American Membrane Technology Association

America's Authority in Membrane Treatment

Industrial Applications of Membranes

Overview

Membrane products are well known for producing potable water in municipal plants and seawater desalination. However what is not appreciated is how much membrane technology is used in industrial applications around the world. Membranes achieve separations without a phase change and the absence of applying heat can be advantageous to some applications. The ability to remove water from a process stream or effluent has shown to be an effective way of concentrating valuable components of an aqueous stream. At times the membrane facility may not be large compared to a municipal plant but the value to the system and process may be critical for overall economic viability. Sometimes, the water available to an industrial facility may not meet the requirements of the application and membranes can be used to improve the quality so that the process can be run. Or perhaps the discharge from the processes is too great and a reduction step is needed that can be facilitated by membranes. At times, the concentration of the solution may not be desirable and an easy, efficient means of adjusting the concentration may be in order by using membranes. Finally, membranes are used in Membrane Bioreactors (MBR) for waste treatment in food and dairy, pharmaceutical and other facilities.

Applications Include:

Food and Beverage:

- Bottled Water
- Beer, wine, and alcoholic beverages
- Fruit juices and maple syrup
- Milk and cheese

Industrial Processes

- Clarification of biochemical processes
- Petroleum refining
- Paint, adhesive, and solvent recovery
- High purity applications such as semiconductor, boiler feed and power industry needs

Mining and Metal Processes

- Plating processes and waste reduction
- Gold and uranium recovery
- Recovery of precious metals
- Landfill leachate reduction

Reasons for Using Membrane Technology

Membrane processes employ a barrier layer that allows water to permeate or pass through it but rejects or retards other components from going along with that filtrate. In the case of microfiltration and ultrafiltration, distinct pores in the polymer allow for water to flow through the barrier but retard/reject the passage of species larger than the pores. Reverse osmosis barrier layers do not have distinct pores but do allow water to diffuse through the barrier layer and reject most of the dissolved ions in the mixture. Since heat is not used to effect the separations, the components in the mixture are less likely to suffer thermal degradation. Membranes are replacing diatomaceous earth filtration (DE), multimedia filtration, centrifugation, extraction, rotary vacuum filters, evaporation and distillation and other unit operations that have been used to make products. Cold sterilization of beverages, pharmaceuticals and milk take advantage of the membrane systems. Most of the membrane products commercially available have a polymeric barrier layer however ceramic membranes with distinct pores have been used in demanding conditions and are finding use in new applications. Ceramic membranes have pore sizes that classify them as microfiltration and ultrafiltration filters.

Membrane Applications

The range of applications that currently take advantage of membranes is impressive and continues to grow. Some of these are discussed below:

Food and Beverage

Bottled water: Since the feed water may vary from site to site, the bottled water industry has embraced membrane technology. Some purified bottled water manufacturers want to produce a reproducible product no matter what the feed source and as such they treat the local water to remove almost all of the constituents and then add back a package of ingredients to give a recognizable taste and feel to that particular brand of bottled water.

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Similarly, bottled water producers utilize membranes for their barrier properties to exclude bacteria and microorganisms. Soft drink manufacturers need safe clean water free of microorganisms and make up water is treated with membranes at a number of soft drink facilities.

Beer production: During the production of beer, brew masters around the world are particularly specific about the consistency and quality of the water that they use for the manufacture of beer. Membrane facilities are able to take locally available water sources and treat them to acceptable ionic content including hardness and alkalinity for use. In addition, membranes are used for continuous beer stabilization to improve operating efficiency of the brewery and continuous clarification and final filtration of the beer.

Wine: Membranes have been used for wine clarification and the avoidance of filter aids such as diatomaceous earth (DE) eliminates a disposal issue and loss of wine that would have been associated with the spent aid. Removal of suspended solids, yeast and bacteria and automation of the filtration process reduces losses, improve economics and minimizes labor when producing wine.

