St. Lawrence TECHNOLOGIES

INNOVATIVE TOOL

POTENTIAL OF MEMBRANE TECHNOLOGIES FOR THE TREATMENT OF DRINKING WATER AND WASTEWATER

ABSTRACT

Since the late 1950s, when they were first invented, membrane technologies have had a major impact on industry. Today, the market for application of this separation technology to the treatment of aqueous and nonaqueous solutions continues to expand.

Their main qualities — selective physical separation by differential pressure, a permeate of consistent quality, and the recovery of primary materials — are matched by few other techniques. They can also be coupled with biological, physico-chemical or other treatment. For treating drinking water or industrial and municipal wastewater, membrane technologies are more than deserving of serious consideration.

HIGHLIGHTS

- **Technology**
  A physical separation technique that produces water of excellent bacteriological and/or physico-chemical quality for a wide range of performances.

- **Environment**
  Better management of water resources (quality and volume consumed), reduction in sludge volumes requiring disposal and maximum retention of pollutants.

- **Cost**
  Savings incurred by recovery of process water, primary materials and/or energy and reduction in volumes of wastewater requiring treatment.

Saint-Laurent Vision 2000

Environment Canada — Environnement Canada
Protection — Protection
Québec Region — Région du Québec

CNETE — Centre National en Électrochimie et en Technologies Environnementales

Canada Economic Development — Développement économique Canada

OBJECTIVES OF THE FACT SHEET

The objective of this fact sheet is to sensitize industrial and political decision-makers to membrane technologies and to demonstrate their environmental and economic potential for water treatment. This physical treatment technology has experienced exponential growth over the past 20 years for treating drinking water as well as industrial and municipal water. Applied to potable water, the technology's premier qualities are a considerable reduction in chemical additives and the near-absolute retention of bacteria, virus, natural organic matter and dissolved multivalent ions — each one reason enough to justify use of this technology in a human health context.
The technology is also attracting interest for application to industrial and municipal water.
The membranes function like water polishers, allowing for the reuse and recovery of primary materials.

BACKGROUND

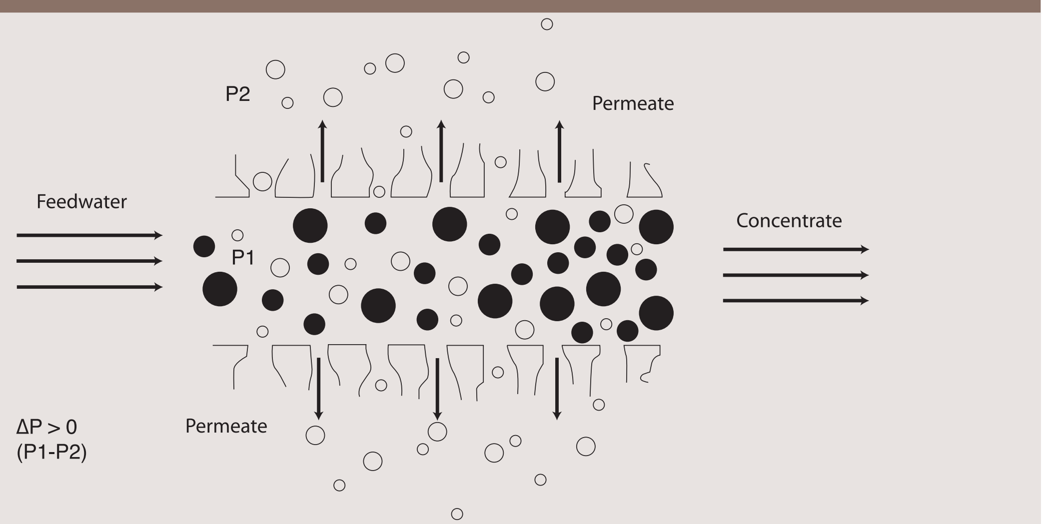
The seemingly unending demand for water by industry, agriculture and household use has increased pollution and led to a depletion of the resource. It is imperative that adequate treatment methods be found to safeguard this natural resource.
Membrane technologies are among the most plausible solutions, given their capacity to treat all types of water and help reduce demand.

TECHNOLOGY

Membranes have experienced unprecedented growth in the past twenty years for agri-food application and the treatment of potable water and municipal and industrial wastewater (Table 1). Among the most widely used techniques are microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO).
These pressure-driven separation techniques can also be coupled with bioreactors. Two different streams are generated, depending on membrane type and structure:
a permeate flow (filtered treated water) and a concentrate flow (retains contaminants). In these technologies, the fluid runs parallel to the membrane surface rather than perpendicular to it, in a self-cleaning mode (Figure 1, tangential filtration).

