truck in water from 30 minutes away at a cost of $95 for each 2000 gallon load.

If we actually did prioritize water resources, how would we decide to divvy up groundwater? The most sustainable allocation is to allow the best quality water to go to farmers who would be required to use drip irrigation since they would be putting it back on the land. Cities can drill deeper for brackish water. The water demand for a city is less than for farms. Cities generate more cash value per gallon than farms can so they have a better chance of generating the capital required for membrane systems. Cities have greater opportunities for conservation, assuming the farms use drip irrigation. Finally, cities need food from farms!

Brackish desalination plants still have a concentrate stream to manage. The level of desalination can be tailored to a certain degree such that the concentrate can be used for irrigation of ball fields and parks, or recovery can be maximized to enable recovery of minerals from the concentrate. With the right water chemistry, it is possible to precipitate minerals in the concentrate and then recycle the supernatant stream. There are many possibilities. The trouble is that they are site specific solutions. A well planned desalination process is not a cookie cutter proposition.

Application to Membrane Separations: Design complete desalination processes for cities using brackish ground water tailored to meet their needs for concentrate management based on the water chemistry and potential productive uses for the concentrate. Develop methods to extract valuable mineral products from the concentrate. Is there a way to mimic nature’s methods for concentrating and crystalizing minerals? Get botanists and agriculturists involved in the design to choose the best grasses for ball fields and parks irrigated with saline water.

Lack of Familiarity with Membrane Processes, Cost, and Operational Issues

During our community interviews we found that the managers knew something about membrane separations and that membranes may be the answer to dwindling water supply and declining quality. However they did not know what such a process might cost, what is involved in operating membrane processes, or the options available for waste management. Towns that have gone to membrane processes usually love them and would never go back to chemicals and media filtration. The managers we spoke to who had surface water were very interested in switching to ultrafiltration (UF) because it is fairly insensitive to incoming water quality. The stagnant reservoirs these towns are drawing from have algae problems and when it does rain, runoff from the dry dusty ground drives turbidity levels over 1000 NTU. Media filtration cannot handle that kind of solids loading.

The aquifers in much of Northwestern Texas are brackish. The towns in that area not lucky enough to have wells in the High Plains Aquifer, get their water from long shallow reservoirs that capture runoff in the rainy season. If the rainy season doesn't arrive, the only other option is brackish groundwater. These managers need competent engineering firms to help them plan upgrades to their water systems. But an engineering firm was present at only one out of the four community interviews.

Application to Membrane Separations: Rather than sending young engineers off to far away countries with Engineers Without Borders, send them to rural America to help small rural towns with their water system up-grades. It would be excellent experience for young engineers, help them see the country, and help us keep rural America alive.

Overworked Regulators and Outdated Regulations

In Texas much of the municipal water system regulations involve describing exactly how the water system is to be designed and operated, when the manger is supposed to notify the public, and what happens if he/she doesn't follow the regulations. Membrane processes are lumped together with anything that is not described in detail as an "Innovative or Alternative Technology" (30 TAC§290.39(l) and §290.42(g)) That membrane processes are called out as "Best Available Technology" for many treatment issues by the Environmental Protection Agency, makes no difference in Texas. A pilot study test plan must be developed by a state certified engineer, which is then reviewed by TCEQ (Texas Commission on Environmental Quality) who decides if it is complete enough. Then state certified operators must carry out the pilot test under supervision of the state certified engineer for at least six weeks. There was a guidance document on the procedure but it expired after TCEQ reviewed our community case studies in which it was referenced. After the pilot test, the engineer must write a report and submit it for review by TCEQ. The process can take a long time.

Due to the great demand for desalination and membrane filtration applications since the start of the drought, TCEQ did enter into discussions last summer with membrane

industry representatives to revise regulations concerning membrane process approvals. Unfortunately a lot of the discussion was focused on the exact design flux rate, cleaning frequency, integrity testing methods, and chemical additives that should be required rather than on streamlining the procedure.

Application to Membrane Separations: Develop and present special training for regulators. The membrane industry must to draft appropriate regulations for membrane processes for municipal water treatment. Otherwise, the regulators may regulate practical membranes applications right out of the water business.

Static Process Design

Civilization in the United States is frequently static. Water treatment plants are built with the same mindset. An engineer estimates how much water there will be to treat and the character of that water as part of the design process. The system is built according to those specifications. Expansion is a matter of adding more or the same kind of parts. Contraction is a matter of taking parts off line. One good aspect of membrane systems is that they can easily be scaled up or down by taking trains off line or adding new ones. Plants are not flexible though in optimizing for the quality of water available. A membrane plant with brackish RO membrane will not do well with seawater. A nanofiltration plant cannot easily switch to treating highly brackish water. In these cases one would need to change the membrane. It may need a different organization of membrane modules for a different recovery rate and a different pump for higher pressure.

In 2010 we converted a seawater system to treat brackish water at 75 percent recovery by bi-passing the energy recovery device and using one third of the system as a second stage. It only involved adding a small section of pipe. It worked fine, using no more energy at 75 percent recovery than would be needed for 50 percent recovery with feed water of equivalent salinity. Such a system could be used in coastal areas that have intermittent access to brackish water due to tidal intrusion into a river. If using mainly seawater, sometimes it is necessary to stop production due to red tides or high turbidity storm periods. During those periods they could switch to using brackish water from wells or from a tide influenced river. A flexible system is capable of switching easily from one source to the other.

All of the towns we visited for the drought planning interviews were facing a change in water source and quality. One town's well water had become more brackish and laced with methane since the drought. Another that was used to good clean High Plains Aquifer water was looking at needing to drill deeper into a saline aquifer. The other two both had surface water sources that were getting very low and were looking for brackish well water to carry them through the drought. If they were to invest in a membrane system, it would be a great selling point if the system would still be useful when the rains come back again and also if the well water began to be more saline than it was at the start.

Application to Membrane Separations: Plan for change in water quality and availability in membrane designs. Make them easy to contract/ expand and flexible in recovery rate and configuration.

In Summary

We have made great strides in development of efficient membrane processes for water separations for industrial and municipal applications. We have not done enough to educate potential users and other involved in the decision of how to treat water. Technology is only valuable if people can use it to improve life. Our challenge now is to make our wonderful technology accessible and adaptable to our changing world.

Reference:

Fishman, C. 2011. "The Big Thirst: The Secret Life and Turbulent Future of Water".
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