GLOSSARY OF TERMS

Adsorption: Adsorption is the binding of a molecule to a surface (solid or liquid) by non-specific physical forces. For example, the removal of free chlorine and chloramines by activated carbon is through the mechanism of adsorption.

Asymmetric Membranes: (See membranes)

Algae: A group of single-celled plants which includes both sea water and fresh water varieties.

Alkalinity: A measurement of the quantity of chemicals present in water which can neutralize acids. These include carbon dioxide, bicarbonate, carbonate and hydroxides. See also titratable alkalinity.

Alum: See aluminum sulfate.

Aluminum sulfate: An aluminum salt commonly used as a flocculant by municipal water treatment facilities.

Amphoteric: A substance, such as aluminum, capable of acting as either an acid or base.

Anions: A negatively charged ion (See ion).

Bacteria: Bacteria are single cell microorganisms capable of replicating on their own. They can be divided into two broad categories, aerobic (requiring oxygen) and anaerobic (not requiring oxygen). Bacteria can live in a very broad range of habitats. Some, for example pseudomonads, can thrive in environments containing a very low level of nutrients. These bacteria are frequently slime producers and are a major problem in water treatment systems. Other bacteria, which adhere to surfaces, secrete a gelatinous material which serves to protect the bacteria from chemical disinfectants. This combination of bacteria and their protective coating is sometimes referred to as biofilm. The concentration of bacteria in water is commonly given in terms of colony forming units (cfu) per ml. A colony forming unit is a viable bacterium able to replicate to form a whole colony when incubated in a given environment.

Cations: A positively charged ion (See ion).

Cellulase: An enzyme which causes the decomposition of cellulose.

Cellulose Acetate: A synthetic polymer derived from naturally occurring cellulose and widely used in the fabrication of membranes. The polymers used for water purification membranes may be diacetate, triacetate or blends of these materials.

Chloramines: Chemicals used to disinfect municipal water. They are formed by reacting ammonia and free chlorine and may occur naturally when free chlorine combines with ammonia arising from the breakdown of vegetation. Chloramines are strong oxidants which are highly toxic in hemodialysis applications.

Chlorinated hydrocarbons: A group of organic chemicals formed by reacting petroleum derived chemicals with chlorine. Such chemicals include pesticides (insecticides) and herbicides and are frequently potent carcinogens.

Chlorine: Chemical used to disinfect municipal water.

Chlorophenoxyls: See chlorinated hydrocarbons.

Coagulant: A chemical which causes dispersed colloidal particles to become destabilized thereby aiding in their removal during municipal water treatment. Aluminum and iron salts are commonly used for this purpose.

Coagulation: A practice common in municipal water treatment in which a chemical (coagulant), most commonly alum, is added to water in order to destabilize colloidal particles by neutralization of their electrical charges. Coagulation is used, together with flocculation, as a process for colloid removal.

Colloid: Undissolved, submicron-sized suspended particles which are well dispersed in a solution and will not readily settle out on standing.

Compaction: The undesirable physical compression of a reverse osmosis or ultra filtration membrane which results in reduced flux rates. The phenomenon is accelerated at higher temperatures and pressures.

Conductivity: The ability of an aqueous solution to carry electric current depends on the presence of ions in the solution. Conductivity is a quantitative measure which describes this ability. Solutions of inorganic ions are relatively good conductors (and exhibit high conductivity), whereas solutions of organic molecules are rather poor conductors (and exhibit low conductivity). Highly purified water is also a poor conductor. Conductivity is expressed in units of Siemen/cm (also known as mhos/cm). Conductivity measurements are frequently encountered in monitoring the performance of reverse osmosis equipment. Conductivity is temperature dependent and should be measured with a temperature-compensated meter. The usual reference temperature is 25°C. Conductivity measurements are sometimes used to estimate total dissolved solids in water. While convenient, this practice is imprecise. (See also resistivity.)

Deionization: Removal of ions from water by exchange with other ions associated with fixed charges on a resin.

Dialysis Dementia: A severe, often fatal encephalopathy which has been attributed to accumulation in the brain of aluminum from dialysate prepared with inadequately purified water and/or aluminum containing phosphate binders.

