Southwest Membrane Operator Association

MEMBRANE GLOSSARY, DEFINITIONS & INFO

Reverse Osmosis (RO) and Nanofiltration (NF) Buzzwords:

Antiscalant(s) -*:* A chemical(s) injected into the feed to a RO that inhibits or prevents precipitation of ions dissolved in the feedwater.

Anti-telescoping Device (ATD) - A plastic device on the ends of a membrane element which provides structural support to the membrane envelopes preventing unraveling and extension. See "Telescoping."

Array - The physical arrangement of the pressure vessel, e.g., 4:3:1 - 3 stages with 8 total vessels; stage 1 has 4 pressure vessels, stage 2 has 3 pressure vessels and stage 3 has 1 pressure vessel. The reject of each stage is the feed stream for the next successive stage.

Asymmetric - Membrane which is constructed of the same material (cellulose acetate or polyamide) that has an increase in porosity from surface to base. The surface has a dense thin barrier skin and a thick porous support layer.

Biofouling – deposition and/or growth of bacteria or algae on the membrane surface.

Brackish Water - Technically is defined as water of TDS levels up to 6,000 mg/L.

Brine Seal – These are plastic or rubber devices that seal the outside of one end of a spiral wound membrane element against the wall of the RO pressure vessel (housing). These devices prevent bypassing of feedwater around the element.

Cellulose Acetate (CA) Membranes - An asymmetric polymer used in the construction of membrane elements (others are polyamide and polysulfone). CA membranes have been largely replaced with polyamide membranes (also called polyamide-thin film composite membranes, or TFC" membranes). CA membranes operate at higher pressure than TFC membranes, have a relatively narrow pH tolerance and can tolerate chlorine. TFC membranes operate at lower pressure, have a wide pH tolerance, but cannot tolerate chlorine.

CA membranes are considered uncharged because their functional groups are not polar (polyamide and polysulfone are). Because they are non-polar they do not attract foulants to the surfaces as easily. Less fouling is observed also due to a smother surface of a CA membrane. CA membranes are easily degraded by bio-fouling.

Compaction - RO Membrane Compaction - Physical compression of the membrane. This compression results in a decrease in flux. The rate of compaction is directly proportional to an increase in temperature and pressure. Compaction occurs naturally over time requiring a greater feed pressure. Feed pumps are sized to the pressure requirements of the third year. Compaction is permanent and can occur quickly in CA membranes if operated at high pressures for any extended period of time. PA membranes have greater structural strength and can be operated at higher than normal pressures with little concern to compaction. Change as a result of compaction is expected for CA and TFC membranes during the first 200 hours of operation.

Concentration Factor (CF)- The degree that feedwater dissolved solids are concentrated in the brine (reject stream). CF = 1/(1- Y) where Y = the recovery of the RO in percentage as a decimal. For example, the Concentration Factor for a 75% recovery RO is 0.75/(1-.75) = 4. This is important to calculate the chemistry of the reject stream. Again, using a 75% recovery RO, if the feedwater has a TDS of 500 ppm, the reject stream will have a TDS of 4 x 500 = 2,000 ppm.

Concentration Polarization - Refers to the concentration gradient of salts on the high pressure side of the membrane surface created by the less than immediate redilution of salts left behind as water permeates through the membrane. The salt concentration in this boundary layer exceeds the concentration of the bulk water. This phenomenon impacts the performance of the process by increasing the osmotic pressure at the membrane's surface, reducing flux, increasing salt leakage and increasing the probability of scale development. Increasing the velocity (turbulence) of the brine stream helps to reduce concentration polarization.

Conversion (more commonly this is referred to as Recovery - the percentage of the feedwater which is converted into permeate. Sometimes referred to as conversion.

RO Cross Flow Separation - Filtration process with the feedwater stream running parallel to the filter media and a concentrate stream continuously removing contaminants from the surface media. Cross flow separation differs in that it has 3 streams associated with it compared to 2 streams found in dead head separation.

Elements - Often referred to as a module, elements are the physical devices that house the membrane. Spiral wound systems can have up to six elements per pressure vessel. Hollow fiber RO systems have only one element per pressure vessel.

Feed Channel Spacer - Found in spiral wound elements, feed channel spacers are a netting material placed between the flat sheets of a membrane to promote turbulence in the feed / concentrate stream. This material is referred to as "Vexar."

Feed Stream - Flow into the first stage of an RO system. The feed stream is separated into a permeate or product stream and a concentrated or brine stream.

Flux or Water Flux (Reverse Osmosis) - Typically expressed as volume per area per unit of time, flux is used to express the rate at which water permeates a membrane. Typical units are gallons per square foot per day (i.e. GFD or GSFD) or liters per square meter per hour ($l/m^2/hr$). The flux of a membrane is directly proportional to temperature and pressure. As a rule of thumb, flux decreases 1.5% per 1^oF. Salt flux is the amount of TDS passed through a given area of membrane per unit of time. It is important to remember that Salt flux is a function of concentration gradient and not driving pressure. Therefore with increasing driving pressure, the concentration of salts in the permeate decreases due to constant salt leakage (e.g., milligrams) and increased water flux (e.g., liters). The net effect of increased drive pressure is to dilute a constant amount of slat with more pure water.

Note: 1 GFD = 1.66 $l/m^2/hr$

Fouling – deposition of suspended particles on the membrane surface**.**

Hollow Fiber Element - One of four possible membrane configurations (others are spiral wound, plate and frame, and tubular). Hollow fiber elements are made of extruded cellulose acetate or polyamide material. Pressurized feed water passes across the outside of the fibers. Pure water permeates the fibers and is collected at the end of the element. Hollow fibers were among the first RO systems.

The hollow fiber element does not allow for turbulent flow or uniform flow across the fiber surface making these elements more prone to fouling and scaling. Once fouled they are more difficult to clean due to the inability to get the cleaning solution to the fouled area. Hollow fiber elements are mostly found in seawater desalination applications and limited brackish water applications where fouling potential is minimal.

Hydrolysis - Chemical breakdown of a membrane from exposure to low or high pH, bio-activity and temperature. Normally associated with CA membranes where the acetyl groups are replaced by hydroxyl groups. Hydrolysis in increased salt leakage (i.e., greater conductivity of the permeate) and a lower feed pressure requirement. Oxidants and temperature can cause hydrolysis in TFC elements.

Langelier Saturation Index or LSI - is a measurement of CaCO3 potential and is used as a key performance indicator in the management of reverse osmosis systems. A positive Langelier Saturation Index indicates that CaCO3 can precipitate. A negative LSI indicates that the water is corrosive to steel.

