Advancements in Membrane Technologies

What are membranes?

Membranes are selective barriers that allow some things to pass through but not others. For example, chicken eggs have a membrane shell that allows oxygen to pass through but not water or other larger molecules. Membranes reject substances based on a number of criteria such as physical and chemical properties.

What is pore size?

Pore size refers to the size of the minute openings in the membrane that allow substances to pass through. Typically, membranes can have pore sizes less than 1 nanometer or up to 2 millimeters. There are several names used for membrane technology filtration that correspond to the pore size range:

- Macrofiltration – 2 micrometers to 2 millimeters (red blood cells, pollen, sand)
- Microfiltration – 0.04-3 micrometers (all bacteria, asbestos, paint pigment)
- Ultrafiltration – 0.002-1 micrometers (all viruses, gelatin, carbon black)
- Nanofiltration – 1-60 nanometers (endotoxins, synthetic dyes, some pesticides, some herbicides)
- Reverse osmosis (hyperfiltration) – 0.2-1 nanometer (metal ions, aqueous salt, sugar)

What are membrane modules?

While each membrane is made for a unique purpose, all membranes are packaged in modules for easy handling. Each module can be place in series or parallel to achieve more purification or handle a large volume of fluid. Membrane modules can be made from a variety of materials and in differing shapes:

- **Tubular** – membranes are inside a porous support tub and several tubes are grouped in a cylindrical shell.
- **Hollow fiber** – consists of a bundle of very fine hollow strands (or “fibers”). Each bundle is encased in a cylindrical shell.
- **Spiral wound** – two flat sheets of membranes are separated by inflow and outflow spacers and then these sheets are rolled into a compact cylindrical shape.
- **Plate and frame** – a series of flat membrane sheets sandwiched with support plates. The water to be treated passes between the membranes of two adjacent membrane assemblies and flows out between the membrane and the plate.
- **Ceramic and Polymeric** – can be either tubular or flat sheet and are typically used to separate aggressive medias (acids or strong solvents). They are typically built into submerged vacuum-driven filtration systems, which consist of stacks of modules each with a number of membranes. Water is filtered by flowing through the outside of the membrane to the inside where fluid is collected in permeate channels inside the membrane.

What are uses for membranes?

Membranes are used in:

- Water and wastewater treatment
- Desalination (top right photo)
- Industrial processes to filter out impurities from fluids used in the manufacturing of goods
- Medical applications such as in artificial kidneys (bottom right photo) or lungs
- Fuel cells

What are the energy requirements?

The energy requirements can be quite high for different membrane technologies. Sea water desalinization takes about 60-85 kilojoules of energy to produce a kilogram (1 quart) of purified water. This is the same amount of energy required to run a hair dryer for about 30 seconds. However, other scenarios can require even more energy for the same volume. The energy required is dependent upon the membrane module type, filtration pore size, fluid composition, impurities, size of the filtration process, energy recovery applications, and much more. While the energy needs to produce clean water or purified industrial fluids may seem onerous, advancements in clean energy production and membrane technologies may lessen the burden.

What are ISTC’s innovations?

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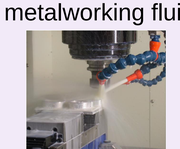
Reusing Metalworking Fluids

Metalworking fluids are used in the metal production industry to cool and lubricate tools used for cutting or stamping metal. They are composed of petroleum or vegetable oil mixed with corrosion inhibitors and other proprietary chemicals. Previously, once the fluids contained too many metal contaminants, they were disposed of at a high cost to the metalworking industry. ISTC researchers developed a series of specialized micro/ultrafiltration membranes that prevent membrane fouling and allowed metal contaminants to be filtered out, which extended the life of the metalworking fluid.

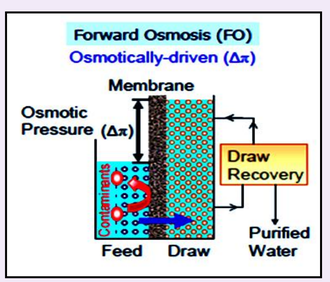


Factory use of metalworking fluid

Lab filtration tests

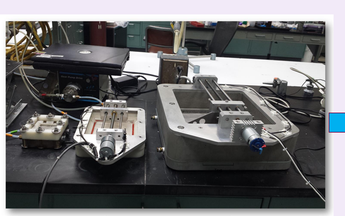
Reducing the Water-Energy Nexus Burden

Forward osmosis (FO) is sometimes considered to be optimal to reverse osmosis due to its lower energy requirement and ability to use low-grade energy (heat vs. electricity). And while forward osmosis technology is not new, it has been under utilized because of the difficulty in perfecting the draw solution so that it has high osmotic pressure while still being easily separated from the water or other fluid it draws across the membrane. ISTC researchers developed just such a draw solution. It uses aqueous magnesium sulfate – a noncorrosive, nontoxic, stable osmotic solution - to raise the osmotic pressure on one side of the membrane. In a departure from established FO practices, the diluted draw solution is recovered for reuse using a combination of a thermo-reversible polymer and heat energy. The end result is a safe, simple process that results in a lower carbon footprint than current FO processes. This process has been dubbed Aquapod© (US Patent No. US8852436).



Eliminating Coal Slurry Ponds

Illinois coal mines produce about 50 million tons of coal per year. Mined coal is made up of 10% ultrafine particles that cannot be used in the energy industry due to the particle size. These ultrafine particles are removed using a washing process and deposited into coal slurry ponds. ISTC researchers have developed a cost-effective dewatering technique to reduce the need for the creation of coal slurry ponds. The technique uses the Aquapod© method (described above) with a physical membrane scraping arm to prevent membrane fouling. The dewatered coal forms a dry shortbread cookie-type product that can be used in construction backfill at coal mines.



Laboratory scale