MICROFILTRATION AND ULTRAFILTRATION

Ata M. Hassan
Saline Water Conversion Corporation, RDC Al-Jubail, Saudi Arabia

Kevin Price
U.S. Bureau of Reclamation, Denver, U.S.A.

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Summary

Filtration is a separation process used in the pretreatment of water to remove from it suspended particles, bacteria, other impurities and pollutants. Various filtration processes have been developed through the ages to produce water with specific qualities. Media filtration is normally employed in the removal of particles greater than > 2 μm. For separation of fine particles in the range of 0.1 to 0.01 μm microfiltration (MF) and ultrafiltration (UF) membrane processes are employed. The media filtrations, MF and UF are true filtration processes used in the removal of particles according to their size and are not effective in removal of hardness or other ionic forms of impurities. The removal of the latter two forms of impurities is best done by the use of nanofiltration (NF) and/or reverse osmosis (RO) membrane processes. Various forms of membrane processes, such as MF, UF, and NF filtration, which proved to be excellent alternatives to media filtration in cleaning contaminants from drinking water can be utilized effectively in the pretreatment of RO and SWRO. Recently it was established that NF pretreatment can be used effectively in cleaning feed to seawater desalination plants from fouling and biofouling constituents (suspended particles and bacteria), in removal of scale-forming hardness ions (Ca^{++}, Mg^{++}, SO_4^{+} and HCO_3^{-}) as well as in lowering of feed TDS, and as a result allows for the improvement of seawater desalination 'plants' performance by raising their production and water recovery ratio as well as improving their water quality. This NF treatment is expected to lower the cost of fresh water production.

1. Introduction

Water quality and the type of pretreatment required to produce it are determined by the product (water) end-use. Thus, various treatment processes have been developed and are used to produce water with specific qualities. Desalination is employed in the separation of high quality fresh water from saline water. Normally, the desalinated water is intended for drinking or for the preparation of high purity water for use in industrial, pharmaceutical or food application. Treatment of river water or ground water, reservoir or lake water for drinking is less demanding unless the water is polluted. For non-polluted ground water the treatment may consist of simple disinfection with or without filtration. For more turbid non-polluted river and other surface water from lakes and water reservoirs various forms of coagulation-filtration followed by disinfection processes are employed. Treatment of industrial water is very much dependent on the nature and type of contaminants it contains. Treatment of waste water requires biological treatment in addition to other forms of secondary and tertiary treatments. Perhaps the most difficult water treatment is that involving certain types of industrial and polluted waters.

Filtration constitutes a major part of all the above treatment processes. It is used in water desalination, in waste water, industrial water and polluted water treatments as well as in the treatment of drinking water derived from rivers, reservoirs, lakes, etc. Because of its multitude of applications various forms of filtration processes have been developed to suit each and every requirement. The type of particles that can be separated from the water stream along with their size, molecular weight and the filtration process used in their separation are illustrated in Figure 1 (Osmonics Inc. 1984). Large particles, with sizes above 1 to 2 μm can be separated from the water stream by the particle filtration processes using media filters with or without coagulation.

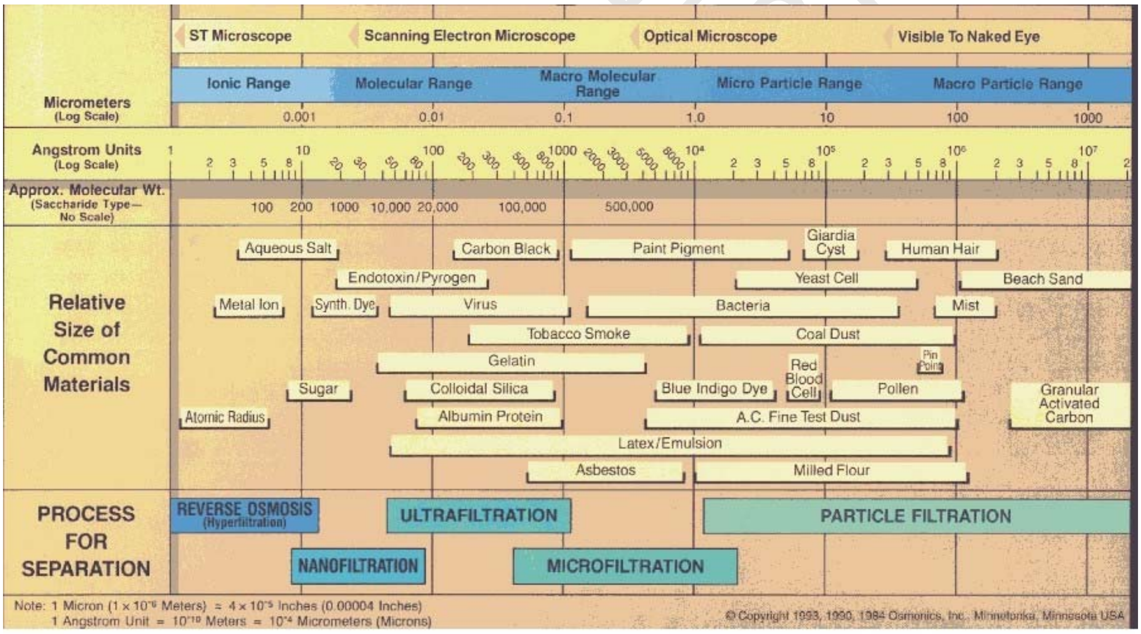

Figure 1. The filtration separation spectrum. (Courtesy of Osmonics Inc. 1984)

Coagulation-filtration allows the fine particles along with other contaminants, such as microorganisms or certain chemicals, to form or to be included in relatively large size flocs that can also be removed by the particle filtration process.