Disinfection: Disinfection is the process of killing micro-organisms, usually by one of a variety of chemical agents, such as formaldehyde and sodium hypochlorite. Disinfection lowers the number of micro-organisms without necessarily killing all those present. Although total killing of all organisms is virtually impossible, sterilization will reduce the number of organisms to a safe predetermined level. Sterilization can generally only be achieved routinely by heat, gamma irradiation, ethylene oxide, and, in certain cases, special filtration. Of these methods, only filtration is suitable for mass sterilization of water and none is suitable for sterilization of water treatment equipment used in hemodialysis facilities. However, a proprietary chemical disinfectant incorporating paracetic acid as the active ingredient has been recently qualified as a sterilant and this agent may be suitable for sterilization of certain water system components.

Empty Bed Contact Time: The empty bed contact time (EBCT) is used as a measure of how much contact occurs between particles, such as activated carbon, and water as the water flows through a bed of the particles. As the EBCT increases, the time available for the particles to adsorb solutes from the water also increases, as does the amount of solute removed from the water during its transit through the bed. EBCT is calculated from:

$$EBCT = Vm/Q$$

where Vm is the volume of particles in the bed and Q is the volumetric flow rate. A consistent set of units must be used when calculating EBCT with this equation. For example, if Vm is given in ft^3, then Q must be expressed in ft^3/min for the EBCT to have units of minutes. Values of Q can be converted from other units, such as GPM, to ft^3/min using the conversion factors.

Encephalopathy: A dysfunction of the brain (see dialysis dementia).

Endotoxin: Bacterial lipopolysaccharide, a substance released from the cell walls of gram-negative bacteria when the organism is broken down.

Feed Water: Water entering a purification system or an individual piece of purification equipment, such as an ultrafilter or reverse osmosis system.

Flocculant: A substance, used in combination with coagulants, which causes submicroscopic suspended matter (colloids) to aggregate into larger particles which can be removed by settling or filtration.

Flocculation: A practice common in municipal water treatment in which destabilized colloidal particles are formed into larger particles (flocs), usually by stirring. The floc is removed from the water by settling or filtration. The process may also incorporate the addition of such compounds as synthetic polyelectrolytes which increases the size of the flocs, thereby making them more easily removed by settling or filtration. Removal of colloids by flocculation is done in combination with coagulation.

Flow Velocity: The flow of fluid at any point in a water treatment system may be expressed quantitatively in two ways, either in terms of the volume of fluid passing the point in a given time (volumetric flow rate) or in terms of the velocity with which fluid passed the point (flow velocity). The flow velocity (V) depends on the geometry of the conduit through which the fluid flows and is related to the volumetric flow (Q) by:

$$V = Q/A$$

where A is the cross-sectional area of the conduit. As an example, the table below shows the volumetric flow rate as a function of flow velocity in PVC schedule 80 pipes of different diameters. (The values in the table are based on actual, rather than nominal, pipe diameters.) Note that for such calculations, it is essential that consistent units be employed. Thus, the term Q would be expressed as ft^3/sec and A as ft^2 to yield V as ft/sec.

PVC Schedule 80 Nominal Pipe Size	Volumetric Flow Rate (GPM *) at Specified Flow Velocities		
(in)	1.5 ft/sec	3.0 ft/sec	5.0 ft/sec
1/4	0.33	0.67	1.12
3/8	0.66	1.31	2.19
1/2	1.09	2.19	3.65
3/4	2.02	4.04	6.74
1	3.36	6.73	11.21

* GPM = gallons/minute

Fluidization: A flowing liquid impinging on a bed of particles imparts some of its momentum to each particle. The imparted momentum is in the direction of the fluid flow. The particles are held to the floor of their container by gravity and to each other by adhesive forces. If the fluid flow is upward through the bed of particles, and if the transfer of momentum from the fluid to the particles is sufficient to overcome both the gravitational and the adhesive forces, the particles become suspended, or fluidized, in the fluid stream.

Fluoride: A salt of hydrofluoric acid which may occur naturally in water supplies or be added by municipal processes for the prevention of dental cavities. Fluoride is considered toxic in the hemodialysis setting and has been implicated with renal bone disease.

