



# Standard Terminology Used for Crossflow Microfiltration, Ultrafiltration, Nanofiltration and Reverse Osmosis Membrane Processes<sup>1</sup>

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## 1. Scope

1.1 This terminology covers the use of crossflow microfiltration, ultrafiltration, nanofiltration and reverse osmosis for membrane separation processes.

## 2. Referenced Documents

### 2.1 ASTM Standards:

D 1129 Terminology Relating to Water<sup>2</sup>

D 2035 Practice for Coagulation-Flocculation Jar Test of Water<sup>3</sup>

## 3. Significance and Use

3.1 The need to understand the relationships found in membrane unit processes for water treatment increases with the continuing demand for these separation systems. Defining the terms common to crossflow microfiltration, ultrafiltration, nanofiltration and reverse osmosis processes assist the manufacturer, consultant and end-user in eliminating inter-process terminology confusion.

## 4. Terminology

### 4.1 Definitions:

**absorption**—the holding of a substance within a solid by cohesive or capillary forces.

**accumulator**—a pulsation dampener installed on the suction and/or discharge lines of pumps, generally plunger type, to minimize pressure surges and provide uniformity of flow.

**accuracy**—the closeness of agreement between an observed value and an accepted reference value. Where an accepted reference value is not available, a measure of the degree of conformity of a value generated by a specific procedure to

the assumed or accepted true value, and includes both precision and bias.

**acetylation**—substitution of an acetyl radical for an active hydrogen. Specifically, formation of cellulose acetate from cellulose.

**acidity**—the quantitative capacity of aqueous media to react with hydroxyl ions.

**activated carbon**—granulated or powdered activated carbon used to remove tastes, odor, chlorine, chloramines, and some organics from water. A family of carbonaceous substances manufactured by processes that develop adsorptive properties.

**adsorption**—the holding of a substance onto the surface of a solid by chemical surface forces, without forming new chemical bonds.

**aerobic bacteria**—bacteria that require oxygen for growth. See **bacteria, aerobes**.

**aggregate**—granular material such as sand, gravel, crushed stone.

**air scour**—distributing air over the entire filter area at the bottom of a filter media flowing upward to improve the effectiveness of backwashing or to permit the use of lower backwash water flow rate, or both.

**algae**—any of a group of chiefly aquatic mono cellular plants with chlorophyll often masked by a brown or red pigment.

**alkalinity**—the quantitative capacity of aqueous media to react with hydrogen ions. “M” alkalinity is that which will react with acid as the pH of the sample is reduced to the methylorange endpoint of about 4.5. “P” alkalinity is that which reacts with acid as the pH of the sample is reduced to the phenolphthalein end point of 8.3. “M” is the total alkalinity which is the sum of hydroxide plus carbonate plus bicarbonate contents, “P” includes all the hydroxyl and half the carbonate content.

**alum**—aluminum sulfate,  $AL_2(SO_4)_3XH_2O$  ( $X = 14-18$ ), a coagulant.

**ambient temperature**—the temperature of the surroundings, typically 20°–25°C.

**amorphous**—non crystalline, devoid of regular cohesive structure.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 11.01.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 11.02.

**anaerobic bacteria**—bacteria that do not use oxygen. Oxygen is toxic to them. See **bacteria**, **anaerobes**.

**amphoteric**—capable of acting as an acid or a base.

**angstrom (Å)**—a unit of length equaling  $10^{-10}$  metres,  $10^{-4}$  µ metres,  $10^{-8}$  centimetres and  $3.937 \times 10^{-9}$  in. The symbol is Å, Å or A.U. .

**anion**—negatively charged ion.

**anion exchange material**—a material capable of the reversible exchange of negatively charged ions.

**anisotropic membrane**—a nonuniform structure in cross-section; typically the support substructure has pores much larger than the barrier layer. See **asymmetric membranes**.

**anode**—positive electrode.

**anionic polyelectrolyte**—usually acrylamide and acrylic acid copolymers, negatively charged, used for coagulation/flocculation, see **Polyelectrolytes**.

**anthracite**—a granular hard coal used as a filtration media, commonly used as the coarser layer in dual and multimedia filters.

**antifoulant**—see **antiscalant**.

**antiscalant**—a compound added to a water which inhibits the precipitation of sparingly soluble inorganic salts.

**anti-telescoping device**—a plastic or metal device attached to the ends of a spiral wound cartridge to prevent movement of the cartridge leaves in the feed flow direction, due to high feed flows.

**AOC**—assimilable organic carbon.

**aquifer**—a water-bearing geological formation that provides a ground water reservoir.

**aramid**—a fully aromatic polyamide.

**array**—an arrangement of devices connected to common feed, product and reject headers; that is, a 2:1 array.

**asymmetric membrane**—membrane which has a change in pore structure with depth. See **anisotropic membranes**.

**ATD**—see **anti-telescoping device**.

**atomic weight**—the relative mass of an atom based on a scale in which a specific carbon atom (carbon 12) is assigned a mass value of 12.

**ATP**—adenosine triphosphate.

**autopsy**—the dissection of a membrane module or element to investigate causes of unsatisfactory performance.

**availability**—the on-stream time or rated operating capacity of a water treatment system.

**a-value**—membrane water permeability coefficient. The coefficient is defined as the amount of water produced per unit area of membrane when net driving pressure (NDP) is unity, a unit of measurement is  $\text{m}^3/\text{hr}/\text{m}^2/\text{kPa}$ .

**AWWA**—American Water Works Association.

**AWWARF**—American Water Works Association Research Foundation.

**backwash**—reverse the flow of water with/without air either across or through a medium or membrane designed to remove the collected foreign material from the bed or membranes.

**bacteria**—any of a class of microscopic single-celled organisms reproducing by fission or by spores. Characterized by round, rod-like spiral or filamentous bodies, often aggregated into colonies or mobile by means of flagella. Widely

dispersed in soil, water, organic matter, and the bodies of plants and animals. Either autotrophic (self-sustaining, self-generative), saprophytic (derives nutrition from non-living organic material already present in the environment), or parasitic (deriving nutrition from another living organism). Often symbiotic (advantageous) in man, but sometimes pathogenic.