All membrane technologies require a membrane and a supporting module.
A membrane is a selective barrier, ranging in thickness from several hundred nanometres to a few millimetres which, under the effect of force, permits or prevents the passage of certain components between two separate environments.
This selective separation or permselectivity corresponds to the rate of permeability of the different substances

FIGURE 1: SCHEMATIC DIAGRAM OF TANGENTIAL FILTRATION



contained in solution. Varying gradients of pressure, concentration, electric potential or temperature act as the driving forces. There are a host of different membrane materials and structures and just as many possible configurations and classifications (Table 2).

Two distinctive types of membranes exist:

- Organic membranes, based on organic polymers (e.g. cellulose acetate, polysulfone, polyamids).
- Mineral or non-organic membranes, made of all-metal bodies, mainly ceramic or sintered metal.

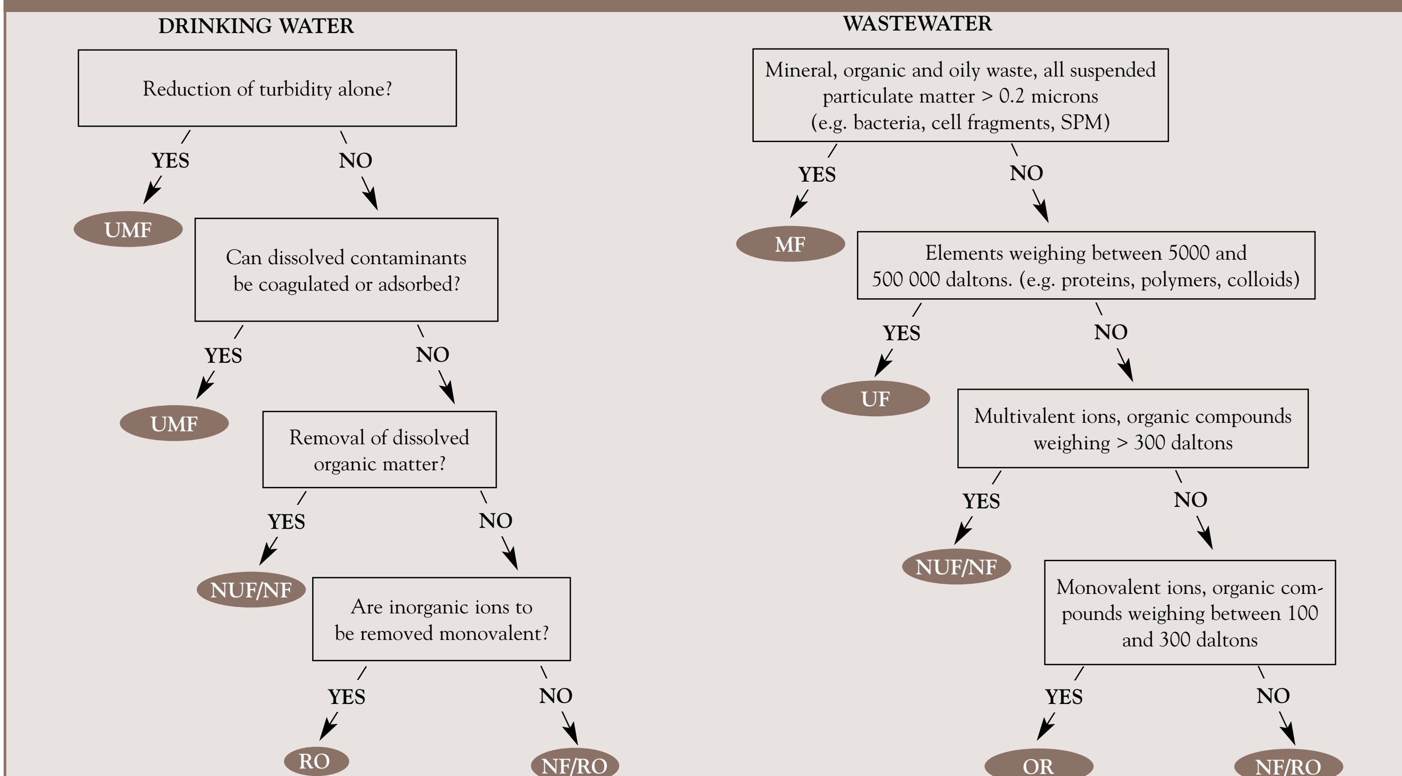
The membranes can be used according to different configurations.