Flux Rate: The rate per unit of area at which water passes through a semi-permeable membrane, such as those used for ultra filtration or reverse osmosis.

Fouling: The deposition of insoluble materials, such as bacteria, colloids, oxides and water-borne debris, onto the surface of a reverse osmosis or ultra filtration membrane. Fouling is associated with decreased flux rates and may also reduce the rejection rates of reverse osmosis membranes.

Fulvic Acids: Acidic substances which are found in humic (organic) soils and which may become suspended in water.

Fungus: A parasitic plant which produces no chlorophyll and is dependent on other life forms for its existence.

Glauconite Sand: A mineral which is frequently used in depth filters.

Grains of Hardness: Although the theoretical hardness of water is the sum of the concentrations of all metallic ions, other than the alkali metals, it is commonly expressed as the equivalent concentration of calcium carbonate in grains. Ionic concentrations can be expressed in terms of their combining potential (Eq/L), the number of moles present (mol/L), or their masses in any of several conventions. In the English system masses are expressed in terms of pounds (avoirdupois) which contain 7000 grains each. Although considered outdated in most of the world, the US water purification industry continues to express hardness in units of grains/gal expressed as calcium carbonate. Grains/gal expressed as calcium carbonate can be converted into metric units (mg/L) by multiplying the former by 17.1. Grains/gal expressed as calcium carbonate can also be converted into mEq/L of a univalent ion, such as sodium (Na^+) by multiplying by 0.342. Care must be taken in using these conversion factors to size equipment based on ion exchange principles since the ionic content of the water will depend on the type of ions present as well as their total mass.

Hardness: Hardness was originally defined as a measure of the ability of water to precipitate soaps made from fatty carboxylic acids. These "soaps" precipitated in the presence of calcium and/or magnesium ions. Today, hardness is used to describe the total concentration of calcium and magnesium, expressed as mg/L of calcium carbonate. It is generally calculated from measurement of calcium and magnesium ion concentrations, using:

$$\text{Hardness (mg } CaCO_3\text{/L)} = 2.497 \times Ca\ (mg/L) + 4.118 \times Mg\ (mg/L)$$

Heinz Body: A small, round inclusion within a red blood cell resulting from the release of hemoglobin following injury to the cell by toxic or oxidative substances, such as chloramines.

Hemolysis: The destruction of red blood cells and the subsequent release of hemoglobin into the plasma.

Hemolytic Anemia: An anemia resulting from the destruction of red blood cells.

Homogeneous membranes: See membranes.

Hydrolysis: A chemical process resulting from reactions with water; frequently used in reference to the breakdown of polymers.

Hydrophilic: Pertaining to a substance which readily absorbs water ("water-loving").

Hydrophobic: Pertaining to a substance which does not readily absorb water ("water-hating").

Hypernatremia: An elevated or excessive plasma sodium concentration.

Ion: An atom or molecule having either a positive or negative electrical charge. Positively charged ions are referred to as cations and ions having a negative charge are termed anions.

Ion Exchange: Ion exchange is based on the principle of electroneutrality, that is, charged species are stable only when they exist as balanced pairs of positive and negative charges. Ion exchange resins, the materials used to carry out the process of ion exchange, are particles which contain fixed charges on their surface. To maintain electroneutrality, each of these charges has an ion of equal and opposite charge held to it; these ions are called counter ions. The counter ions are mobile and can leave the fixed charge if some other counter ion is available to replace it. The replacement ion must be of the same charge as the initial counter ion in order to maintain electroneutrality. The initial counter ion is established by washing the resin with a concentrated solution of the desired counter ion. For example, the softener resins are cation exchangers containing carboxylic acids on their surfaces. If these resins are washed with strong NaCl solutions, the predominant cation in solution is Na^+ and it will become the counter ion. In use, the perfusing water will provide competing counter ions, such as Ca^{2+}. Because of the preference of carboxylic acids for Ca^{2+} over Na^+ in dilute solutions, the water will be depleted of Ca^{2+} in exchange for the Na^+ initially present.