**bactericide**—agent capable of killing bacteria.

**bacteriostat**—substance that prevents bacterial growth and metabolism but does not necessarily kill them.

**bank**—a grouping of devices. See **array**, **block**, **train**.

**bar**—unit of pressure; 14.50 lbs/in.<sup>2</sup>, 1.020 kg/cm<sup>2</sup>, 0.987 atm, 0.1 MPa.

**BAT**—best available technology.

**baume scale, °Be**—a measure of the density of a solution relative to water.

$$^{\circ}\text{Be} = 145 - \frac{145}{\text{specific gravity}^*}$$

United States for densities greater than unity.

$$^{\circ}\text{Be} = \frac{140}{\text{specific gravity}^*} - 130$$

For densities less than unity.

\*60°F/60°F

**bed depth**—the depth of the filter medium or ion exchange resin in a vessel.

**bed expansion**—the depth increase of filter medium or ion exchange resin that occurs during backwashing.

**binders**—in reference to cartridge filters, chemicals used to hold, or 'bind', short fibers together in a filter.

**biocide**—a substance that kills all living organisms.

**biological deposits**—the debris left by organisms as a result of their life processes.

**biomass**—any material which is or was a living organism or excreted from a micro-organism.

**biostat**—a substance that inhibits biological growth.

**binding**—in surface filtration, a build-up of particulates on the filter, restricting fluid flow through the filter at normal pressures.

**block**—a grouping of devices in a single unit having common control. See **array**, **bank**, **train**.

**BOD (biochemical oxygen demand)**—the amount of dissolved oxygen utilized by natural agencies in water in stabilizing organic matter at specified test conditions.

**body feed**—the continuous addition of filter medium (for example, diatomaceous earth) to sustain the efficacy of the filter.

**BOO**—build, own, operate.

**BOOT**—build, own, operate and transfer.

**boundary layer**—a thin layer at the membrane surface where water velocities deviate significantly less than those in the bulk flow.

**brackish water**—water with an approximate concentration of total dissolved solids ranging from 1000 to 10 000 mg/L. See **high brackish water**, **sea water**.

**breakpoint chlorination**—the point at which the water chlorine demand is satisfied and any further chlorine is the chlorine residual, the "free" chlorine species.

**break tank**—a storage device used for hydraulic isolation and surge protection.

**brine**—the concentrate (reject) stream from a crossflow membrane device performing desalination. Portion of the feed stream which does not pass through the membrane.

**brine (concentrate) seal**—a rubber lip seal on the outside of a spiral wound cartridge which prevents feed by-pass between the cartridge and the inside pressure vessel wall.

**brine seal carrier**—see **ATD**.

**brine system staging**—a process in which the concentrate, under pressure, of a group of membrane devices is fed directly to another set of membrane devices to improve the efficiency of the water separation.

**bubble point pressure**—the pressure necessary to displace a liquid held by surface tension forces from the largest equivalent capillaries in a membrane filter.

**bubble point test**—a nondestructive membrane filter test used to assess filter integrity and proper installation.

**bundle**—a general term for a collection of parallel filaments or fibres.

**B-value—salt diffusion coefficient**—The coefficient is defined as the amount of salt transferred per unit area of membrane when the difference in salt concentration across the membrane is unity. A unit of measurement is m/h.

**BWRO**—brackish water reverse osmosis.

**CAC**—combined available chlorine.

**calcium carbonate equivalents (mg/L as CaCO<sub>3</sub>)**—a method for expressing mg/L as ion in terms of calcium carbonate. Concentration in calcium carbonate equivalents is calculated by multiplying concentration in mg/L of the ion by the equivalent weight of calcium carbonate (50) and dividing by the equivalent weight of the ion. (See Table 1).

**carbonate hardness**—the hardness in a water caused by carbonates and bicarbonates of calcium and magnesium. The amount of hardness equivalent to the alkalinity formed and deposited when water is boiled. In boilers, carbonate hardness is readily removed by blowdown.

**calcium hypochlorite**—Ca (HClO)<sub>2</sub>, a disinfection agent.

**cartridge**—see **spiral-wound cartridge**.

**catalyst**—a substance whose presence initiates or changes the rate of a chemical reaction, but does not itself enter into the reaction.

**cathode**—negative electrode.

**cation**—positively charged ion.

**cation exchange material**—a material capable of the reversible exchange of positively charged ions.

**cationic polyelectrolyte**—a polymer containing positively charged groups used for coagulation/flocculation, usually dimethyl - aminoethyl methacrylate or dimethyl-aminoethyl acrylate. See **polyelectrolyte**.

**cellulose**—an amorphous carbohydrate (C<sub>6</sub>H<sub>10</sub>O<sub>5</sub>) that is the principal constituent of wood and plants.

**cellulose acetate (CA)**—in the broad sense, any of several esters of cellulose and acetic acid.

**celsius (°C)**—the designation of the degree on the International Practical Temperature Scale. Formerly called centigrade, °C = K minus 273.15. K = Kelvin.

**centigrade**—since 1948, now called Celsius, a temperature scale.

**ceramic membrane**—generally a glass, silica, alumina, or carbon based membrane. Generally used in micro and ultrafiltration. They tend to withstand high temperatures and wide pH ranges and be more chemically inert than polymeric membranes.

**CFU**—colony forming unit; unit used in the measure of total bacteria count (TBC).

**channeling**—unequal flow distribution in the desalination bundle or filter bed.

**chelating agents**—a sequestering or complexing agent that, in aqueous solution, renders a metallic ion inactive through the formation of an inner ring structure with the ion.

**chemical feed pump**—a pump used to meter chemicals, such as chlorine or polyphosphate, into a feed water supply.

**chloramine**—a combination of chlorine and ammonia in water which has bactericidal qualities for a longer time than does free chlorine.

**chlorine**—chemical used for its qualities as a bleaching or oxidizing agent and disinfectant in water purification.

**chlorine demand**—the amount of chlorine used up by reacting with oxidizable substances in water before chlorine residual can be measured.