- Spiral module: membrane sheets wound into spirals.
- Flat sheet module: flat membrane sheets.
- Tubular module: shaped like a polymeric tube or bundled into a ceramic casing, with a large pore diameter (more than 1 cm).
- Hollow fibre module (small polymer tubes, 1 mm to 1 µ in diameter).

METHOD

The successful application of membrane technologies depends on a sound evaluation protocol, based on a detailed study of the issue and the quality of the water. All the parameters must be determined from the outset, to ensure clients receive a product best suited to their needs. The different steps in the research process are shown in figures 2 and 3.

FIGURE 2: DECISION TREE FOR SELECTING A MEMBRANE TECHNOLOGY FOR TREATMENT OF POTABLE WATER AND WASTEWATER



UMF: limit between UF and MF. NUF: limit between NF and UF.

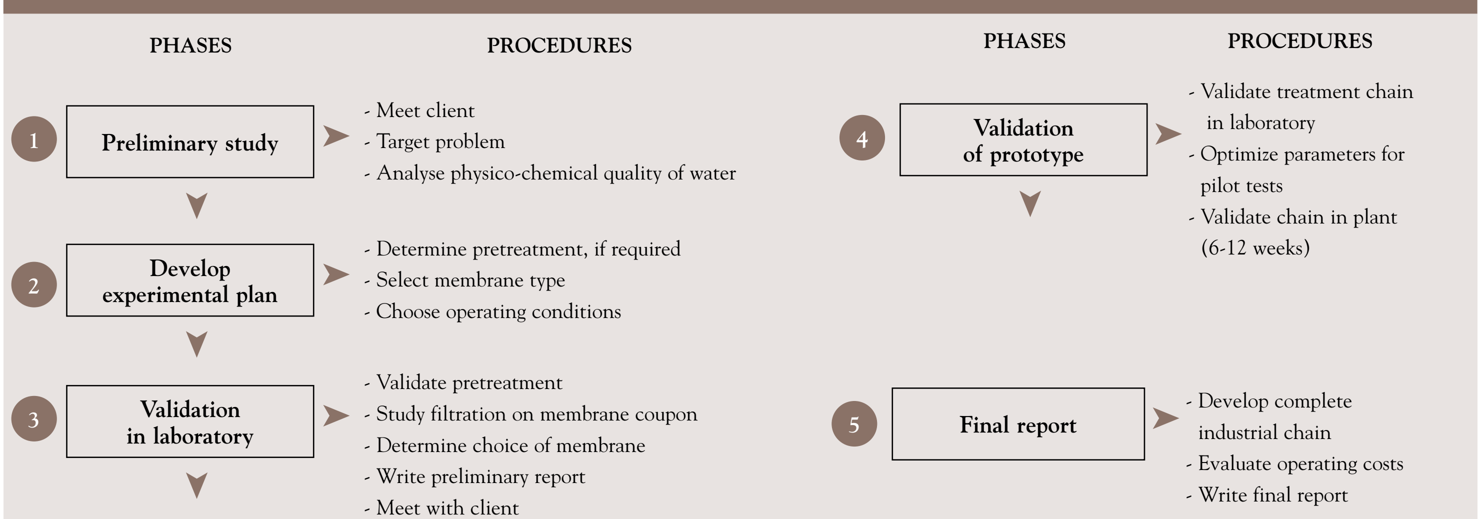
TABLE 1: EXAMPLES OF EFFLUENTS TREATED BY MEMBRANE TECHNOLOGIES

TYPE OF TECHNOLOGY (PORE SIZE)	TYPE OF EFFLUENT TREATED	SECTORS
Microfiltration (0.05–3 microns)	•.Clarification process, protective barrier against protozoan cysts • Decontamination of agri-food products (e.g. milk, cheese) • Recycling of alkaline solutions • Retention of colloids • Solutions containing oily liquids • Solutions containing suspended organic or inorganic matter	• Agri-food • Drinking water • Metallurgy • Mines • Petrochemicals • Pulp and paper • Textiles
Ultrafiltration (3–130 nm)	• Removal of colloids, virus and part of natural organic matter • Reduction of colour in water • Recovery of hot water • Recovery of residue in coated papers • Treatment of effluents with low organic substance loads • Adding value to abattoir waste • Removal of SPM, oils and lubricants • Treatment of effluents containing glue • Treatment of petrochemical effluents containing polyols	• Drinking water • Mines • Metallurgy • Petrochemicals • Pulp and paper • Tannery • Textiles
Nanofiltration (0.9–6 nm)	• Removal of multivalent ions, 80–95% of natural organic matter and colour • Recovery of water and/or dyes • Removal of micro-pollutants (pesticides, herbicides, insecticides) • Concentration and recovery of metals • Concentration and recovery of proteins • Concentration and treatment of contaminated acid or alkaline effluents	• Aeronautics • Agri-food • Chemicals • Drinking water • Metallurgy • Mines • Pulp and paper • Tannery • Textiles
Reverse Osmosis (0.1–1.5 nm)	• Removal of monovalent ions, desalination of sea water and brackish water • Recovery of coloured effluents • Recovery of ultrafiltered bleach plant effluents or ultrafiltered white water • Production of ultra-pure water for use in sensitive processes • Recovery of mining effluent water • Concentration and treatment of contaminated acid or alkaline effluents • Treatment of previously microfiltered or ultrafiltered water for reuse	• Agri-food • Aeronautics • Chemicals • Drinking water • Electronics • Metallurgy • Mines • Petrochemicals • Pharmaceuticals • Pulp and paper • Tannery • Textiles
Membrane Bioreactor	• Replacement of secondary settling by internal or external filtration • All types of end-of-pipe water	• Any industry where biological treatment is applied.

