French-American Innovation Day: Membrane technologies as tools for sustainability in water management

The water industry is on the verge of a breakthrough.

Fifty years ago a series of breakthroughs in materials science led to the development of membranes, a new generation of filter materials. Materials science continues to produce new materials with improved properties, because it benefits from the digital revolution, from progress in biotechnology, and from our ability to better understand and mimic materials in nature.

Society also better understands the constraints related to water and to value water more highly. There is increasing discussion about the nexus of food, water, and energy, and new solutions are needed to improve the environmental sustainability of these basic needs.

The technology-push from developments in materials science and market-pull from societal changes are complementary. Together they are likely to lead to more breakthroughs and new solutions, for water and for membranes.

Historically both France and the United States have had a huge influence on shaping the field of membranes, starting in 1748 when Jean-Antoine Nollet first observed osmosis. The development of novel membranes, membrane processes, and membrane applications, as well as the water industry in general, have had major contributions from – and cooperation between – the two countries.

This combination of being on the verge of a breakthrough and having a history of French-American cooperation and contribution makes "Membrane Technologies as Tools for Sustainability in Water Management" an ideal topic for the tenth anniversary French-American Innovation Day (FAID) that was recently organized by the Office of Science and Technology (OST) of the French Consulate in Boston. Each year the OST chooses a topic that is ripe for innovation and transatlantic cooperation and brings together professionals from both countries to jump-start the process.

This year the event was co-organized with Veolia and spanned two days. The first day was devoted to a series of presentations by nineteen different people working in academia and in industry from both sides of the Atlantic. Each person gave a 15-minute overview of their work, the technologies they use, and the areas where they would like to collaborate. This format of short presentations was intended to spark later, more in-depth conversations.

The second day was devoted to workshops and in-depth discussions, to develop some of the themes that were presented the first day, and explore areas for collaboration.

Although the first day resembled other scientific conferences, the intent was very different. The intent was to be more of a think-tank, with the objective of creating new partnerships to develop new membrane technologies and new applications in water management. The OST also was careful to include speakers and participants from both industry and academia.

The focus of the event was on current work and current research, but some presenters also touched on more general topics. They noted that using membranes to process wastewater enables the water to be reused in a
way that was not possible before membranes were introduced to the process. Membranes also enable desalination of water with much lower use of energy than was previously possible. Membranes allow industry to operate in a more environmentally sustainable way, and to be less constrained by water management issues.

The water industry tends to move slowly, for various reasons, but the water crisis provoked by the Cryptosporidiosis outbreak in Milwaukee in 1993 helped the industry grow quickly. People realized that membranes could remove similar contaminants for which current water treatment processes were ineffective.

The industry has also been helped by the construction of desalination plants around the world beginning in the 1970s. This has been prompted by insufficient supplies of fresh water in many parts of the world.

The adoption of membranes to treat drinking water has shifted the industry from being largely the realm of civil engineering to being largely a process industry. The sensors in membrane plants provide a wealth of data, which has also increased the importance of data mining and data management.

Membranes are used in numerous processes, such as:
- Manufacturing pharmaceuticals
- Gas purification
- Filtering industrial emissions
- Filtering automotive emissions
- Uranium separation in the nuclear industry
- Waste water treatment
- Purifying drinking water (both desalination and water-organic separation)
- Processing produced water in the oil industry
- Producing demineralized cheese whey for the dairy industry
- Removing titrates from wine to keep crystals from forming
- Separation and purification of sugar
- Separation and purification in green chemistry (derived from plants, rather than from petroleum)
- Removing nitrates when fertilizer has polluted the water table
- Filtering the water in swimming pools

Each application requires different techniques and different types of membranes. The FAID focused on using membranes for water treatment, but even within the area of water treatment a wide variety of techniques and membranes were discussed.

Some of the topics covered by the various presenters at FAID were:

- Minimizing bio-fouling with reverse osmosis (organic material deposited on the surface of the membrane). This was discussed during several presentations. The techniques discussed included:
  - Various ways to pretreat the water before it passes through the membrane
  - Adding nanoparticles to the membrane, or treating it with silver
  - Creating a charged surface so it’s anti-microbial
- Increasing the recovery rate of reverse osmosis (percentage of usable water produced compared to the total amount of water needed). With current technology the recovery rate is around 45%, meaning that more than
half of the water that enters the system exits the system as unusable brine. This is an intrinsic limit of the process due to osmotic pressure. Attempts to increase the recovery rate are focused on combining reverse osmosis with other technologies.

- Using electrodialysis to increase the recovery rate. The recovery rate can be 80% or more with electrodialysis alone, and 90% or more when combined with reverse osmosis.
- Creating stronger membranes that will last longer, even under demanding conditions. Adding nanoparticles to the membrane shows promise in this area, as well as in reducing bio-fouling. Adding 1% or 1.5% of nanotubes significantly increases the strength of the membrane. Membranes can then be spun into hollow fibers, which create very thin, nearly self-supported, membranes for reverse osmosis. There is a relatively small sacrifice of permeability, but both salt rejection and rejection of organic matter increase.
- Processing trace organic compounds that tend to pass through waste water treatment plants. At some point, trace organic compounds in the drinking water supply could be a public health concern.
- Creating membranes with a larger surface area. This would allow a greater flow of water for larger applications, and also reduce the overall cost (because the plant requires less of all the other things that surround the membrane). It would also increase the efficiency of membrane manufacturing.
- Processing produced water. This is water that is a by-product of oil production, either water that occurs naturally or that is added while extracting the oil. The oil sands in Alberta have large amounts of this that need to be processed. An additional problem is the cost of installing equipment in Alberta. On-site erection costs can be staggering.
- Using computer simulation to model new membrane designs before creating a prototype.
- Using solar energy to power water treatment plants.
- When you optimize the water purification process, it's no longer enough to just think about the quality of the water. You also must think about sustainability.

The Office of Science and Technology is now planning the next FAID at the end of 2013. We are looking for both a topic and a French partner. Complete details can be found on their website, in English and French.

French version:

English version:
http://www.france-science.org/FAID-2013-Call-for-partnership.html

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