**chlorine, residual**—the amount of available chlorine present in water at any specified time.

**chlorine, free available**—the chlorine (Cl<sub>2</sub>), hypochlorite ions

**TABLE 1 Conversion Factors<sup>A,B</sup>**

mg/l as ion	mg/l as CaCO <sub>3</sub>	Clark or English Degree	Grain per US Gallon	French Degree	German Degree	EPM MEQ/L	Atomic Weight
Ca <sup>++</sup>	2.495	0.175	0.0583	0.250	0.140	0.0499	40.08
Mg <sup>++</sup>	4.112	0.288	0.0583	0.411	0.231	0.0823	24.32
Na <sup>+</sup>	2.175	0.152	0.0583	0.218	0.122	0.0435	22.99
K <sup>+</sup>	1.279	0.089	0.0583	0.128	0.072	0.0256	39.10
Sr <sup>++</sup>	1.141	0.080	0.0583	0.114	0.064	0.0288	87.63
Ba <sup>++</sup>	0.728	0.051	0.0583	0.073	0.041	0.0146	137.36
Fe <sup>++</sup>	1.791	0.125	0.0583	0.179	0.101	0.0358	55.85
HCO <sub>3</sub> <sup>-</sup>	0.819	0.057	0.0583	0.082	0.046	0.0164	61.02
SO <sub>4</sub> <sup>-</sup>	1.041	0.073	0.0583	0.104	0.058	0.0208	96.07
Cl <sup>-</sup>	1.410	0.098	0.0583	0.141	0.079	0.0282	35.46
F <sup>-</sup>	2.632	0.184	0.0583	0.263	0.148	0.0526	19.00
NO <sub>3</sub> <sup>-</sup>	0.806	0.056	0.0583	0.081	0.045	0.0161	62.00
CO <sub>3</sub> <sup>--</sup>	1.666	0.117	0.0583	0.167	0.094	0.0323	60.01
PO <sub>4</sub> <sup>---</sup>	1.579	0.110	0.0583	0.158	0.089	0.0316	94.98

<sup>A</sup>To convert from mg/l as ion to any other unit multiply by factor.

<sup>B</sup>To convert to mg/l as ion from any other unit divide by factor.

(OCl<sup>-</sup>), hypochlorous acid (HOCl) or the combination thereof present in water.

**chlorine, total available**—the sum of free available chlorine plus chloramines present in water.

**CIP**—cleaning-in-place.

**citric acid**—C<sub>3</sub>H<sub>4</sub>(OH)(CO<sub>2</sub>H)<sub>3</sub>, membrane cleaning chemical.

**clarifier**—a tank in which precipitate settles and supernatant overflows, a liquid-solids separation unit using gravity to remove solids by sedimentation.

**clark degree**—number of grains of substance per one British imperial gallon of water expressed CaCO<sub>3</sub>. Concentration in Clark or English degree is calculated by dividing concentration in calcium carbonate equivalents by 14.3. One grain weighs 1/7000 lb and one imperial gallon of water weighs 10 lbs at 25°C. (See Table 1.)

**coagulant**—chemical added in water and wastewater applications to cause destabilization of suspended particles and subsequent formation of flocs that adsorb, entrap, or otherwise bring together suspended matter that is so fine, it is defined as colloidal. Compounds of iron and aluminum are generally used to form flocs to allow removal of turbidity, bacteria, color, and other finely divided matter from water and waste water.

**coalescing**—the separation of mixtures of immiscible fluids (such as oil and water) based on different specific gravities and surface tensions. Can occur whenever two or more droplets collide and remain in contact and then become larger by passing through a coalescer. The enlarged drops then separate out of solution more rapidly.

**COD—chemical oxygen demand**—the amount of oxygen required under specified test conditions for the oxidation of water borne organic and inorganic matter.

**colloid**—a substance of very fine particle size, typically between 0.1 and 0.001 μm in diameter suspended in liquid or dispersed in gas. A system of at least two phases, including a continuous liquid plus solid, liquid or gaseous particles so small that they remain in dispersion for a practicable time.

**colony forming unit (CFU)**—unit used in the measure of total bacterial count (TBC).

**compaction**—in crossflow filtration, the result of applied pressure and temperature compressing a polymeric membrane which may result in a decline in flux.

**composite membrane**—a membrane having two or more layers with different physical or chemical properties. Membrane manufactured by forming a thin desalinating barrier layer on a porous carrier membrane.

**concentrate**—the stream exiting a crossflow membrane device which has increased concentration of solutes and particles over the feed stream. Portion of the feed stream which does not pass through the membrane. The stream in which dissolved solids or particulates, or both, are concentrated in a membrane separation process.

**concentrate recycle**—a technique for improving recovery in which a fraction of the concentrate is recycled through the membrane system.

**concentration factor, CF**—

$$CF = \frac{C_B \text{ (brinewater concentration)}}{C_F \text{ (feedwater concentration)}}$$

$$= \frac{1}{1 - \text{conversion}} \text{ (approximation)}$$

**concentration polarization**—the increase of the solute concentration over the bulk feed solution which occurs in a thin boundary layer at the feed side of the membrane surface, resulting from the removal of the solvent.

**conductivity**—the property of a substance's (in this case, water and dissolved ions) ability to transmit electricity. The inverse of resistivity. Measured by a conductivity meter, and described in microsiemens/cm or micromhos/cm, μS/cm.

**contaminant**—any foreign substance present which will adversely affect performance or quality.

**continuous deionization**—a deionization process that does not require regular interruptions in service to discharge ionic materials collected from the water being processed.

**control block**—a group of devices having a common piping and control system.

**conversion (Y)**—product water flow rate divided by feed water flow rate. Also called recovery; given as fraction or decimal. See **recovery**.

**conversion factors**—see Table 1.

**corrosion products**—products that result from chemical or electrochemical reaction between a metal and its environment.

**CPU**—chloroplatinate unit (color indicator).

**crossflow membrane filtration**—a separation of the components of a fluid by semipermeable membranes through the application of pressure and flow parallel to the membrane surface. Includes the processes of reverse osmosis, ultrafiltration, nanofiltration, and microfiltration.

**Dalton**—an arbitrary unit of molecular weight, 1½ the mass of the nuclide of carbon 12. Unit of measure for the smallest size of the molecular retained by an ultrafilter.

**DBP**—disinfection by-products (a rule as part of the SDWA).

**dead end filtration**—a process in which water is forced through a media which captures the retained particles on and within it, where the process involves one influent and one effluent stream.