Fruit juice: Fruit juice manufacturers take advantage of membrane technology in a number of ways. Concentration of natural juices can be achieved in which water is removed as permeate and the concentrated juice is left behind. Since no heat is applied there is no degradation of the many complex juice sugars and flavor components. Color can be controlled and even enhanced during the concentration step. Produced juice can be purified and clarified by removal of fine particles from juice which clarifies the mixture and gives it a haze-free property that allows for longer shelf life.

Since bacteria and microorganisms are excluded in membrane processes, the juice is less likely to spoil and will remain safe to drink for longer periods of time. Fruit solids can be recovered in some cases and bitterness components removed by appropriate use of membranes. Removal of limonin and polyphenols has been done in a number of fruit juices including orange, grapefruit, tangerine and many more. Apple juice clarification and concentration as well as removal of biological species that are thermal resistant have been accomplished with membrane systems.

Maple Sap: The sugar concentration of natural maple sap from a maple tree is very low and traditional methods of making maple syrup involved boiling off the water. Membranes have become the means for the initial removal of water to concentrate the sugar content by 75 - 90%. Not only does this conserve energy but it avoids early application of heat to the syrup components to avoid early decomposition and change of the mixture.

Vinegar: Production of vinegar utilizes membranes to clarify the vinegar to give high quality product with low haze potential.

Dairy applications: The dairy industry has embraced membranes for many years. An obvious use is the concentration of milk and whey to reduce shipping costs, produce condensed milk or provide concentrated milk for cheese production. Membranes are being used on sweet/acid whey concentration before evaporation or spray-drying. Removal of bacteria and spores from milk aids shelf life and product stability. Acids and caustic are used to clean the equipment at dairies and membranes are being used to clarify the cleaning solutions by removing suspended and dissolved solids to allow reuse of the solutions.

Cheese manufacturing produced whey that was a troublesome by-product however membrane technology has allowed for use of this material via partial demineralization and concentration. Separation of casein from whey products allow for cheese production and whey protein concentration.

Industrial Processes

Clarification and purification of cell broths take advantage of the barrier layer of membranes. Extraction of amino acids and lipids can be accomplished and reused in blood and other cell cultures.

Enzymes are important to industrial processes and they improve the speed or efficiency of biochemical reactions. Advancements in enzyme production have been facilitated by the use of microfiltration. The cells that generated the enzymes are rejected by the barrier layer of membranes but the enzymes can pass though the pores. Prior methods of

centrifugation and filtration were hard on the enzymes and limited productivity.

Separation of sugars such as dextrose and maltose from fibrous and undesirable proteins while purifying the mixture can be done with membranes. Clarification of the process stream after saccharification has been done in different facilities. Gelatin, egg whites, soy protein and other natural products can be improved using microfiltration and ultrafiltration.

Wet corn milling grinds the corn and then membranes have been used for removal of the mud for dextrose clarification, cell and biomass removal, protein, peptide and enzyme recovery, purification of dextrose, and maltose clarification.

Methanol removal from organic mixtures has been achieved by taking advantage of the hydrophilic nature and low molecular weight of that alcohol. Extraction of valuable volatiles, dehydration of organic solvents, aroma extraction can be done. Natural essential oils and flavors can be enriched and improved via membrane fractionation and recovery.

Nutraceuticals is a growing market in which nutrition and pharmaceutical are combined. Membranes are being used for the extraction, separation, concentrate and purifications of materials that fill this demand.

Animal processing facilities generate significant volumes of blood that traditionally has been a costly waste stream. However, by concentrating the blood plasma, a valuable additive for biochemical processes or pet food can be produced, and a potential cost item becomes a revenue generating product.

Waste stream effluent reduction with membrane systems is wide spread. Pulp and paper mills utilize membrane systems to filter the effluent prior to discharge and minimize the actual amount of liquid that will be discharged from the facility.