Membranes - An RO membrane is a semi permeable material, that is, a material through which water passes relatively quickly, while other substances cannot (or do so relatively slowly). Membranes provide the barrier layer or interface for cross flow separation. Membranes are thin, porous material constructed of organic polymer (e.g., cellulose acetate, polyamide and charged polysulfone). RO membranes will typically reject contaminants with molecular weights greater than 200. Ultrafiltration membranes will reject contaminants with molecular weights between 10,000 and 0.1 micron.

Microfiltration is related to Ultrafiltration (see below) and also cross flow separation technique used to remove colloidal, very fine particles and macromolecules from a water stream. Pore sizes in a Microfiltration (MF) system range from 0.1 to 5.0 microns. MF is often used as pretreatment to RO. MF does not remove dissolved salts from water

Modules – This is often synonymous with “element” or “membrane” or “membrane element”.

Nanofiltration - Similar to reverse osmosis but are not as effective at removing dissolved solids. Nanofilters are commonly referred to as membrane softeners because they will usually reject the double-positively charged hardness ions (i.e., calcium & magnesium) fairly well but cannot reject the single-positive charged soft ions (e.g., sodium & potassium).

Nanofilters are most commonly used in the drinking water industry where the dissolved solids must be reduced to below 500 mg/L (Safe Drinking Water Act). The choice between nanofiltration in these applications comes down to economics. Nanofilters require less pumping pressure but would require a greater percentage of the total flow compared to RO systems which require greater feed water pressure but could be blended with the raw water due to the lower TDS level of the RO permeate.

Net Driving Pressure - NDP, the difference between the feed pressure and the osmotic pressure. It is the measure of the actual driving pressure available to force the water through the membrane. As net driving pressure increases, the flux increases proportionally (given all other factors are held constant).

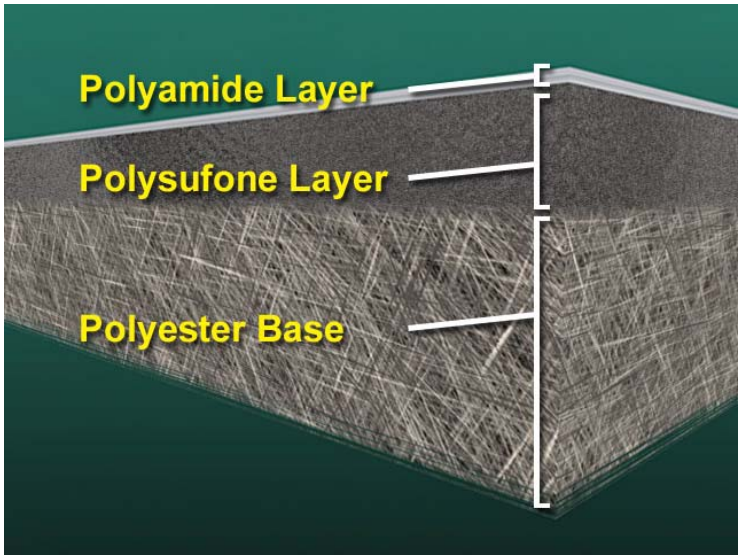
Normalized Permeate Flow - NFP is a calculation that allows the comparison of a measured permeate flow rate to a standard (or start up) condition. Permeate flow is a function of Net Driving Pressure (NDP), temperature and membrane condition. By normalizing measured permeate flow for observed NDP and temperature, a measure is obtained that can be used to compare the condition of the membrane to original start up conditions. A decrease in NPF of 10-15% indicates that membrane cleaning is required.

O-Rings - Used to seal the permeate water tube inter-connectors of adjacent elements. The prevent the intrusion of high pressure feedwater (poor quality) into the low pressure permeate water (good quality). A damaged O-ring will result in higher salt concentration of the permeate in that section of the system.

Osmotic Pressure - Is the pressure required to prevent the flow of water across a semi permeable membrane separating two solutions having different ionic strengths. For RO systems it is osmotic pressure that has to be overcome in order to produce permeate. A “rule of thumb” is for every 100 mg/L of TDS difference between feed and permeate, 1 psi of osmotic pressure exists.

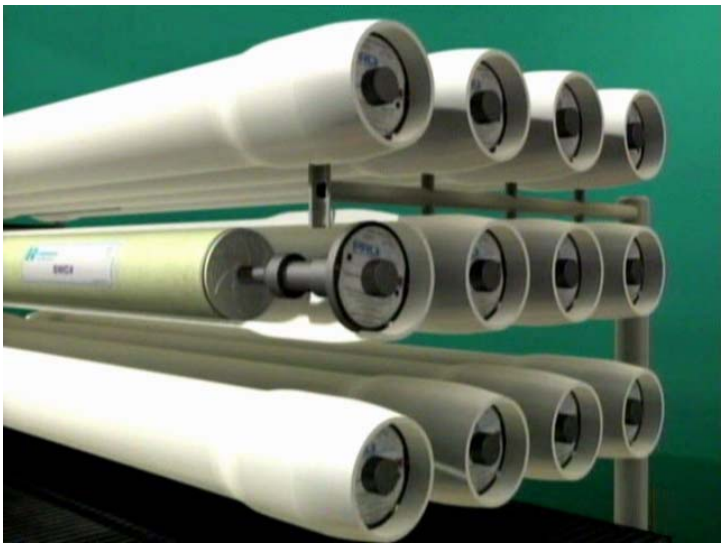
Permeate – This is the portion of the feedwater that passes through the RO membrane – it also referred to as “Product” water. The amount of permeate through the membrane equals feedwater – concentrate.

Polyamide Membranes - Introduced in the early 1970’s this asymmetric polymer is used in the construction of thin film composite (TFC) spiral wound membrane. Polyamide membranes are the most typical membrane construction material due to less pressure requirements and more flexible operating conditions. Polyamide membranes are oxidant (chlorine, chloramine, bromine, ozone etc.) intolerant. Also noteworthy is that surface of the polyamide membrane carries an anionic charge that makes it slightly more susceptible to fouling from contaminants carrying a cationic charge. See cutaway diagram below:



Picture courtesy of Hydranautics

Pressure Vessel – This is a tubular device that contains the membrane elements. For spiral wound elements the pressure vessel is sometimes referred to as the pressure tube or housing and can contain up to six membrane elements.

