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Standard Terminology Used for Microfiltration, Ultrafiltration, Nanofiltration and Reverse Osmosis Membrane Processes[1]

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1. Scope

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1129 Terminology Relating to Water

D2035 Practice for Coagulation-Flocculation Jar Test of Water

D3739 Practice for Calculation and Adjustment of the Langelier Saturation Index for Reverse Osmosis

D4582 Practice for Calculation and Adjustment of the Stiff and Davis Stability Index for Reverse Osmosis

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 microfiltration, ultrafiltration, nanofiltration and reverse osmosis processes assist the manufacturer, consultant and end-user in eliminating inter-process terminology confusion. This standard expands the definitions found in Terminology D1129.

4. Terminology

4.1 *Definitions:*

absolute filter rating—particle size above which 100 % of particles that are trapped on or within the filter medium.

absorption—the release for desorption 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, accuracy is a description of a measure of the degree of conformity of a value generated by a specific procedure to the assumed or accepted true value, including both precision and bias.

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 header—the pipe running within a cassette that distributes the air to the individual modules or aerators.

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

air stripping—removal of volatile substances from a water solution by passing a gas through the solution.

algae—a major group of lower plants, generally aquatic, photosynthetic of extremely varied morphology and physiology, 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, carbonate, and

[1] This terminology is under the jurisdiction of ASTM Committee D19 on Water and is the direct responsibility of Subcommittee D19.08 on Membranes and Ion Exchange Materials.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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, generally assumed to be 20°– 25°C.

amorphous—non crystalline, devoid of regular cohesive structure.

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

anion—negatively charged ion.

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

anion exchange membrane—membrane containing fixed cationic charges and mobile anions that can be exchanged with other anions present in an external fluid in contact with the membrane.

anisotropic membrane—a non-uniform 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 or acrylamide and acrylic copolymers, negatively charged, used for coagulation/flocculation. See **Polyelectrolyte**.

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. 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 per unit of net driving pressure (NDP); units of measurement are $m^3/hr/m^2/kPa$.

AWWA—American Water Works Association.

AWWARF—American Water Works Association Research Foundation.

backflush—temporary reversal of the permeate or retentate flow.

backpulse—pumping treated water with or without added chemicals in the reversed direction from the lumen to the feed side of the membrane (inside-out).

backwash—reversing 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.

baffle—a deflector plate in a vessel that disperses the inlet fluid.

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

bar—unit of pressure; 14.50 lbs/in. ^{2}, 1.020 kg/cm^2, 0.987 atm, 0.1 MPa.

BAT—best available technology.

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

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

United States for densities greater than unity.

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

For densities less than unity.

*at 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.

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

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.

bioremediation—the biological degradation treatment of waste sludge and soils to breakdown organic and hydrocarbons.

biostat—a substance that inhibits biological growth.

bipolar membrane—synthetic membrane containing two oppositely charged ion-exchange layers that are in contact with each other.

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 are significantly less than those in the bulk flow.

brackish water—water with an approximate concentration of total dissolved solids ranging from 500 to 10 000 mg/L. See **high brackish water, potable 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 differential at which bubbles first appear on one surface of an immersed porous membrane as gas pressure is applied to the other side.

bubble point pressure—the pressure differential 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.

buffer—a substance in solution that accepts hydrogen or hydroxyl ions added to the solution minimizing a change in pH.

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

B-value—salt diffusion coefficient—defined as the amount of salt transferred per unit area of membrane per unit of concentration difference across the membrane. A unit of measurement is m/h or more specifically, $m^3/m^2/h$.

BWRO—brackish water reverse osmosis.

CAC—combined available chlorine.

cage—a structural fabrication fitted around the perimeter of the cassette with one or more lifting eye suitable for installing or removing the cassetter. The four bottom corners of the cage rest within the frame in the tank.

cake layer—layer comprised of particulate materials residing on the upstream face of a membrane.

calcium carbonate equivalents (mg/L as $CaCO_3$)—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—$Ca(HClO)_2$, a disinfection agent.