TABLE 2: ADVANTAGES AND DISADVANTAGES OF DIFFERENT MODULES AND DIFFERENT MEMBRANE STRUCTURES

SHAPE OF MODULE	ADVANTAGES	DISADVANTAGES
Flat sheet	• Low cost of membranes • High-pressure system • Parallel or serial	• Low membrane surface to volume ratio (100–400 m^2/m^3) • Major capital costs • Difficult to replace membranes
Tubular	• High concentration of SPM • High-pressure system • Parallel or serial	• Low membrane surface to volume ratio (below 300 m^2/m^3) • High fuel requirements • Storage of long membranes
Hollow fibre	• Modulable • High membrane surface to volume ratio (600–1200 m^2/m^3) • High concentration of SPM	• Only in parallel • Low pressure obligatory
Spiral	• High membrane surface to volume ratio (300–1000 m^2/m^3) • Modulable • High-pressure system • Parallel or serial	• High risk of clogging
Organic membrane (all modules)	• Wide range of constituent materials • Inexpensive	• Difficult to sterilize • Not very resistant to solvents, residual chlorine and ozone • Maximum temperature of use: 85°C
Inorganic membrane (flat sheet and tubular modules)	• Long life cycle • Resists solvents, chemicals and high temperatures • Easy to sterilize using steam or chlorine	• High cost • Relatively linear scale-up factor

FIGURE 3: EVALUATION OF TREATABILITY OF DRINKING WATER AND WASTEWATER BY MEMBRANE TECHNOLOGIES



POTENTIAL AND LIMITATIONS

Potential

Membranes have major economic and environmental potential:

- Reuse of treated water reduces water consumption and allows for recovery of its calorific value.
- Reuse of primary materials (e.g. chemicals, solvents, pigments, proteins).
- Replacement of some chemical processes, thereby eliminating problems related to ordering, handling, transporting, storing and disposing of chemicals.
- Concentration of effluents for disposal.
- Coupled with a bioreactor, membranes reduce sludge volumes and produce treated water of good quality.
- Treating waters at the source rather than at the end of the pipe, where they are mixed together.
- Concentration of solutions containing elements of high added value.

Membrane technologies use compact and adaptable modular systems and can treat volumes of water ranging from one litre to millions of litres per minute.

Limitations

Being physical barriers, membranes are subject to clogging, and physical (abrasion, temperature) or chemical (solvents, chlorine) degradation, depending on the structuring material. Although their tolerance thresholds are constantly expanding, membranes still require pretreatment in most cases. The cost-effective limit of water desalination is somewhere around 45 g of salt per litre of water.

INFORMATION

This fact sheet is based on a literature review and experimental research conducted by the Centre National en Électrochimie et en Technologies Environnementales (CNETE). Environment Canada provided funding for the project.

Fact sheets are available from:

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St. Lawrence TECHNOLOGIES

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