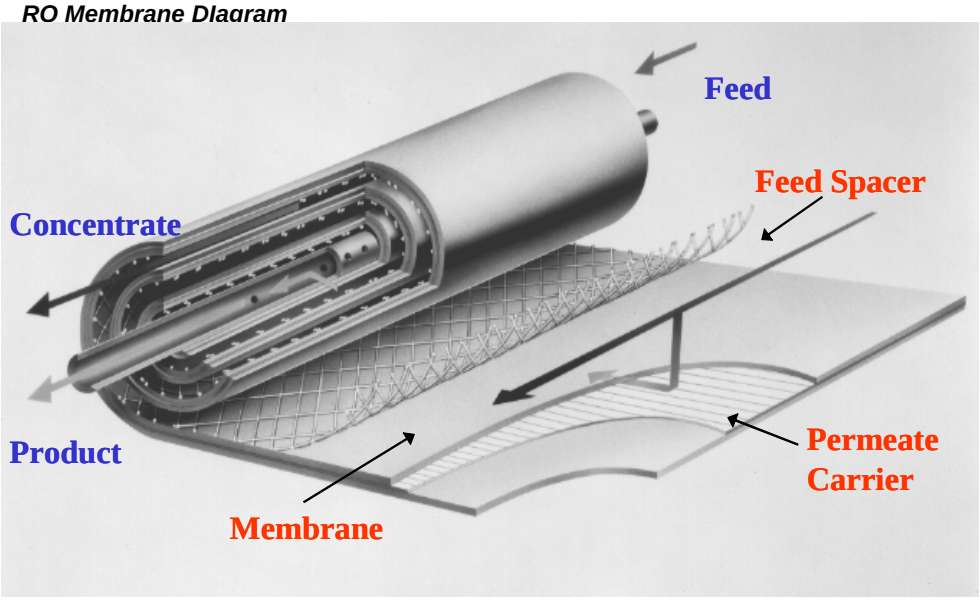


Picture courtesy of Hydranautics

Product Channel Spacer - this is also known as a Permeate Water Carrier. In the construction of a membrane element, the product channel spacer is placed between two layers of the flat sheet membrane. This spacer is a knit fabric called Tricot and is used to prevent the membrane from closing off on itself under the high pressure of operation. Permeate water will flow in a spiral path across the product channel spacer into the product collection tube. See the RO Membrane Diagram below:

Product Collection Tube - Collects the permeate water and directs to a product water header. The product collection tube is in the center of a spiral wound membrane element with the "membrane-product channel spacer - membrane- feedwater channel spacer" sandwich wrapped around it. See the RO Membrane Diagram below:

RO Membrane Diagram



Product Stream - Same as permeate. Often referred to as "product," permeate is the portion of the feedwater stream water which passes through the membrane.

Permeate = Feedwater - Concentrate

Recovery - Recovery is the percentage of the feedwater which is converted into permeate. (Sometimes referred to as conversion).

Salt Passage - The quantity of salt, as a percentage, which passes through the membrane into to the permeate stream. Salt passage is a function of temperature, velocity and concentration gradient (i.e., concentration of salt in the brine versus the permeate).

> Note: Salt Passage = 1 - Salt Rejection
> Salt passage = (Product TDS) / (Feed TDS) x 100

Salt Rejection - The quantity of salt removed from the feedwater stream as a percentage

> Note: Salt Rejection = 1 - Salt Passage
> Salt Rejection = (Feed TDS – Product TDS) / (Feed TDS) x 100

Scaling – Deposition of sparingly soluble salts on the membrane surface and/or the feed channel material

Silt Density Index (SDI) - Silt Density Index is an empirical test used to characterize the fouling potential of a feedwater stream. Test is based on measuring the rate of plugging a 0.45 micron filter using a constant 30 psi feed pressure for a specified period of time. SDI15 refers to a silt density index test which was run for 15 minutes. RO membranes typically need a SDI <3 to avoid fouling (and voiding the membrane manufacturer's warranty).

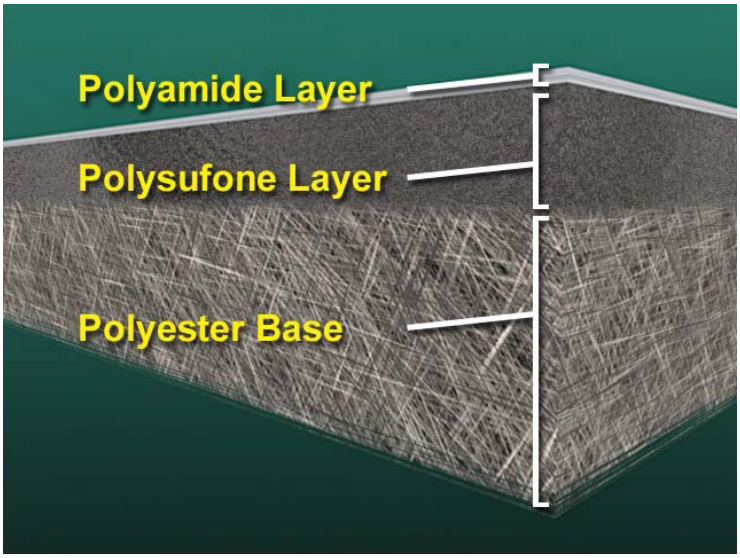
Spiral Wound Element - A membrane configuration which is comprised of "flat sheet membrane-permeate channel spacer - flat sheet membrane - feed channel spacer" combinations rolled up around a product collection tube. See RO Membrane Diagram above.

Staging - "Reject Staging" refers to a technique where the reject from one group of RO pressure vessels becomes the feed stream of a second group of RO pressure vessels. Reject staging is used to increase the recovery of water. A one stage system typically could recover 50 - 60% of the feed water stream with 2 and 3 stage systems operating at 75 - 80% and greater than 85% respectively.

"Product Staging" referred to as "multiple pass", is a technique where the product of the first group of RO pressure vessels becomes the feed water stream for a second stage. Product staging is used to increase the quality of the product water.

Telescoping - Longitudinal unraveling of spiral wound elements which results in the RO membrane leaves extending beyond the spacing material between the leaves. Can be caused by hydraulic surges or by temperature extremes. It is physically damaging to the construction of the membrane element. Most manufactures install anti-telescoping devices (ATD's) on their elements. Depending on severity, it may effect salt rejection.

Thin Film Composite (TFC) - Is an RO membrane composed of and manufactured as three layers bonded together. The two base layers of the asymmetric design have a thin skin (3rd) layer of either polyamide or charged polysulfone deposited on the surface. The thin film is the salt rejecting layer where the two base layers provide a porous structure whose function is strength. See picture below.



Picture courtesy of Hydranautics

Ultrafiltration - A cross flow separation technique used to remove colloidal, very fine particles and macromolecules from a water stream. Pore sizes in an Ultrafiltration (UF) system range from 0.001 to 0.1 micron. UF membrane systems are characterized by the molecular weight cut-off points (e.g., 3,000, 10,000, 20,000, and 80,000 Daltons). Unlike RO systems, UF does not remove dissolved salts from water.