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

cassette—an assembly of membrane elements (or modules), membrane aerators, air and permeate manifolds, and hardware in the cage; this is how the membranes are installed or removed from the process tank.

TABLE 1 Conversion Factors[A,B]

mg/l as Ion	mg/l as $CaCO_3$	Clark or English Degree	Grain per US Gallon	French Degree	German Degree	EPM MEQ/L	Atomic Weight
Ca++	2.495	0.175	0.0583	0.250	0.140	0.0499	40.08
Mg++	4.112	0.288	0.0583	0.411	0.231	0.0823	24.32
Na+	2.175	0.152	0.0583	0.218	0.122	0.0435	22.99
K+	1.279	0.089	0.0583	0.128	0.072	0.0256	39.10
Sr++	1.141	0.080	0.0583	0.114	0.064	0.0288	87.63
Ba++	0.728	0.051	0.0583	0.073	0.041	0.0146	137.36
Fe++	1.791	0.125	0.0583	0.179	0.101	0.0358	55.85
$HCO3^-$	0.819	0.057	0.0583	0.082	0.046	0.0164	61.02
SO_{4-}	1.041	0.073	0.0583	0.104	0.058	0.0208	96.07
Cl^-	1.410	0.098	0.0583	0.141	0.079	0.0282	35.46
F^-	2.632	0.184	0.0583	0.263	0.148	0.0526	19.00
NO_3^-	0.806	0.056	0.0583	0.081	0.045	0.0161	62.00
CO_3^{--}	1.666	0.117	0.0583	0.167	0.094	0.0323	60.01
PO_4^{---}	1.579	0.110	0.0583	0.158	0.089	0.0316	94.98

[A]To convert from mg/l as ion to any other unit multiply by factor.
[B]To convert to mg/l as ion from any other unit divide by factor.

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.

cation exchange membrane—membrane containing fixed anionic charges and mobile cations that can be exchanged with other cations present in an external fluid in contact with the membrane.

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 ($C_6H_{10}O_5$) 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. °C = (°F–32)*0.556.

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.

charge-mosaic membranes—synthetic membranes composed of two-dimensional or three dimensional alternating cation and anion echange channels throughout the membrane.

check valve—a valve that will allow water to pass in one direction but will close and prevent flow in the opposite direction.

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 of 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_2), hypochlorite ions (OCl^-), 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—$C_3H_4(OH)(CO_2H)_3$, 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 $CaCO_3$. 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.)

clear well—a collection basin that houses filtered or clarified water.

coagulant—chemical added in water and wastewater applications to cause destablization 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. Coalescence occurs 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.

co-current flow—flow pattern through a membrane in which the fluids on the upstream and downstream sides of the membrane move parallel to the membrane surface and in the same directions. (See Fig. 1.)

coliform bacteria—a particular group of bacteria primarily found in human and animal intestines and wastes.

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 diametre 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.

completely mixed (perfectly mixed) flow—flow through a membrane module in which fluids on both the upstream and downstream sides of the membrane are individually well-mixed. (See Fig. 1.)

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.