Langelier Saturation Index: The precipitation of calcium and magnesium carbonates in water purification systems is a serious cause of system failure. The insolubility of these compounds are a complex function of the pH of the water, the dissolved carbon dioxide content, the carbonate content, the presence of other salts, and the temperature. The Langelier Saturation Index is a method of predicting whether or not carbonate deposits will form under given conditions. Calculation of the Langelier Saturation Index is complex and will not normally be done by hemodialysis personnel. Reverse osmosis vendors may use the index in determining the maximum recovery and rejection rates that can be obtained from a reverse osmosis system before carbonate deposits will seriously reduce water quality and recovery. It should be noted that the utility of such determinations is limited to those situations in which a softener is not used as part of the pre-treatment scheme for reverse osmosis.

Lignin: A polysaccharide found in the cell walls of plants; a breakdown product of decaying vegetation which may be present in surface water supplies.

Limulus amebocyte lysate (LAL): An extract from horseshoe crabs which forms a gel or clot in the presence of bacterial endotoxin and is widely used for quantitative measurements of these substances.

Lipopolysaccharide: See endotoxin.

Membranes: Membranes are thin films made with structures designed to provide selective transport of solutes. In general, the selectivity of a membrane is based on its ability to pass or exclude species according to their size. Membrane structures may become homogeneous or asymmetric. Homogeneous membranes have structures which are uniform in cross-section, at lease to a magnification of 100 x . Most homogeneous membranes have been developed for micro-filtration and hemodialysis.

Membranes reduce not only the flow of undesirable solutes, but also the flow of solvent. In order to minimize the reduction in solvent flow, asymmetric membranes have been developed. These membranes are made with asymmetric cross-sections, that is, they consist of two parallel layers. The resistance to flow of the skin layer, which gives the membrane its filtration selectivity, is minimized by reducing its thickness. The resistance to flow of the thicker support layer, which provides structural strength, is minimized because of its open pore structure. These different layers may be made from the same material, as in asymmetric cellulose acetate membranes, or from different materials, as in thin-film composite membranes.

Membranes used in water treatment equipment are fabricated in two forms, as flat sheets or as hollow fibers.

Methemoglobinemia: The presence in blood of methemoglobin, a substance related to normal oxyhemoglobin but having no oxygen-carrying capabilities, and induced by exposure of blood to certain toxic chemicals, such as nitrates and chloramines.

Microcytic Hypochromic Anemia: An anemia characterized by small red blood cells containing a reduced amount of hemoglobin.

Microporous: In the context of water purification, membranes having an average pore size which is between 0.1 and 1.0 microns in diameter.

Monovalent Ion: A cation or anion having a single electrical charge.

Nitrate: An anion comprised of one nitrogen atom and three oxygen atoms. Nitrates are considered toxic in hemodialysis water and are also harmful to infants when consumed orally.

Osmotic Pressure: When a solution, such as salt water, is separated from pure water by a membrane which is impermeable to the salt, a flow of water will occur from the pure water to the salt solution. The driving force for this flow is called the osmotic pressure and its magnitude depends on the number of salt particles in the solution. Note that the osmotic pressure depends on the number of particles and not on the total mass of particles. For example, 1 g/L of a small solute, such as sodium chloride, will exert a greater osmotic pressure than 1 g/L of a large solute, such as a protein. For water to flow from the salt solution to the pure water, the solution must be exposed to a hydrostatic pressure greater than its osmotic pressure. This is the principle of reverse osmosis.

Osteodystrophy: Abnormal bone development which, in renal patients, may be attributed to parathyroid gland dysfunction and is characterized by high serum phosphorus and alkaline phosphate and low serum calcium levels.

Osteomalacia: A softening of bone due to an accumulation of osteoid and reduced mineralization which may cause fractures with minimal stress.

Osteoporosis: Demineralization of bone which may cause fractures with minimal stress.

Oxidants (oxidizing agents): Chemicals which provide oxygen and accept an electron in an oxidation-reduction reaction. Free chlorine and chloramines are oxidants which are widely used for disinfection.

Ozone: An extremely active oxidizing agent which consists of three oxygen atoms. It is formed by the action of a high voltage electrical field on oxygen or air.

Parallel: In water purification, an arrangement of equipment in a side-by-side configuration such that water flow is divided and passes through one or both of these branches.