Ultrapure Water - Term used to characterize electronic grade process water. Essentially ultrapure water is free of particles, colloids, organic and inorganic contaminants.

COMMON TERMS USED IN WATER TREATMENT

Aeration - A water treatment process that mixes water with air in a chamber or tower filled with packing material to disperse the water, allowing for sufficient contact time. As the water trickles down over the material, air is passed upward, removing the contaminants from the water. Aeration is effective at removing volatile organic compounds.

Air Gap Separation - A physical separation between the free flowing discharge end of a potable water supply pipeline, and the overflow rim of an open or non pressure receiving vessel, used to prevent backflow in a water distribution system.

Annular spaces - Openings or voids found around the casing of a well.

Aquifer - A water-bearing stratum of permeable rock, sand, or gravel.

Atmospheric Vacuum Breaker - A type of device used to prevent backflow in a water distribution system that allows air to enter the water line when the line pressure is reduced to a gauge pressure of zero or below.

Backflow - Water that flows back to the distribution system. It is sometimes caused by a loss of pressure in the water system.

Bacteria - Prokaryotic unicellular round, spiral, or rod-shaped single-celled microorganisms that are often aggregated into colonies or motile by means of flagella that live in soil, water, organic matter, or the bodies of plants and animals. Examples of bacteria that may contaminate water systems include coliform, salmonella, Legionella, and E coli.

Bailer - A section of pipe with a check valve at the bottom, used to remove crushed soil material from inside a well casing, accumulated during the process of drilling a well using the cable-tool method.

BAT - Best Available Technology, The current technology available to detect and treat the contaminant of concern.

Biological Characteristics - A characteristic of water defined by the levels of bacteria, viruses, and microscopic animals present.

Blow-off hydrant - A hydrant used to flush the water main. Also called flushing hydrants.

Bowl-assemblies - Found in vertical turbine well pumps, used to house the impellers, which spin to push water to the surface through the well column.

Carbon - A treatment technology used to treat copper and lead in water.

Casing - Lengths of pipe welded or coupled together in a well to form a continuous casing from the surface to the aquifer.

Chemical - One cause for corrosion in pipes; chemicals that can cause corrosion include carbon dioxide, oxygen, hydrogen sulfide, hydrochloric acid, chloride, and sulfuric acid.

Chemical Characteristics - A characteristic of water defined by the amounts of organic or inorganic compounds present.

Chlorination - A method of water disinfection where gaseous, liquid, or dissolved chlorine is added to a water supply system.

Chlorine Demand - The minimum amount of chlorine needed to react in a water purification system; used as a monitoring measurement by system operators.

Coagulation with Filtration - A treatment technology used to remove copper and lead from water, whereby a chemical such as alum is added to the water. When the water is stirred, the alum forms sticky globs that attach to small particles, which can then be filtered out.

Condensation - The conversion of water from the vapor state to a liquid state usually initiated by a reduction in temperature of the vapor.

Column - The vertical pillar of water formed by water being pumped out of a well.

Combined Chlorine Residual - The amount of chlorine used up in a water purification system; used as a monitoring measurement by system operators.

Compound Meter - A water meter used in places with high fluctuations in water usage; includes a positive displacement meter and a turbine meter.

Conditional waiver - An exemption given by the State to a water system if an MCL cannot be met; given that certain conditions are met by the water system.

Confined aquifer - An aquifer situated above an impermeable layer such as rock or clay.

Consumer Confidence Report - A report that community water systems must provide or make available to their customers annually, designed to inform the customers of the quality of the water they are drinking.

Continuous Chlorination - A treatment technology used to remove bacteriological contamination from water.

Continuous Ozone - A treatment technology used to remove bacteriological contamination from water, whereby water is exposed to ozone, which destroys bacterial cells.

Corrosion Control - A technology used to keep lead and copper out of water systems.

Cross Connections - Unwanted connections which allow nonpotable water to infiltrate a potable water supply; can occur due to backflow.

Cubitainer® - A type of plastic container used for collecting certain types of water samples.

Direct-read - A type of water meter read by looking at the numbers on the top of the meter dial or on a remote registering head.

Dissolved Oxygen - DO, The amount of oxygen dissolved in water; introduced through aeration, photosynthesis from plants, or as part of a treatment process to remove certain contaminants.

Dissolved solids - Substances found in solution in water due to the tendency of water to break down the materials it comes into contact with.

Distribution system - A part of a water system consisting of the water mains, water services, valves, hydrants, meters, and treatment equipment; used to supply water to the customers.

Dosage - The amount of chlorine per gallon or other unit of measurement found in a water purification system.

Double Check Valve - A device used in a distribution system to prevent backflow, which consists of two internally loaded check valves, two full ported shutoff valves, and four test cocks.

Drawdown - The difference between the static water level and the pumping water level in a well; determined by the ability of the aquifer to replace the amount of water that is being pumped.

Dry-barrel hydrant - A freeze-proof hydrant with the operating valve located at the bottom of the barrel that keeps the water below the frost line.

Ductile iron - A type of iron used for water mains that generally has the properties of high strength, ductility, and resistance to impact.

Electrical conductivity - A physical characteristic of water used to indicate the level of TDS in water; the level of electrical conductivity is proportional to the amount of dissolved solids found in the water.

Electrochemical - One cause for corrosion in pipes; an electrochemical reaction involves the transfer of electric charge between matter.

Electrolysis - The producing of chemical changes by passage of an electric current between two metallic surfaces; can cause corrosion in pipes.

Elevated tank - A method of storing water aboveground prior to distribution in a water supply system.

Evaporation - The process of water changing phases from a liquid state to a vapor.

Filtration - A treatment technology used to remove inorganic compounds from water whereby water passes through layers of sand, coal or other granular material.

Fire hydrant - A hydrant used to access water directly from the main, equipped with a fire hose connection for use in the event of a fire.

First-draw - A water sampling method for lead and copper, whereby the water is allowed to remain motionless in the plumbing for a minimum of six hours.

Flushing hydrant - A hydrant used to flush the water main. Also called blow-off hydrants.

Free Chlorine Residual - The amount of chlorine remaining in a water purification system after the chlorine demand; used as a monitoring measurement by system operators.

Gallons Per Minute - GPM, A unit of measurement used to express the yield of a well.

Gas - A form of chlorine used for disinfection that is contained in pressurized cylinders and uses regulators that control the amount of chlorine being added.

Gross alpha test - A "total" measurement of alpha emitting particles in water, including Radium and Uranium. Radioactive elements emit alpha particles, which are believed to be carcinogenic.