**deaerator**—a device to remove air from water.

**decarbonator**—a device to remove carbon dioxide from water.

**degasification**—the process of removing dissolved gasses from water.

**deionization (DI)**—the removal of ions from a solution by ion exchange.

**demineralization**—the process of removing minerals from water.

**desalination**—see **demineralization**.

**detergent**—a cleansing agent; any of numerous synthetic water soluble or liquid-organic preparations that are chemically different from soaps but resemble them in the ability to emulsify oils and hold dirt in suspension.

**dialysis**—a separation process dependent on different diffusion rates of solutes across a permeable membrane without an applied hydraulic driving force.

- diatom**—single cell marine animal having a coating consisting principally of silica.
- diatomaceous earth (DE) filtration**—filtration using an amorphous, lightweight siliceous earth medium occurring naturally as the fossil remains of diatoms.
- disinfection**—the process of killing organisms in a water supply or distribution system by means of heat, chemicals, or UV light.
- dissolved solids**—the residual material remaining after filtering the suspended material from a solution and evaporating the solution to a dry state at a specified temperature. That matter, exclusive of gases, which is dissolved in water to give a single homogeneous liquid phase.
- distillation**—the process of condensing steam from boiling water on a cool surface.
- electrodialysis (ED)**—a process in which ions are transferred through membranes from a less concentrated to a more concentrated solution using direct current electric power as the driving force.
- electrodialysis reversal (EDR)**—same as ED with the addition of a polarity reversal step added to improve performance.
- element**—the component containing the membrane, generally replaceable, such as a spiral wound cartridge.
- English degree**—number of grains of substance per one British imperial gallon of water. (See Table 1.)
- EPA—Environmental Protection Agency (USA)**—an organization that has set the potable water standards.
- equivalent per million (EPM)**—a unit chemical equivalent weight of solute per million unit weights of solution. Concentration in equivalents per million is calculated by dividing concentration in ppm by the equivalent weight of the substance or ion. Equivalent weight is the atomic weight of the substance divided by the valence of the substance.
- equivalent weight**—the weight of an ion determined by dividing the sum of the atomic weights of its component atoms by its valence.
- ERD**—energy recovery device.
- ERT**—energy recovery turbine.
- ESWTR**—enhanced surface water treatment rule.
- evaporation**—process where a liquid (water) passes from a liquid to a gaseous state.
- FAC**—free available chlorine.
- Fahrenheit (°F)**—designation of a degree on the Fahrenheit temperature scale that is related to the International Practical Temperature Scale.
- FDA**—Food and Drug Administration (USA).
- feed**—the input solution to a treatment/purification system or device, including the raw water supply prior to any treatment. The liquid entering the module.
- feed channel spacer**—a plastic netting between membrane leaves which provides the flow channel for the fluid passing over the surface of the membrane and increases the turbulence of the feed-brine stream.
- feed distributor**—the plastic mesh cylinder at the core of the fiber bundle which distributes the feed evenly.
- feed water**—that water entering a device or process.
- ferric chloride**—crystalline form of  $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ , a coagulant.
- ferric sulfate**— $\text{Fe}_2(\text{SO}_4)_3 \cdot 9\text{H}_2\text{O}$ , a coagulant.
- ferrous sulfate**— $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ , a coagulant.
- fiber bundle**—the heart of the permeator consisting of the hollow fiber polymer membrane, epoxy tube sheet, nub and feed distributor.
- filter cake**—the accumulated particles on a filter surface, usually from a slurry mixture.
- filtrate**—the portion of the feed stream which has passed through a filter.
- fixed matter**—residues from the ignition of particulate or dissolved matter, or both.
- flat sheet membrane**—a sheet type membrane may be coated onto a fabric substrate.
- floc**—a loose, open-structured mass produced by the aggregation of minute particles.
- flocculent**—chemical(s) which, when added to water, form bridges between suspended particles causing them to agglomerate into larger groupings (flocs) which then settle or float by specific gravity differences.
- flocculation**—the process of agglomerating fine particles into larger groupings called flocs.
- flow balancing**—the use of an imposed pressure drop (flow balancing tube), to minimize conversion differences of modules operating in parallel.
- flow balancing tube**—see **flow balancing**.
- flux**—the membrane throughput, usually expressed in volume of permeate per unit time per unit area, such as gallons per day per  $\text{ft}^2$  or litres per hour per  $\text{m}^2$ .
- fouling**—the reduction of flux due to a build-up of solids on the surface or within the pores of the membrane, resulting in changed element performance.
- fouling index (FI)**—see **SDI**.
- FRC**—free residual chlorine.
- freeboard**—the space above a filter bed in a filtration vessel to allow for expansion of the bed during back washing.
- free (available) chlorine**—chlorine existing as hypochlorous acid or its dissociated ions. Chlorine remaining after the demand has been satisfied.
- French degree**—calcium carbonate equivalents expressed in parts per hundred thousand. Concentration in French degree is calculated by dividing concentration in calcium carbonate equivalents by ten. (See Table 1.)
- FRP**—fiberglass reinforced plastic.
- fungus**—primitive plants distinguished from algae by the absence of chlorophyll.
- GAC**—granular activated carbon.
- galvanic corrosion**—accelerated corrosion of a metal because of an electrical contact with a more noble metal or non metallic conductor in an electrolyte.
- GD**—gallons per day. See **GPD**.
- GFD (GPDSF)**—unit of permeate rate or flux; gallons per day per square foot of effective membrane area.
- GPD**—unit of flow rate; gallons per day. See **GD**.
- German degree**—Calcium oxide equivalents expressed in parts per hundred thousand. Concentration in German degree is calculated by dividing concentration in calcium carbonate equivalents by 17.86 (See Table 1.)
- Grain**—unit of weight, 0.648 g, 0.000143 lb.