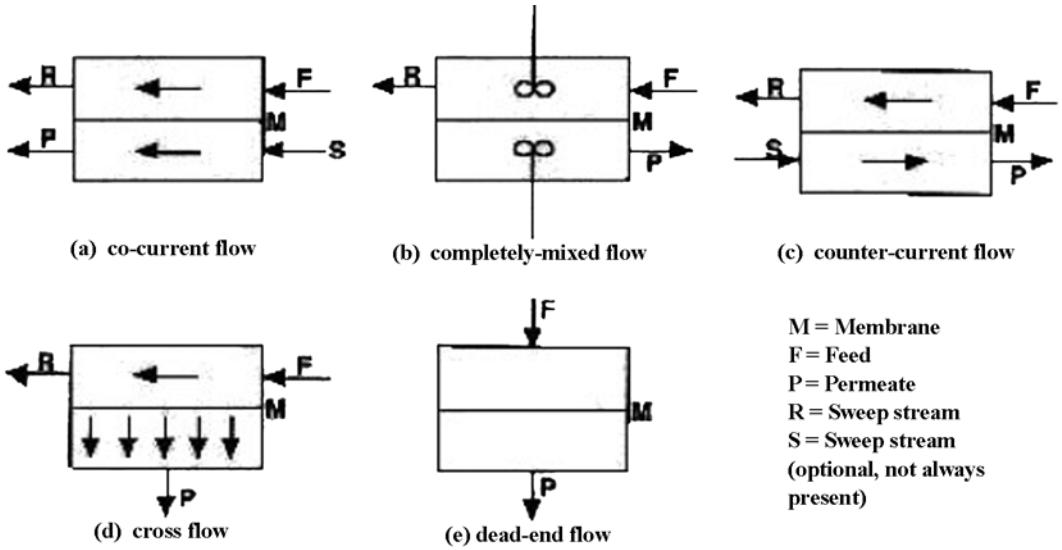

FIG. 1 Types of Ideal Continuous Flows Used in Membrane-Based Separations

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—the ratio of the concentration of a component in the retenate (concentrate, brine) to the concentration of the same component in the feed

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

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

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. Concentration profile that has a higher level of solute nearest to the upstream membrane surface compared with the more-or-less mixed bulk fluid far from the membrane surface.

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.

counter-current flow—flow through a membrane module in which the fluid on the upstream and downstream sides of the membrane move parallel to the membrane surface but in the opposite direction. (See Fig. 1.)

CPU—chloroplatinate unit (color indicator).

cross flow—flow through a membrane module in which the fluid on the upstream side of the membrane moves parallel to the membrane surface and the fluid on the downstream side of the membrane moves away from the membrane in the direction normal to the membrane surface. (See Fig. 1.)

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, utrafiltration, nanofiltration, and microfiltration.

cryptosporidium—a waterborne protozoan that forms cysts and causes acute gastrointestinal illness in humans.

Dalton—an arbitrary unit of molecular weight, one twelfth the mass of the nuclide of carbon 12.

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.

dead end flow—flow through a membrane module in which the only outlet for the upstream fluid is through the membrane. (See Fig. 1.)

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.

denitrification—aqueous nitrate reduction or removal.

dense (non-porous) membrane—membrane with no detectable pores.

desalination—see **demineralization**.

desorption—opposite of absorption. See **absorption**.

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. It is a process in which transport is driven primarily by concentration differences, rather than by pressure or electrical potential differences, across the thickness of a membrane.

dialysis permeability coefficient—permeability coefficient on a transmembrane driving force expressed in terms of the concentration difference of a given component.

diatom—single cell marine animal having a coating consisting principally of silica.

diatomaceous earth (DE) filtration—filtration using an amphorous, lightweight siliceous earth medium occurring naturally as the fossil remains of diatoms.

differential pressure (ΔP, dP)—the difference in pressure between two points.

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.

Donnan exclusion—reduction in concentration of mobile ions within an ion exchange membrane due to the presence of fixed ions of the same sign as the mobile ions.

downstream—side of a membrane from which permeate emerges.

dynamic membrane formation—process in which an active layer is formed on the membrane surface by the deposition of substances contained in the fluid being treated.

E. coli—one of the members of the coliform bacterium associated with animal and human waste.

effluent—exit stream from a unit/vessel.

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 or cassette.

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.

EPS—extra-cellular polysaccharide produced by bacteria to form a protective coating especially after attaching to the membrane surface.

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.

Escherichia colia—see **E. coli**.

ESWTR—enhanced surface water treatment rule.

evaporation—process where a liquid (water) passes from a liquid to a gaseous state.

FAC—free available chlorine.

facultative organisms—microbes capable of adapting to either aerobic or anaerobic environments.

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 pretreatment—process carried out on a crude (raw) feed stream prior to feeding to a membrane separation system to eliminate objectionable components such as biological agents and colloids that might impede the stable operation of the membrane.

feed water—that water entering a device or process.

ferric chloride—crystalline form of $FeCl_3\ 6H_2O$, a coagulant.

ferric sulfate—$Fe_2(SO_4)_3$-$9H_2O$, a coagulant.

ferrous sulfate—$FeSO_4$-$7H_2O$, 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.