Granulated Activated Carbon - GAC, A treatment technology used to remove dissolved organic compounds from water, whereby water is passed through beds of activated carbon to which organic contaminants adsorb.

Ground storage - A method of storing water prior to distribution in a water supply system.

Grout - A type of cement used to fill the annular spaces around a well casing.

Hardness - A measure of the amount of dissolved minerals found in water, specifically calcium and magnesium.

Hard water - Water that contains high amounts of dissolved minerals, specifically calcium and magnesium.

Hydrant - A device used to access water directly from the main.

Hydropneumatic tank - A method of storing water prior to distribution in a water supply system, whereby the water system pressure is maintained between a specified pressure range; also called pressure tanks.

Impeller - Rotors found in well pumps that are used to push water to the surface through the well column.

Impermeable - Underground formations that do not allow water to percolate through them.

Infiltration - The process of water moving into and through the soil.

Ion Exchange - A method of water softening where hardness causing ions are exchanged with sodium ions; also effective in removing many inorganic contaminants such as nitrates, copper, and lead; and treating aesthetic water problems.

Laterals - The pipes that carry water from the water mains to the customers, also called services.

Liquid or Solid - A form of chlorine used for disinfection that is fed by pumps into the water supply system.

Lime Softening - A method of water softening where hydrated lime is added to water in order to precipitate out hardening agents, which are then removed by sedimentation or filtration.

Main Valves - Valves installed at tees or crosses where two or more water mains intersect, so that the mains can be isolated for emergency repair or maintenance.

Municipal Water System - MC, A water system that serves at least 25 people, or has 15 service connections or more used by residents more than six months per year; and is owned by a governmental entity such as a city, county, town, village, sanitary district, state, or federal institution.

Nonpotable water - Water that is not suitable for drinking.

Nontransient Noncommunity Water System - NTNC, A water system that serves at least 25 of the same people more than six months of the year, but not as a primary residence; such as schools, businesses, and day cares.

Occupational Safety and Health Administration - OSHA, An agency created by the United States Congress in 1970 whose mission is to prevent work-related injuries, illnesses and deaths.

Other-Than-Municipal - OTM or OC, A water system that serves at least 25 people, or has 15 service connections used by residents more than six months per year; and is owned by an entity that is not governmental, such as a manufactured housing park, subdivision, apartment complex, or condominium association.

Ozone - A method of water disinfection where water is exposed to ozone, which destroys bacterial cells.

Percolation - The downward movement of water through the soil.

Perched aquifer - An unconfined aquifer contained by impermeable rock.

Permeable - A characteristic of underground formations, which have pores or openings that permit liquids to pass through.

pH - A measure of acidity and alkalinity of a solution that is a number on a scale on which a value of 7 represents neutrality, lower numbers indicate increasing acidity, and higher numbers indicate increasing alkalinity. Each unit of change represents a tenfold change in acidity or alkalinity and is the negative logarithm of the effective hydrogen-ion concentration or hydrogen-ion activity in gram equivalents per liter of the solution.

Physical Characteristics - A characteristic of water defined by the temperature, turbidity, color, taste, and odor of the water.

Point-of-entry sample - A type of water sample taken after treatment and before reaching the first consumer.

Positive Displacement Meter - A water meter used in normal and low-flow conditions.

Potable water - Water that is suitable for drinking.

Primacy authority - The authority given by the USEPA to the States to implement and enforce the Safe Water Drinking Act.

Precipitation - The process of water falling to earth in various forms.

Pressure Vacuum Breaker - A type of device used to prevent backflow in a water distribution system that consists of a spring loaded check valve, an independently operating air inlet valve, two resilient seated shutoff valves, and two resilient seated test cocks.

Protozoan - A member of the phylum or subkingdom Protozoa, which are chiefly motile and heterotrophic unicellular protests, such as amoebas, trypanosomes, sporozoans, and paramecia.

Public Notification Rule - A method of keeping the customer informed about the quality of their drinking water, which specifies the method, timeframe, language, and action in the event of a MCL violation or emergency situation.

Public Service Commission of Wisconsin - PSC, An independent regulatory agency responsible for the regulation of Wisconsin public utilities, including those that are municipally-owned, which receives its authority and responsibilities from the State Legislature.

PVC - Poly(vinyl chloride), A type of plastic used for water mains that has the properties of hardness and resistance to water and fire.

Pumping water level - The water level in a well while the pump is running.

Radiological Characteristics - A characteristic of water defined by the amount of radionuclides present in the water.

Radionuclide - A radioactive nuclide. Radioactivity is the property possessed by some elements, such as uranium; or isotopes, such as carbon 14; of spontaneously emitting energetic particles, such as electrons or alpha particles, by the disintegration of their atomic nuclei.

Reduced Pressure Device - A type of device used to prevent backflow in a water distribution system that consists of two independently acting spring loaded check valves separated by a spring loaded differential pressure relief valve, two full ported shutoff valves, and four test cocks. During normal operation, the pressure between the two check valves, referred to as the zone of reduced pressure, is maintained at a lower pressure than the supply pressure. If either check valve leaks, the differential pressure relief valve maintains a differential pressure of at least two (2) psi between the supply pressure, and the zone between the two check valves, by discharging water to atmosphere.

Remote-read - A type of water meter that generates a signal, which is read by radio, telephone, or by use of a handheld computer.

Residual - The amount of chlorine remaining after the initial reaction in a water purification system; used as a monitoring measurement by system operators.

Reverse Osmosis - RO, A treatment technology used to remove inorganic contaminants, where water with a low level of total dissolved solids passes through a semi permeable membrane into a solution containing a higher level of total dissolved solids; pump pressure is applied to the concentrated solution causing it to flow back across the membrane.

Sanitary Surveys - Periodic on-site inspections performed by WDNR consisting of a review of a system's compliance, monitoring records, and facilities.

Saturated - The state of soil when it is completely full of water and no more water can infiltrate.

Screen - A meshed wire mounted at the bottom of a well used to keep sediment out of gravel-packed wells.

Serve - Having water available for people to drink, but not necessarily that people actually drink the water.

Services - The pipes that carry water from the water mains to the customers, also called laterals.

Service Valves - Valves used to isolate a single building from the water main; installed on the service line between the water main and the building, usually near the street curb; also called curbstop valves.

Source Water Assessments - An assessment conducted by WDNR for drinking water sources that requires WDNR to delineate the assessment area boundaries from which public water systems receive supplies of drinking water, inventory significant potential sources of contamination within those boundaries, determine the susceptibility of the public water systems to potential sources of contamination, and provide the assessment results to the public.