- grains per U.S. gallon (GPG)**—number of grains of substance per one U.S. gallon of water. Concentration in GPG is calculated by dividing concentration in ppm of the ion by 17.1. One grain weighs 1/7000 lb and one U.S. gallon weighs 8.3 lb.
- GRAS**—materials “generally regarded as safe,” as listed by the FDA.
- gravity filter**—a filter through which water flows through it by gravity.
- greensand**—a mineral (glaucanite), used as a filtration medium. See **manganese greensand**.
- groundwater**—water confined in permeable sand layers between rock or clay; that part of the subsurface water that is in the saturated zone.
- HAA**—A group of six halo acetic acids regulated in drinking water (mono, di and tri-chloroacetic acid, mono and di bromoacetic acid and chlorobromoacetic acid).
- halogen**—any element of the family of the elements fluorine, chlorine, bromine and iodine (definition for purpose of this standard).
- hardness**—the polyvalent-cation concentration of water (generally calcium and magnesium). Usually expressed as mg/L as CaCO<sub>3</sub>.
- header**—see **manifold**.
- head loss**—the reduction in liquid pressure usually associated with the passage of a solution through a filter media bed.
- heavy metals**—elements having a high density or specific gravity of approximately 5.0 or higher. A generic term used to describe contaminants such as cadmium, lead, mercury, etc. Most are toxic to humans in low concentration.
- high brackish water**—water with an approximate concentration of total dissolved solids ranging from 10 000 to 30 000 mg/L. See **brackish water** and **sea water**.
- high-purity water**—highly treated water with attention to microbiological, particle, organics and mineral reduction or elimination.
- hollow fiber (HF) membrane**—self-supporting membrane fibers which have a hollow bore like a cylinder. In reverse osmosis, the membrane is usually on the outside with the bore conveying the permeate. In ultra and micro filtrations the membrane is generally on the inside.
- HPC**—heterotrophic plate count. Formerly called SPC.
- humic acid**—a variety of water-soluble organic compounds, formed by the decayed vegetable matter, which is leached into a water source by runoff or percolation. Present in most surface and some ground waters. Higher concentrations cause a brownish tint. Difficult to remove except by adsorption, ultrafiltration, nanofiltration or reverse osmosis.
- humidity, absolute**—the mass of water vapor per unit volume of the atmosphere usually measured as grams per m<sup>3</sup>.
- humidity, relative**—the ratio of the actual pressure of existing water vapor to the maximum possible (saturation) pressure of water vapor in the atmosphere at the same temperature, expressed as a percentage.
- hydrated lime**—dry calcium hydroxide.
- hydrophilic**—having an affinity for water.
- hydrophobic**—lacking an affinity to water.
- hydroxyl alkalinity**—see **alkalinity**.
- hyperfiltration**—separation of dissolved ions from a feed stream as in nanofiltration and reverse osmosis.
- imperial gallon (IG)**—1.2 times U.S. gallon.
- in-line coagulation**—a filtration process performed by continually adding a coagulant to the raw feedwater and then passing the water through a filter(s) to remove the microfloc which has been formed.
- interconnector**—a device to connect adjacent membrane elements in series and to seal the product channel from the feed-brine channel.
- ion**—a charged portion of matter of atomic or molecular dimensions.
- ion exchange**—a reversible process by which ions are interchanged between a solid and a liquid with no substantial structural changes in the solid; ions removed from a liquid by chemical bonding to the media.
- ion-exchange capacity (volume basis)**—the number of milliequivalents of exchangeable ions per millilitre of backwashed and settled bed of ion-exchange material in its standard form.
- ion-exchange capacity (weight basis)**—the number of milliequivalents of exchangeable ions per dry gram of ion-exchange material in its standard form.
- ion-exchange material**—a water insoluble material that has the ability to reversibly exchange ions in its structure, or attached to its surface as functional groups, with ions in a surrounding medium.
- ion-exchange membrane**—an ion-exchange material in a form suitable for use as a barrier between two fluids.
- ion-exchange particle**—an ion-exchange material in the form of spheroids or granules.
- ion-exchange resin**—an organic ion-exchange material substrate, usually synthetic.
- ionic strength**—measure of the overall electrolytic potential of a solution, the strength of a solution based on both the concentrations and valencies of the ions present.
- ionization**—the disassociation of molecules into charged particles (ions).
- jackson turbidity unit, JTU**—unit of measure used with the jackson candle turbidimeter.
- jar test**—a laboratory procedure for the evaluation of a treatment to reduce dissolved, suspended colloidal and non settleable matter from water (see Practice D 2035).
- langelier saturation index, LSI**—an index calculated from total dissolved solids, calcium concentration, total alkalinity, pH, and solution temperature that shows the tendency of a water solution to precipitate or dissolve calcium carbonate.
- LD-50**—concentration required for 50 % mortality (lethal dose).
- leaf**—the sandwich layer of flat-sheet membrane/product channel spacer/flat-sheet membrane, glued together on the sides and across the outer end in a spiral wound element.
- lime**—Ca(OH)<sub>2</sub>, calcium hydroxide, a common water treatment chemical.
- lime soda softening**—use of lime and Na<sub>2</sub>CO<sub>3</sub> for softening water.
- limestone**—either calcite limestone (CaCO<sub>3</sub>) or dolomitic limestone (CaCO<sub>3</sub>-MgCO<sub>3</sub>).

**loose RO**—see **nanofiltration**.

**LSI**—langelier saturation index, measure of  $\text{CaCO}_3$  solubility in brackish waters. See **S&DSI**.

**manganese greensand**—a manganese dioxide coated greensand used as a filter medium for removal of manganese and iron. See **greensand**.

**manifold**—an enlarged pipe with connections available to the individual feed, brine and product ports of a desalination device.

**mass transfer coefficient (MTC)**—mass (or volume) transfer through a membrane based on driving force.

**MCL**—maximum contaminant level.

**megohm**—unit of measurement of water purity by electrical resistance; One million ohms; reciprocal of conductivity. See **microsiemens, ohm**.

**membrane**—engineered thin semipermeable film which serves as a barrier permitting the passage of materials only up to a certain size, shape, or electro-chemical character. Membranes are used as the separation agent in reverse osmosis, electrodialysis, ultrafiltration, nanofiltration, and microfiltration, as disc filters in laboratories, and as pleated filter cartridges, particularly for microfiltration.

**membrane area**—the active area available for micro, nano and ultrafiltration and reverse osmosis.

**membrane compaction**—see **compaction**.

**membrane configuration**—the design and shape of a given membrane element (cartridge) such as tubular, spiral wound or hollow fiber.

**membrane element**—a bundle of spiral membrane envelopes or hollow fiber membranes bound together as a discrete entity.

**membrane filter**—geometrically regular porous matrix; removes particles above pore size rating by physical size exclusion.

**membrane salt passage**— $SP_m$  is the concentration of a compound in the permeate related to its average concentration on the feed/concentrate side.