Permeate: See product water.

pH: Water (H_2O) can dissociate into two ions: hydrogen (H^+) and hydroxyl (OH). These ions can also be added to water in combination with other oppositely charged ions. Thus, a solution of hydrochloric acid added to water provides both H^+ and the chloride anion, Cl^-. The concentration of H^+ in the water is a measure of water's acidity and the concentration of OH^-, a measure of its alkalinity.

To simplify quantitation of H^+ differences, where numbers with a wide range of exponents are encountered, scientists devised a logarithmic scale called pH. The pH values range from 1 to 14. A pH value of 7 is considered neutral. Lower values of pH indicate acidic conditions and higher pH values indicate alkaline conditions. Because pH is a logarithmic scale, an increased of 1 pH unit corresponds to a ten-fold change in acidity.

Phenols: Weak aromatic acids which are indicative of industrial pollution of water supplies. When combined with chlorine, they produce an objectionable taste and odor. However, while indicative of pollution, phenols themselves are not known to be hazardous to hemodialysis patients.

Polyamide: A synthetic polymer of the nylon family used in the fabrication of reverse osmosis and ultra filtration membranes.

Polysulfone: A synthetic polymer used in the fabrication of reverse osmosis and ultra filtration membranes which are characterized by extreme thermal stability and chemical resistance.

Polyvalent Ion: A cation or anion having a multiple electrical charge.

Polyvinyl Chloride (PVC): A thermoplastic material produced by the polymerization of vinyl chloride. Used extensively in the U.S. for piping, food packaging, and injection molded plastic parts. PVC is the most common pipe material used in the U.S. for dialysis applications.

Potassium Permanganate: An oxidizing agent commonly used for the regeneration of manganese greensand iron filters and occasionally used as a disinfectant.

Pressure Drop: Expenditure of a certain amount of energy is required for a fluid to flow through any channel, such as a pipe, particle bed, or membrane. The pressure at any point is a measure of the energy content of the fluid at that point. Since some of this energy is expended in flowing to a second point downstream, the pressure at the downstream point is less than at the original point. The amount of energy expended, and hence the decrease in pressure (or pressure drop), is dependent on the flow rate and viscosity of the fluid, and the size and shape of the channel. Pressure drops are usually expressed in terms of lb/in^2 or PSI, or in

the SI system, kPa (kilopascals) or Kg/cm^2. Pressure drop is sometimes referred to colloquially as "delta P".

Product Water: The purified water stream from purification equipment, such as reverse osmosis units and ultra filters.

Pyrogenic Reactions: A physical response to the presence of endotoxin in the blood stream which is characterized by fever and occasionally, chills or shaking rigors.

Pyrolysis: A breakdown process which occurs when organic matter is subjected to elevated temperatures.

Recovery (percent recovery): A measurement applied to reverse osmosis and ultra filtration equipment which characterizes the ratio of product water to feed water flow rates. The measurement is descriptive of reverse osmosis or ultra filtration equipment as a system and not of individual membrane elements. Expressed as a percentage, recovery is defined as:

% Recovery = (Product flow rate/Feed flow rate) x 100

Rejection (percent rejection): A measure of the ability of a reverse osmosis membrane to remove salts. Expressed as a percentage, rejection is defined as:

% Rejection = (1-Product concentration/Feed concentration) x 100

Resistivity: Resistivity is a measure of the current-resisting characteristics of a substance when an electrical charge is applied (and is the reciprocal of conductivity). The standard unit of resistance is the Ohm. Because of the variable nature of water, a distance between measuring probes must be maintained if accurate measurements are desired. The almost universal standard distance for this is the centimeter, hence the "Ohm-cm". Resistivity measurements, like conductivity measurements, can be used in many ways to improve the management of a water purification system, and are commonly used to asses the quality of water produced by deionizers. Because temperature effects resistivity of water, temperature compensating devices are frequently used. These adjust the resistance meter to indicate what the water resistance would be at one temperature, usually 25°C.

ROMA: Reverse osmosis membrane assembly includes vessel housing, end caps, internal inter connecting parts, o-rings and the RO membrane.