Specific capacity - A well measurement expressed in gallons per minute per foot determined by dividing the yield by the drawdown.

Standpipe - A method of storing water and equalizing water pressure to minimize the pulsations of water flowing in the mains, used prior to modern pumping methods, consisting of a large vertical pipe in which a column of water rises and falls; often built inside towers.

Static water level - The water level in a well when the pump is not running.

Submersible pump - A water pump with the motor and pump assembly located below ground at the bottom of the well column.

Surface Runoff - The process of precipitation moving across saturated or impervious soils.

Surface water - Water found in lakes, reservoirs, rivers, and oceans.

Total Chlorine Residual - The total of free residual and combined residual chlorine in a water purification system; used as a monitoring measurement by system operators.

Tier I Violation - A level of water regulation violation that has potential for human health to be immediately impacted.

Tier II Violation - A level of water regulation violation that does not pose an immediate risk to human health, and involves a contaminant that exceeds EPA or state standards or hasn't been treated properly.

Tier III Violation - A level of water regulation violation that does not have a direct impact on human health and violates a drinking water standard.

Transient Noncommunity Water System - TN, A water system that serves at least 25 of the same people more than six months of the year, but not as a primary residence; such as schools, businesses, and day cares.

Transpiration - The process of plants taking up water through their root system and allowing it to enter the atmosphere through the surface of their leaves.

Turbine Meter - A water meter used in higher-flow conditions.

Unconfined aquifer - An aquifer that is located in a permeable formation where the water table is free to rise and fall depending on factors such as the amount of rainfall.

Ultra Violet - UV, A method of water disinfection where water is exposed to UV light; certain wavelengths of UV light deactivate the DNA of bacteria, viruses and other pathogens and thus destroy their ability to multiply and cause disease.

Vacuum - A condition created in a well when air is not allowed to be displaced between the casing and the pump column.

Valve - A mechanical device by which the flow of liquid may be started, stopped, or regulated by a movable part that opens, shuts, or partially obstructs one or more ports or passageways.

Variance - An exemption given by the State to a water system if an MCL cannot be met; given that certain conditions are met by the water system.

Vent - A pipe installed in the well casing to allow for the displacement of air between the casing and the pump column.

Vertical turbine pump - A water pump with the motor located above ground, connected by a shaft to the pump below.

Virus - Any of a large group of submicroscopic infective agents that are regarded either as extremely simple microorganisms or as extremely complex molecules that typically contain a protein coat surrounding an RNA or DNA core of genetic material, but no semi permeable membrane that are capable of growth and multiplication only in living cells, and that cause various important diseases in humans, lower animals, or plants.

Vulnerability Assessments - An assessment performed for all community and nontransient noncommunity public water systems every three years; which consists of an inventory of potential sources of contamination within a delineated area, an evaluation of well construction, an evaluation of pesticide susceptibility and industrial chemical use, and an assessment of vulnerability to volatile organic compounds, ethylene dibromide, asbestos, and coal tar.

Water flow - The amount of water available in a water supply system.

Water hammer - A occurrence caused when flowing water in a system is immediately stopped due to a valve or hydrant being closed too quickly, which sends a sudden pressure wave down the water line, shocking the pipes.

Water Main - A primary pipe used to carry water from the source to storage facilities and to points along the distribution system.

Water meter - A device used to measure the volumetric flow of water.

Water pressure - The force of the water available in a water supply system.

Water source - The origin of water in a water supply system, usually a well.

Water storage facility - An area used to store water during low demand periods for distribution to customers during high demand periods in a water supply system.

Water table - The water level in a well when the pump is not running.

Well - Any opening into the ground used to obtain water, where the depth of the opening is greater than the largest surface dimension.

Well Abandonment - A process to permanently close a well, which has certain criteria and requirements and that must be followed.

Well caps - Seals installed on the top of well casings used to prevent any solid material or insects from entering the well.

Wellhead Protection - Actions that are used to prevent groundwater from becoming contaminated including source water assessments, vulnerability assessments, wellhead protection plans, and well abandonment.

Wellhead Protection Plan - Well-specific plans used to implement the principles found in source water assessments and vulnerability assessments, typically developed by community water systems for new wells.

Wet-barrel hydrant - A hydrant with the operating valve located at the top so that the entire hydrant contains pressurized water.

Yield - A measurement, usually in units of GPM, of the amount of water a well can produce.

DEFINITIONS, TERMS & APPLICATIONS WITH REVERSE OSMOSIS (and NANOFILTRATION)

Reverse osmosis (RO) – This applies to Nanofiltration (NF) as well.

RO is a separation process that uses pressure to force a solution through a membrane that retains the solute on one side and allows the pure solvent to pass to the other side. More formally, it is the process of forcing a solvent from a region of high solute concentration through a membrane to a region of low solute concentration by applying a pressure in excess of the osmotic pressure. This is the reverse of the normal osmosis process, which is the natural movement of solvent from an area of low solute concentration, through a membrane, to an area of high solute concentration when no external pressure is applied. The membrane here is semi permeable, meaning it allows the passage of solvent but not of solute.

The membranes used for reverse osmosis have a dense barrier layer in the polymer matrix where most separation occurs. In most cases the membrane is designed to allow only water to pass through this dense layer while preventing the passage of solutes (such as salt ions). This process requires that a high pressure be exerted on the high concentration side of the membrane, usually 2–17 bar (30–250 psi) for fresh and brackish water, and 40–70 bar (600–1000 psi) for seawater, which has around 24 bar (350 psi) natural osmotic pressure which must be overcome.
This process is best known for its use in desalination (removing the salt from sea water to get fresh water), but it has also been used to purify fresh water for medical, industrial and domestic applications since the early 1970s.
When two solutions with different concentrations of a solute are mixed, the total amount of solutes in the two solutions will be equally distributed in the total amount of solvent from the two solution.

Instead of mixing the two solutions together, they can be put in two compartments where they are separated from each other by a semi permeable membrane. The semi permeable membrane does not allow the solutes to move from one compartment to the other, but allows the solvent to move. Since equilibrium cannot be achieved by the movement of solutes from the compartment with high solute concentration to the one with low solute concentration, it is instead achieved by the movement of the solvent from areas of low solute concentration to areas of high solute concentration. When the solvent moves away from low concentration areas, it causes these areas to become more concentrated. On the other side, when the solvent moves into areas of high concentration, solute concentration will decrease. This process is termed osmosis. The tendency for solvent to flow through the membrane can be expressed as "osmotic pressure", since it is analogous to flow caused by a pressure differential.
In reverse osmosis, in a similar setup as that in osmosis, pressure is applied to the compartment with high concentration. In this case, there are two forces influencing the movement of water: the pressure caused by the difference in solute concentration between the two compartments (the osmotic pressure) and the externally applied pressure.