**membrane softening**—use of crossflow membrane to substantially reduce hardness ions in water. See **nanofiltration**.

**MGD (MGPD)**—millions of gallons per day.

**Mho**—a measure of water purity by conductance, reciprocal of ohms. See **ohm**.

**microaerophilic bacteria**—aerobic bacteria that require 2-10 % oxygen in order to grow. See **bacteria (microaerophiles)**.

**microfiltration (MF)**—filtration designed to remove particles in the approximate range of 0.05 to 2  $\mu\text{m}$ .

**microbe**—bacteria and other organisms that require the aid of a microscope to be seen.

**micron (micrometre)**—a metric unit of measurement equivalent to  $10^{-6}$  metres,  $10^{-4}$  centimetres. Symbol is  $\mu\text{m}$ .

**microorganism**—see **microbe**.

**microsiemens**—unit of measurement of water purity by electrical conductivity; one micromho; reciprocal of resistivity. See **megohm, ohm**.

**milliequivalent per litre (meq/L)**—a weight-volume measurement obtained by dividing the concentration expressed

in milligrams per litre by the equivalent weight of the substance or ion. If specific gravity is unity meq/L is the same as epm.

**milligram per litre (mg/L)**—a weight-volume measurement which expresses the concentration of a solute in milligrams per litre of solution. When specific gravity is unity  $\text{mg/L} = \text{ppm}$ . When specific gravity is not unity,  $\text{mg/L}$  divided by specific gravity of solution equals ppm.

**mixed-bed**—a physical mixture of anion-exchange and cation-exchange materials.

**module**—a membrane element combined with the element's housing. Pressure vessel containing membrane element(s).

**molality ( $m_1$ )**—Moles (gram molecular weight) of solute per 1000 g of solvent.

**molarity ( $m_1$ )**—moles (gram molecular weight) of solute per litre of total solution.

**molecular weight cut off (MWCO)**—the rating of a membrane for the size of uncharged solutes it will reject. Also referred to as nominal molecular weight cut off (NMWCO).

**multimedia filter**—filter with a bed consisting of three or more separate filter media. The coarsest, lowest density at the top and the finest, highest density at the bottom.

**m-value**—the negative slope of a curve plotting log flow versus log time. A measurement of the degrees of membrane compaction as a result of temperature, pressure and time.

**NaHMP**—sodium hexametaphosphate, an antiscalant.

**Nanofiltration (NF)**—a crossflow process with pore sizes designed to remove selected salts and most organics above about 300 molecular weight range, sometimes referred to as loose RO.

**NOM**—natural organic matter.

**nephelometer**—a device used to measure mainly the turbidity of water with results expressed in nephelometric turbidity units (NTU). Measures light at  $90^\circ$ .

**non-carbonate hardness**—hardness caused by chlorides, sulfates, and nitrates of calcium and magnesium.

**nonionic polyelectrolyte**—neutral charged polymers, usually polyacrylamides, used for coagulation/flocculation. See **polyelectrolytes**.

**normalization**—converting actual data to a set of reference conditions in order to “standardize” operation to common base.

**NTU**—see **nephelometer**.

**OEM**—original equipment manufacturer.

**O&M**—operation and maintenance.

**ohm**—unit of electric resistance equal to the resistance of a circuit in which a potential difference of one volt produces a current of one ampere.

**operating pressure**—the gage hydraulic pressure at which feedwater enters a device.

**osmosis**—the spontaneous flow of water from a less concentrated solution to a more concentrated solution through a semipermeable membrane until chemical potential equilibrium is achieved.

**osmotic pressure**—a measurement of the potential energy difference between solutions on either side of a semipermeable membrane. A factor in designing the operating pressure of reverse osmosis equipment. The applied pressure must