Salt Passage Rate: A measurement of the passage of salts through a reverse osmosis membrane. Salt passage is related to rejection by:

% Salt passage = 100 - % Rejection

Scaling: In reference to reverse osmosis equipment, scaling is the precipitation of sparingly soluble salts, such as calcium carbonate, onto the surface of a membrane. Scaling is associated with decreased flux and reduced reverse osmosis rejection rates.

Sedimentation: The process by which solids are separated from water by gravity and deposited on the bottom of a container or` basin.

Semi-permeable: Descriptive of a material, such as a reverse osmosis or ultra filtration membrane, which allows the passage of some molecules and prevents the passage of others.

Series: In water purification, an arrangement of equipment in a successive or end-to-end configuration.

Silt Density Index: The silt density Index (SDI) is a measure of the ability of water to foul a membrane or plug a filter. SDI is measured using an apparatus which typically consists of an inlet pressure regulator and pressure gauge followed by a filter holder containing a 0.45 micron microporous membrane filter. Commercial test kits, complete with instructions on how to calculate the index, are available.

Sorbent: See adsorption.

Sterilization: A physical or chemical process that reduces the number of organisms to a safe predetermined level.

Superficial Velocity: The velocity of a fluid flowing through a tank containing a bed of particles is described in terms of the superficial velocity. The superficial velocity is defined as the velocity which would be achieved by the fluid if it flowed at the same volumetric flow rate through the tank when it was empty of particles. Mathematically, the superficial velocity (Vs) is given by:

$$Vs = Q/A$$

where Q is the volumetric flow rate and A is the cross-sectional area of the empty tank. For example, if an ion exchange tank has a cross-sectional area of 640 cm^2 and water is pumped through it at a rate of 64 cm^3/sec, the superficial velocity is 64/640 or 0.1 cm/sec. The actual velocity at the surface of any particle may be greater or less than the superficial velocity because flow will not be uniform throughout the bed and because the particles occupy some of the cross-section. Nevertheless, engineers have found it useful to calculate superficial velocities in this manner to aid in estimating mass transfer between a flowing liquid and the stationary surfaces of a particle. (See also Empty Bed Contact Time.)

Surge Tank: A type of pressurized water storage vessel also known as a bladder tank. Used almost exclusively on residential well water systems, they provide a small amount of pressurized water to downstream valves or equipment without requiring a pump. When installed on a piston type pump, they reduce violent pressure spikes. Surge tanks typically have large areas of stagnation that offer opportunistic bacteria a favorable environment for multiplication.

Titratable Alkalinity: When certain anions, such as carbonate (CO_3^-), are dissolved in water, they bind hydrogen ions (H^+) and thus shift the water equilibrium (see definition of pH) to produce free hydroxyl ions (OH^-). This excess concentration of OH^- is termed alkalinity. Titratable alkalinity can be measured by determining the amount of H^+ (in mEq or mmol) which must be added to water to restore the pH to 7.0, the condition of neutrality where $[H^+] = [OH^-]$.

Total Dissolved Solids (TDS): The sum of all organic, inorganic and ionic contents in a solution (excluding all dissolved gasses). Since a TDS meter cannot measure organic content of water, most TDS readings are an approximation. TDS measurements are widely used in the water and waste water industries to monitor final water quality. The TDS meter derives its' values from resistivity and conductivity measurements of the product water.

Total Organic Carbon: Organic compounds dissolved in water are characterized by their carbon content. Total organic carbon is the mass of carbon present in a water sample, excluding the carbon present as CO_2 and/or carbonates. The values are determined by catalytically

oxidizing (burning) all dissolved carbon (after CO_2/CO_3^- removal by acidification) to CO_2. The resulting CO_2 may be measured directly by infra-red absorption, or it may be reduced in a furnace with hydrogen to form methane, which is measured by flame ionization detectors.

Turbidity: Turbidity is a measure of the presence of colloidal matter in the water that remains suspended. Suspended matter in a water sample, such as clay, silt, or finely divided organic and/or inorganic material will scatter the light from an incident light beam. The extent of scattering is expressed in Jackson or Nephelometric turbidity units (JTU and NTU, respectively).

Ultra filters: A membrane based filtration system in which the pore sizes range from 0.001 to 0.1 microns.

Virus: The smallest infectious microorganism, made of RNA or DNA in a protein shell and which grow only in other, living cells.