Applications

Reverse Osmosis (and Nanofiltration)

- **Reducing Total Dissolved Solids** with Reverse Osmosis or Nanofiltration (this is what RO and NF are best at). Nanofiltration (Softening membrane) removes most of the Hardness and only about half of the sodium at a lower pressure (and therefore cost) than reverse osmosis.
- **Source Water for potable drinking water** – All Sources, including sea water, rivers affected by tides, rivers affected by droughts, wells, and Ground Water Under the Influence (GWUDI) of surface waters. See discussion below.
- Utilizing Integrated Membrane Systems (UF/RO) for **treating Tertiary Effluent or Title 22 water for recycle for ground water replenishment and water re-use**
- **Reducing Nitrates** (Ion Exchange may be a more cost effective or more practical solution however)
- **Reducing Hardness** (if hardness is the only issue, Nanofiltration would be the best choice)
- Reducing **Sulfates**
- Removing **Radium** with Reverse Osmosis (concentrate disposal will be an issue), Ion Exchange may be a better choice

Ultrafiltration

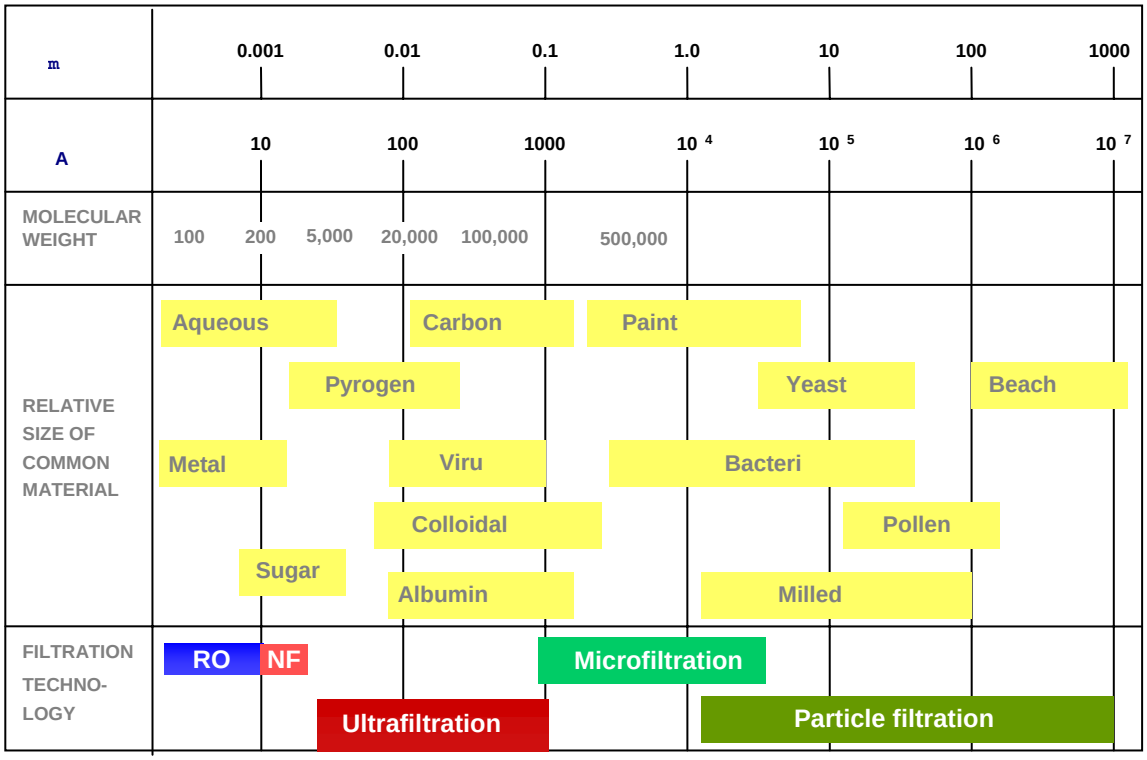
- Ultrafiltration is used to protect **the Reverse Osmosis Membranes**
- Utilizing Integrated Membrane Systems (UF/RO) for **treating Tertiary Effluent or Title 22 water for recycle for ground water replenishment and water re-use**
- Utilizing Integrated Membrane Systems (UF/RO) for **treating Seawater when there is a shoreline intake, or tidal influenced river water**

Further Discussion on Applications:

Drinking water purification

Membrane pore sizes can vary from 1 to 50,000 angstroms depending on filter type. "Particle filtration" removes particles of 10,000 angstroms or larger. Microfiltration removes particles of 500 angstroms or larger. "Ultrafiltration" removes particles of roughly 30 angstroms or larger. "Nanofiltration" removes particles of 10 angstroms or larger. Reverse osmosis is in the final category of membrane filtration and removes particles larger than 1 angstrom. Refer to the chart below (“THE FILTRATION SPECTRUM”) for a chart of types of contaminants, their sizes and which ones pass through the various types of membranes.

THE FILTRATION SPECTRUM



Water and wastewater purification

Rain water collected from storm drains is purified with reverse osmosis water processors and used for landscape irrigation and industrial cooling in Los Angeles and other cities, as a solution to the problem of water shortages.

In industry, reverse osmosis removes minerals from boiler water at power plants. The water is boiled and condensed repeatedly. It must be as pure as possible so that it does not leave deposits on the machinery or cause corrosion. It is also used to clean effluent and brackish groundwater.

Deionized Water

Reverse osmosis product can be used for the production of deionized water.

Dialysis

Reverse osmosis is the technique used in dialysis, which is used by people with kidney failure. The kidneys filter the blood, removing waste products (e.g. urea) and water, which is then excreted as urine. A dialysis machine mimics the function of the kidneys. The blood passes from the body via a catheter to the dialysis machine, across an osmotic filter. Many hospitals have reverse osmosis units.

Food Industry

In addition to desalination, reverse osmosis is a more economical operation for concentrating food liquids (such as fruit juices) than conventional heat-treatment processes. Research has been done on concentration of orange juice and tomato juice. Its advantages include a low operating cost and the ability to avoid heat treatment processes, which makes it suitable for heat-sensitive substances like the protein and enzymes found in most food products.
Reverse osmosis is extensively used in the dairy industry for the production of whey protein powders and for the concentration of milk to reduce shipping costs. In whey applications, the whey (liquid remaining after cheese manufacture) is pre-concentrated with RO from 6% total solids to 10-20% total solids before UF (ultrafiltration) processing. The UF retentate can then be used to make various whey powders including WPI (whey protein isolate) used in bodybuilding formulations. Additionally, the UF permeate, which contains lactose, is concentrated by RO from 5% total solids to 18–22% total solids to reduce crystallization and drying costs of the lactose powder.