- first overcome the osmotic pressure inherent in the chemical solution in order to produce any flux.
- oxidation-reduction potential**—the electromotive force developed by a noble metal electrode immersed in the water, referred to the standard hydrogen electrode.
- oxygen demand**—the amount of oxygen required for the oxidation of waterborne organic and inorganic matter under the specified test conditions.
- PAC**—powdered activated carbon or poly-aluminum chloride.
- parts per billion (ppb)**—a measure of proportion by weight, equivalent to a unit weight of solute per billion unit weights of solution (approximate  $\mu\text{g/L}$  or  $\text{mg/m}^3$  in dilute solutions).
- parts per million (ppm)**—a measure of proportion by weight, equivalent to a unit weight of solute per million unit weights of solution (approximate  $\text{mg/L}$  or  $\text{g/m}^3$  in dilute solutions).
- parts per trillion (ppt)**—a measure of proportion by weight, equivalent to a unit weight of solute per trillion unit weights of solution (approximate  $\text{g/L}$  or  $\mu\text{g/m}^3$  in dilute solutions).
- pass**—a treatment step or one of multiple treatment steps producing in a membrane system a product stream.
- permanent hardness**—the total milliequivalents of hardness minus the milliequivalents of bicarbonate alkalinity in a water. See **hardness, alkalinity**.
- permeable**—allowing material to pass through.
- permeate**—that portion of the feed stream which passes through a membrane.
- permeate collector fabric**—see **product (permeate) channel spacer**.
- permeator**—a reverse osmosis module of the hollow fiber configuration consisting of membrane(s) and pressure vessel.
- pervaporation**—a separation process involving vaporization of one liquid from a mixture of two or more liquids, with the aid of a membrane which functions as a barrier to the liquid phase.
- pH**—negative logarithm of the effective hydrogen-ion activity, approximately  $-\log_{10} [\text{H}^+]$  where  $[\text{H}^+]$  is equivalents per litre concentration.
- phase**—a state of matter, either solid, liquid, or gaseous.
- plant capacity**—manufacture of product per unit time, expressed as  $\text{m}^3/\text{day}$ ,  $\text{m}^3/\text{h}$ , GPD, MGD.
- plugging factor**—see **fouling factor** and **SDI**.
- polarization**—see **concentration polarization**.
- polyelectrolyte**—synthetic (or natural) molecules, containing multiple ionic groups, used as coagulants and flocculants; available as anionic, cationic and nonionic.
- polymers**—a substance consisting of molecules characterized by the repetition of one or more types of monomeric units.
- pore**—an opening or void in a membrane or filter matrix.
- porous**—substances containing pores for fluids to pass due to an open physical structure.
- porosity**—that portion of a membrane filter volume which is open to fluid flow, also known as void volume.
- post treatment**—a process of applying chemical(s) to a membrane after formation to improve its performance.
- post treatment**—the addition of chemicals to the product or concentrate stream to make it suitable for the desired end use application.
- post treatment**—utilization of equipment such as degasifiers to make the product or concentrate stream, or both, suitable for the desired end use application.
- precipitate**—an insoluble product of a chemical reaction of soluble compounds in water.
- precoat**—the initial coating of the septum in a diatomaceous earth filter to provide initial straining medium.
- pressure filtration**—filtration performed in an enclosed pressurized filter vessel.
- pressure vessel**—the vessel containing one or more individual membrane elements and designed to withstand safely the hydraulic pressure driving the separation mechanism.
- pretreatment**—processes such as chlorination, filtration, coagulation, clarification, acidification which may be used on feedwater ahead at membrane devices to improve quality, minimize scaling and corrosion potential, control biological activity.
- product staging**—a process in which the permeate from one membrane plant is used as the feed to another membrane plant in order to further improve product quality.
- product channel spacer (permeate carrier)**—the fabric or other material through which permeate water flows after it passes through the flat sheet membrane.
- productivity**—flow rate of product water.
- product tube**—the tube at the center of the spiral wound cartridge which collects permeate water.
- product water**—purified water produced by a process. See **permeate**.
- projection**—a calculation, usually performed by a software package, which predicts the performance of parts or all of a water plant.
- pyrogens**—any substance capable of producing a fever in mammals. Often a bacterial endotoxin such as lipo polysaccharide generated by gram negative bacteria at destruction. Chemically and physically stable, pyrogens are not necessarily destroyed by conditions that kill bacteria.
- quicklime**—CaO, calcium oxide.
- ranney collector**—an underground water collection system sometimes called ranney wells.
- raw water**—water which has not been treated. Untreated water from wells, surface sources, the sea or public water supplies.
- recovery—Y (conversion)**—the ratio of product quantity (permeate stream flow rate) over the feed quantity (feed stream flow rate), given as fraction or in percent.
- regeneration**—in ion exchange systems, the process of using either an acid, alkali, or salt solution to remove the accumulated cations or anions. The cation exchange resins take on hydrogen or sodium ions and the anion exchange resins take on hydroxide ions to restore themselves to the original hydrogen or hydroxide form when using strong acid and strong alkali solutions for the process.
- reject**—brine, (concentrate) stream from a desalination device. Portion of the feed stream which does not pass through the membrane.
- resin particle**—specially manufactured polymer beads used in the ion exchange process to remove dissolved salts from water.

**resistivity**—the property of a substance (in this case, water) to resist the flow of electricity; the measurement of that resistance. The inverse of conductivity. Measured by a resistivity monitor, and described in ohms-cm.

**retentate**—see **concentrate**.

**reverse osmosis (RO)**—the separation process where one component of a solution is removed from another component by flowing the feed stream under pressure across a semipermeable membrane. RO removes ions based on electrochemical forces, colloids, and organics down to 150 molecular weight. May also be called hyperfiltration.

**RO train**—one of two or more complete RO installations, including membranes and high pressure pump operating in parallel.

**ryznar stability index (RSI)**—an index indicating if a water has a tendency to corrode or precipitate  $\text{CaCO}_3$ ; equals  $2 \text{ pH} (\text{CaCO}_3 \text{ saturation}) - \text{pH} (\text{actual})$ ,  $\text{RSI} < 6.0$  scale formation,  $> 7.0$  corrosive.

**salinity**—the concentration of inorganic salts in water.

**salt flux**—amount of dissolved salt passing through the membrane, moles per day per square unit of membrane area.

**salt passage, SP**—

$$SP = \frac{CP \times 100}{CF}$$

the ratio of product ( $CP$ ) and feed ( $CF$ ) salt concentrations expressed as percent.

**salt rejection, SR**— $(100 - \text{salt passage})$  expressed as percent:

$$SR = 100 \left( 1 - \frac{CP}{CF} \right)$$

**sanitization**—reduction in the number of bacterial contaminants to safe levels. See **disinfection**.

**saturation**—the point at which a solution contains enough of a dissolved solid, liquid, or gas so that no more will dissolve into the solution at a given temperature and pressure.

**SBS**—sodium bisulfite,  $\text{NaHSO}_3$ .

**scale inhibitor**—a chemical which inhibits the growth of micro-crystals (inhibits precipitation of sparingly soluble salts). See **antiscalant**.

**scaling**—the build-up of precipitated salts on a surface, such as membranes, pipes, tanks, or boiler condensate tubes.

**SDI**—**silt density index**—an index calculated from the rate of plugging of  $0.45 \mu\text{m}$  membrane filter. It is an indication of the amount of particulate matter in water, sometimes called fouling index.

**S&DSI**—Stiff and Davis saturation index, measure of  $\text{CaCO}_3$  solubility in seawater or highly saline water. See **LSI**.

**SDWA**—Safe Drinking Water Act of the United States, specifying required purity levels of municipal potable water.

**sea water**—water with an approximate concentration of total dissolved solids ranging from 30 000 to 60 000 mg/L. See **brackish water, high brackish water**.

**sedimentation**—the precipitation or settling of insoluble materials from a suspension, either by gravity or artificially. For example, centrifuge, pressure.

**semipermeable membrane**—a membrane which preferentially allows the passage of specific compounds while rejecting others.

**SHMP**—sodium hexametaphosphate. ( $\text{NaHMP}$ )

**Siemens**—a measure of electrical conductance in water, equivalent to a mho. See **Mho, Ohm**.

**slime**—biological deposits of gelatinous or filamentous matter.

**sludge**—a water-formed sedimentary deposit.

**sludge blanket**—suspended bed of solids in a solids contact or sludge blanket clarifier.

**SMBS**—sodium metabisulfite,  $\text{Na}_2\text{S}_2\text{O}_5$ .

**softening**—see **membrane softening**.

**softener**—water treatment equipment that uses a sodium based ion-exchange resin principally to remove cations as calcium and magnesium.

**solids contact clarifier**—water treating device used in lime softening, waste water treatment and coagulation processes.