Membrane filtration is employed in the removal of fine particles less than 2 μm in size. Membrane filtration can be classified into microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and hyperfiltration/reverse osmosis (RO). Each of the filtration membranes has its own characteristic pore size and separation limits (see Figure 1). In general, the ability of membranes to reject particles is controlled by their pore size of 0.08 to 2 μm for MF membranes and 0.002 to 0.1 μm for UF membranes as compared to less than 0.001 μ for RO membranes. Pore size in NF membranes falls between the RO and UF and is in the order of 0.001 μ to 0.01 μ. Because of these differences in membrane pore size, MF is used for particle separation in the range size of 0.08 to about 2.0 μ. The UF membrane process is suited for the separation of finer particles in the range of 0.002 to about 0.1 μ or having molecular weight (MW) in the range of 400 to 400,000 g mol^{-1}. Both the MF and UF membrane processes are true filtration processes where particle separation occurs according to their size. On the other hand, the RO process deals with separation of ionic size particles in the range of 0.001 μ or less, molecular weight 200 g mol^{-1} or less and is based on the well-known RO desalination principle. The rejection by NF membrane, however, is based on two principles: the rejection of neutral particles is done according to their sizes and the ionic rejection of inorganic matter (salts) is achieved by their electrostatic interaction with the negatively charged NF membrane (Rautenbach, 1990).

Saline feed or feed containing very small particle size is separated into a product permeate stream that passes through the membrane, and a reject or concentrate stream which does not pass through the membrane. In the MF and UF membrane processes the reject stream contains fine particles plus bacteria and other pollutants found in the feed, while in addition to these the concentrate from the NF and RO processes also contains the salt ions rejected by the membranes.

Membrane nanofiltration falls in between the RO and UF separation range, and is suited to the separation of particle sizes in the range of 0.001 to 0.002 μ, MW 200 to 400 g mol^{-1}. The rejection by NF, however, is based on two principles: the rejection of neutral particles is done according to their sizes, i.e., particles of MW larger than 200-400 g mol^{-1}, and the ionic rejection of inorganic matter is achieved by their electrostatic interaction with the negatively charged membrane (Rautenbach 1990).

Both the particle filtration and RO separation processes are discussed in detail in other sections (See: Raw water pre-treatment - Introduction and Overview; Preparation / Characterization of Micro and Ultrafiltration Membrane) of this Encyclopedia and are not dealt with here. This article discusses MF, UF and NF membrane processes as a precleaning process upstream of membrane desalination plants together with a brief description of type of membranes, modules, plant set-up and their main application in water treatment.

The MF, UF and NF filtration processes normally consist of the membrane modules, a pressure pump, cartridge filter and a raw water supply system. This is shown schematically for a typical softening plant with NF membrane in Figure 2 (Bergman 1995). In this case the product is also degasified and post-treated. In many respects, the process resembles that of RO with the feed derived from underground or beach wells. The main difference, however, is in the magnitude of applied pressure and, therefore, materials of construction. Unlike RO which is normally operated at high pressure of 300-500 psi for brackish water RO (BWRO) and 800-1200 psi for seawater RO (SWRO), the pressure required in the operation of NF is about 90 to 150 psi and is lower in the case of UF and MF, about 50-80 psi or less.

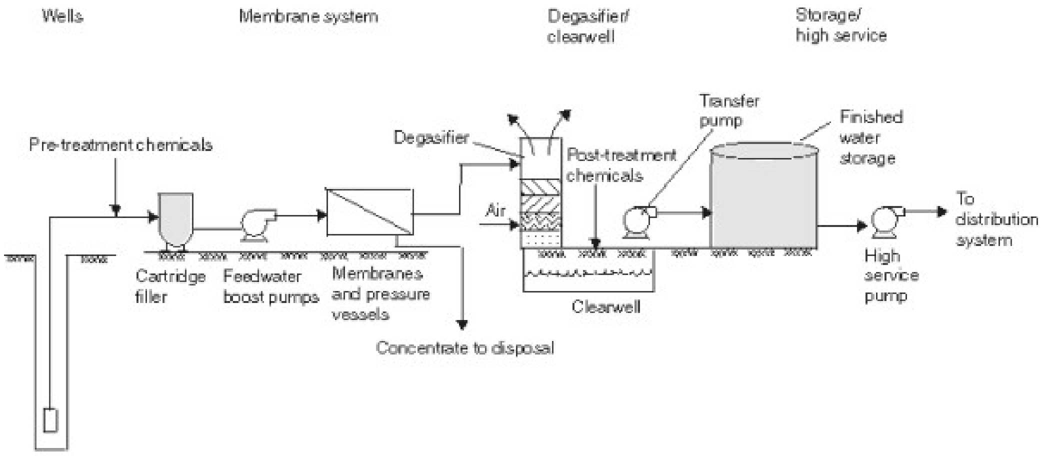

Figure 2. Typical membrane softening plant schematic. (Taniguchi 1995)

Elements used in membrane filtration could be of spiral wound, hollow fine fiber tubular or plate configuration, although spirally wound type membranes dominate. A good number of the companies that produce the RO membranes also produce a variety of commercial filtration membranes with different compositions to perform different separation treatments. The first membranes developed for water softening were made of cellulosic RO membrane chemically treated to reduce ion rejection and maximize hardness ions rejection (Conlon 1989). At present, nearly all the NF membranes are made of noncellulosic thin film composite polymers with spiral wound configuration. The polymer is normally a hydrophobic type incorporating negatively charged groups (Raman 1988).

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