Although use of the process was once frowned upon in the wine industry, it is now widely understood and used. An estimated 60 reverse osmosis machines were in use in Bordeaux, France in 2002. Known users include many of the elite classed growths (Kramer) such as Château Léoville-Las Cases in Bordeaux.
Reverse osmosis is used globally throughout the wine industry for many practices including wine and juice concentration, taint removal; such as acetic acid, smoke taint and brettanomyces taint; and alcohol removal. The patent holder for these processes, Vinovation, Inc., claims to have served over 1000 wineries worldwide, either directly or through one if its licensed partners, in the last 15 years. Its use has become so widely accepted that patent infringers have sprung up on several continents.

Car Washing

Because of its lower mineral content, Reverse Osmosis water is often used in car washes during the final vehicle rinse to prevent water spotting on the vehicle. Reverse osmosis water displaces the mineral heavy reclamation water (municipal water). Reverse Osmosis water also enables the car wash operators to reduce the demands on the vehicle drying equipment such as air blowers.

Maple Syrup Production

Starting in the 1970s, some maple syrup producers started using reverse osmosis to remove water from sap before being further boiled down to syrup. The use of reverse osmosis allows approximately 75–80% of the water to be removed from the sap, reducing energy consumption and exposure of the syrup to high temperatures. Microbial contamination and degradation of the membranes has to be monitored.

Desalination

A lot of attention has been, is and will be focused on using the ocean as a source of water (desalination). Reverse osmosis is the most common method of desalination, although a large percentage of desalinated water is produced in multistage flash plants. This is very energy intensive – more so than RO. Large reverse osmosis and multistage flash desalination plants are used in the Middle East, especially Saudi Arabia. The energy requirements of the plants are large, but electricity can be produced relatively cheaply with the abundant oil reserves in the region. The desalination plants are often located adjacent to the power plants, which reduces energy losses in transmission and allows waste heat to be used in the desalination process of multistage flash plants, reducing the amount of energy needed to desalinate the water and providing cooling for the power plant.

Sea Water Reverse Osmosis (SWRO) is a reverse osmosis desalination membrane process that has been commercially used since the early 1970s. Its first practical demonstration was done by Sidney Loeb and Srinivasa Sourirajan from UCLA in Coalinga, California. Because no heating or phase changes are needed, energy requirements are low in comparison to other processes of desalination, though still much higher than other forms of water supply (including reverse osmosis treatment of wastewater).

The typical single pass SWRO system consists of the following components:

- Intake
- Pre-treatment
- High-pressure pump
- Membrane assembly
- Remineralization and pH adjustment
- Disinfection

RO Pre-treatment

Pre-treatment is absolutely critical when working with RO and nanofiltration (NF) membranes due to the nature of their spiral wound design. The material is engineered in such a fashion to allow only one way flow through the system. As such the spiral wound design doesn't allow for back-pulsing with water or air agitation to scour its surface and remove solids. Since accumulated material cannot be removed from the membrane surface systems they are highly susceptible to fouling (loss of production capacity). Therefore, pretreatment is a necessity for any RO or NF system. If the pretreatment is properly designed, the RO will run reliably and trouble-free. Pretreatment includes (but is not limited to) the following:

Screening of solids

Solids within the water must be removed and the water treated to prevent fouling of the membranes by fine particle or biological growth, and reduce the risk of damage to high-pressure pump components.

Screening of biologicals

If there are gross amounts of biological material (for example, with an open seawater intake for seawater RO) there will need to be a screening mechanism to remove the material.

Filtration

This can take many forms depending upon the suspended solids in the feedwater. It can be as simple as a multimedia filter or as sophisticated as an ultrafilter. It is vital to characterize the suspended solids and run a Silt Density Index (SDI) prior to design.

pH adjustment

If the pH of upstream saline water is above 5.8 in the acidic-alkaline measurement scale, sulfuric acid or other acidic solution may be used to adjust the pH of water at 5.5 to 5.8. This will be determined by running a projection with design software.

Cartridge filtration

Protective 10 or 5 micron cartridge filters are always placed in front of the RO after all other pretreatment as a protective device.

High pressure pump

The pump supplies the pressure needed to push water through the membrane, even as the membrane rejects the passage of salt through it. Typical pressures for brackish water range from 180 to psi. In the case of seawater, they range from 800 to 1,180 psi.

Membrane assembly
The membrane assembly consists of a pressure vessel with a membrane that allows feedwater to be pressed against it. The membrane must be strong enough to withstand whatever pressure is applied against it.

Reinmineralization and pH adjustment
In seawater applications, the desalinated water is very corrosive and is "stabilized" to protect downstream pipelines and storages usually by adding lime or caustic to prevent corrosion of concrete or cement lined surfaces. Liming material is used in order to adjust pH at 6.8 to 8.1 to meet the potable water specifications, primarily for effective disinfection and for corrosion control. pH adjustment may necessary in brackish systems as well.

Disinfection
Post-treatment consists of stabilizing the water and preparing for distribution. Desalination processes are very effective barriers to pathogenic organisms, however disinfection is used to ensure a "safe" water supply. Disinfection (sometimes called germicidal or bactericidal) is employed to kill the any bacteria protozoa and virus that have bypassed the desalination process into the product water. Disinfection may be by means of ultraviolet radiation, using UV lamps directly on the product, or by chlorination or chloramination (chlorine and ammonia). In many countries either chlorination or chloramination is used to provide a "residual" disinfection agent in the water supply system to protect against infection of the water supply by contamination entering the system.

RO Disadvantages
The main technical disadvantage of reverse osmosis is the disposal of the concentrate (brine). Near the coast in Los Angeles, this is not a problem because of a “brine line” that has been installed and takes the discharge into the ocean. Inland, RO concentrate is problematic since most water districts do not want the salts in the RO concentrate to go back into the groundwater. The next big disadvantage is capital cost and operating cost – RO is expensive and energy intensive. A typical brackish RO requires a feed pressure on the order of 180 psi. Seawater plants are over 900 psi. However, as the technology continues to improve, both the capital and operating costs continue to decline. RO is remains the superior technology to remove TDS.

Appendix - Contributing Authors

A special thank you to the following individuals that have contributed to the writing of the SWMOA Membrane Glossary:

Jim Elliott, Layne Christensen Company

It is the intent of SWMOA that all Contributing Authors have been recognized. If someone has been left from the list, we apologize.