Production of paint and adhesives may use membranes and in the automotive and appliance industry that use water soluble paints, membranes are being used to recover the paint while improving batch conductivity by removing salts and process metals. Improvements in maintenance of the solids level in the process and reuse of the paint reduce the waste load from the plant and make the overall process economics more favorable. RO for the recycle of rinse water for pre-paint rinse system and recovery of paint solids from treatment waste streams has been used to improve painting economics.

Fine chemicals and pharmaceutical production employ membranes for recovery and are used within the processes.

Aquarium salinity control – large outdoor aquariums are subject to rain water that actually dilutes the sea water concentration from the optimum levels needed to sustain the oceanic sea life. In these cases, a small RO system will remove fresh water as permeate and the concentrate can be added back the tank to maintain an acceptable salinity. Permeate can be discarded or perhaps used in some other water application on the site.

Petroleum refining uses membranes for removal of particulates and tar products from the process streams. Biofuels are increasing in production and membranes are used in the process to remove by-products and raw materials from the final product.

There are some applications that demand very high purity or ultrapure water such as semiconductor chip rinsing and processing, high pressure boiler water make-up and assorted power plant needs. Membranes play an important part in producing this very low tds water. In these uses, the presence of a salt ion or impurity could be detrimental to the final product or the equipment in use and membrane technology coupled with other separation processes allow their success.

There is a technique for washing windows that employs highly purified water to accomplish the task rather than use detergents and membranes are used to produce this water in an environmentally friendly way that reduces the organic load in the wash water.

Metal Removal and Treatment

Mining applications can range from reuse of mine water, treatment of secondary effluent for use in the mining operation, treating waste water to allow discharge from the plant, recycling mine drainage. Potable water can be recovered from acid mine drainage for use at the mine or in neighboring communities.

Recovery of high value metals such as gold and uranium from bleed and waste streams in mining plants can be done. Likewise, valuable metals like copper, zinc, cobalt, molybdenum and tungsten can be separated from process and effluent streams. Pre-separation of copper and gold in a mining operation has been reported.

Industrial plants utilizing homogeneous catalysts employ membrane technology to recover the valuable catalytic materials. Reusing these expensive

materials impacts the economics of the process and minimizes potentially hazardous waste streams that are costly to dispose of at these facilities.

Metal recovery – electroplating baths become contaminated with metals from the process and membrane technology has been used to clean up the baths and allow reuse of the solution thereby reducing the plating waste stream. A rechargeable nickel cadmium battery plant used a membrane system to remove dissolved metals such as mercury, lead, cadmium, silver, copper and chromium.

Landfill leachate contains a variety of components and membrane treatment has been used to remove water from the stream for safe disposal and then recycle of the concentrated leachate back to the pile. Radioactive species are rejected well by membranes and contaminated water can be treated to remove and concentrate the radioactive contaminants.

Other Applications

Nanofiltration has been used in organic solvents to separate larger molecules from the organic solvent so that it can be reused. Non-thermal solvent recovery, decolorization of solvents, solvent exchange at room temperature, in-situ recovery of organic solvent, monomer removal are all uses that allow reuse and deliver product upgrades. Non-thermal recovery of solvents and room temperature solvent extraction are accomplished with membranes.

Some membranes can be operated in pure solvents or mixtures. They can be used for recovery of antibiotics and peptides, dissolved chemicals, polymeric binders and pigments, dissolved catalyzed and even recycling of hydrocarbons in cleaning processes.

Some other applications include:

- Pigments and paints
- Latex suspensions
- Inks and dyes
- Emulsified oils
- Color removal for alcoholic beverages

Summary

Membrane processes have found a great variety of applications in which their use has improved products, recovered valuable components, added stability to the mixture, enhanced the aesthetics of the solutions and contributed to the economics of the processes. Microfiltration, ultrafiltration, reverse osmosis and nanofiltration each offer different separation options for industrial applications that will continue to grow in their use.

This material has been prepared as an educational tool by the American Membrane Technology Association (AMTA). It is designed for dissemination to the public to further the understanding of the contribution that membrane water treatment technologies can make toward improving the quality of water supplies in the US and throughout the world.

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