**solubility product**— $[\text{M}^+]^a [\text{X}^-]^b / [\text{MX}]$  where the brackets indicate the concentrations of the components of the ionization equilibrium  $\text{M}_a\text{X}_b \rightleftharpoons a\text{M}^+ + b\text{X}^-$ . For sparingly soluble salts  $[\text{MX}]$  is essentially unity.

**solutes**—matter dissolved in a solvent.

**solvent**—here defined as water.

**SPC**—**standard (heterotrophic) plate count**—measurement method for enumerating bacteria.

**specific gravity**—the ratio of the mass (density) of a sample material to the mass (density) of an equal volume of water at the same specified temperature.

**specific flux**—flux divided by net pressure driving force.

**spiral wound cartridge**—a crossflow membrane element design consisting of a product tube, flat membrane leaves, feed channel spacers, anti-telescoping devices, and brine (concentrate) seal.

**spiral wound membrane**—a flat sheet membrane with one or more feed channel spacers and barrier layers, all of which are rolled into a spiral configuration.

**stage**—a sequential arrangement of pressure vessels, usually reject staged such as 2:1 array, sometimes permeate staged as in double pass RO.

**staging**—see **brine staging** and **product staging**.

**standard test conditions**—the parameters under which a membrane manufacturer tests devices for flow and salt rejection.

**sterilization**—destruction or removal of all viable organisms.

**Stiff & Davis stability index, S&DSI**—an index calculated from total dissolved solids, calcium concentration, total alkalinity, pH and solution temperature that shows the tendency of a water solution to precipitate or dissolve calcium carbonate. S&DSI is used primarily for seawater RO applications.

**STP**—sodium triphosphate -  $\text{Na}_5\text{P}_3\text{O}_{10}$ , a cleaning agent.

**STPP**—sodium tripolyphosphate. See **STP**.

**supersaturation**—a state in which the inorganic salt (s) are in solution at a level higher than the respective solubility product.

**suspended solids (SS)**—solid organic and inorganic particles that are held in suspension in a liquid.

**SWRO**—seawater reverse osmosis.

**symmetric membrane**—membrane and bulk polymer have equivalent characteristic (isotropic).

**TBC**—total bacteria count, the total number of viable microorganisms present in the sample, excluding anaerobic organisms.

**TCC**—total colony count.

**TDS**—total dissolved solids, usually expressed as mg/L or ppm (parts per million).

**telescoping**—the movement of the outer layers of a spiral wound cartridge in the direction of the feed flow caused by excessive pressure drop through the feed channel spacer.

**temperature correction factor (TCF)**—defines the effect of temperature on permeate flow relative to a base temperature (25°C), is mainly a function of fluid characteristics but also membrane polymer.

**temporary hardness**—usually the bicarbonate salts of calcium and magnesium.

**thickener**—a vessel designed to concentrate treatment sludges; similar to a clarifier.

**thin film composite (TFC)**—see **composite membrane**.

**threshold treatment**—the process of stopping precipitation at the start of occurrence; usually does not stop the formation of nuclei but does inhibit growth. See **antiscalant**.

**THM**—trihalomethanes; a group of low molecular weight molecules which can result from chlorination of organics typically found in surface water.

**THMP**—trihalomethane precursors; organic molecules found in water which have the potential of reacting with chlorine to form THMs.

**thrust collar**—a plastic cylinder placed between the last spiral wound cartridge and vessel end plate to support the last cartridge in a pressure vessel against telescoping.

**TOC**—total organic carbon, a measure of the level of organic constituents in water.

**TOCl**—total organic chlorine.

**TOX**—total organic halides.

**TOXFP**—total organic halide formation potential.

**train**—a grouping of devices. See **array**, **bank**, **block**.

**transmembrane pressure**—the net driving force across the membrane. The hydraulic pressure differential from the feed side to permeate side less the osmotic pressure differential on each side.

**TRC**—total residual chlorine.

**trisodium phosphate (TSP)**— $\text{Na}_3\text{PO}_4 \cdot 12\text{H}_2\text{O}$ , a cleaning agent.

**TSS**—total suspended solids. Concentration of undissolved solids in a liquid, usually expressed in mg/L or ppm.

**TTHM**—total trihalomethane.

**turbidity**—a suspension of fine particles that scatters or absorbs light rays.

**turbidity, jackson candle (JTU)**—an empirical measure of turbidity in special apparatus, based on the measurement of the depth of a column of water sample that is just sufficient to extinguish the image of a burning standard candle observed vertically through the sample.

**turbidity, nephelometric (NTU)**—an empirical measure of turbidity based on a measurement of the light-scattering characteristics (tyndall effect) of the particulate matter in the sample.

**tyndall effect**—the path of light through a heterogeneous medium made visible by the solid particles.

**ultrafiltration (UF)**—a process employing semipermeable membrane under a hydraulic pressure gradient for the separation of components in a solution. The pores of the membrane are of a size which allow passage of the solvent(s) but will retain non-ionic solutes based primarily on physical size, not chemical potential.

**ultra pure water**—water generally used in semiconductor industry having specifications (chemical, physical and biological) for extremely low contaminant levels.

**USEPA**—U.S. Environmental Protection Agency.

**ultraviolet (UV) radiation**—wave lengths between 200 to 300 nm. These wave lengths have a strong germicidal effect. The maximum effect is at 253.7 nm.

**viable**—ability to live or grow. For example, bacteria, plants.

**VOC (viable organism count)**—a measure of biological activity (living or growing) in water.

**VOC (volatile organic compound)**—an organic compound with a vapor pressure higher than water.

**WQA**—water quality association.

**water softener**—a vessel having a cation resin in the sodium form that removes cations such as calcium and magnesium from water and releases another ion such as sodium. The resin is usually regenerated. See **softener**.

**Y**—conversion, recovery.

**zeolite**—any of various natural or synthetic hydrated aluminum silicates used as ion exchange substrates in water softening.

**zero discharge**—a condition whereby a facility discharges no process effluent.

**zeta potential**—colloidal stability measured in millivolts. High negative value (–10 to –30 mv) results in particulate stability.

## 5. Summary

5.1 This terminology is common to membrane separation processes but independent of the source of manufacture.

## 6. Keywords

6.1 crossflow; membranes; microfiltration; nanofiltration; reverse osmosis; terminology; ultrafiltration

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