KLM Technology Group
P. O. Box 281
Bandar Johor Bahru,
80000 Johor Bahru, Johor,
West Malaysia

Kolmetz Handbook Of Process Equipment Design

WATER TREATMENT UNIT SELECTION, SIZING AND TROUBLEHOOTING

(ENGINEERING DESIGN GUIDELINE)

Co Authors

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Author / Editor

Karl Kolmetz

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INTRODUCTION

Scope

Freshwater uses for manufacturing, food production, domestic and public needs, recreation, hydroelectric power production, and flood control. The primary sources of freshwater are rainfall in cisterns and water jars; groundwater from springs, artesian wells, and drilled or dug wells; surface water from lakes, rivers, and streams; desalinized seawater or brackish groundwater; and reclaimed wastewater.

Some water supplies may also contain disinfections by-products, inorganic chemicals, organic chemicals, and radionuclides. Specialized methods for controlling formation or removing them can also be part of water treatment.

Water treatment processes are applied to surface water sources. Typically, a water treatment plant (WTP) undergoes a series of processes which include the units presedimentation, rapid mix, flocculation, sedimentation, filtration, adsorption, and disinfection, with appropriate chemical feeds and residual treatment processes

General Design Consideration

Water may be treated differently in different communities depending on the quality of the water that enters the treatment plant. Typically, surface water requires more treatment and filtration than ground water because lakes, rivers, and streams contain more sediment and pollutants and are more likely to be contaminated than ground water.

Some water supplies may also contain disinfections by-products, inorganic chemicals, organic chemicals, and radionuclides. Specialized methods for controlling formation or removing them can also be part of water treatment.

Drinking water sources are subject to contamination and require appropriate treatment to remove disease-causing agents. Public drinking water systems use various methods of water treatment to provide safe drinking water for their communities.

Table 1. USEPA Secondary Drinking Water Standards

Contaminant	Maximum contaminant level
Aluminum	0.05 – 0.2 mg/L
Chloride	250 mg/L
Color	15 color units
Copper	1 mg/L
Corrosivity	Neither corrosive nor scale-forming
Fluoride	2.0 mg/L
Foaming agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	Three threshold odor numbers
pH	6.5-8.5
Silver	0.1 mg/L
Sulfate	250 mg/L
Total dissolved solids	500 mg/L
Zinc	5 mg/L

Even though EPA regulates and sets standards for public drinking water, many Americans use a home water treatment unit to:

- Remove specific contaminants
- Take extra precautions because a household member has a compromised immune system
- Improve the taste of drinking water

A major water treatment plant design effort now and in the future will be devoted to retrofit rather than new design. In developing a water treatment train, the multiple treatment capabilities of the different methods and materials should all be considered to both simplify and reduce the cost of facility construction and operation. A treatment train should not be considered simply as a sequence of process steps. In essence, a treatment train encompasses a combination of processes that, when integrated, achieve the desired water quality changes and improvements. Multiple capabilities of the different options in table below.

Table 2. Most Common Drinking Water Treatment Processes

Water quality parameter	Process components
Turbidity-particulate reduction	• Filtration • Rapid sand---conventional (Coagulation, Flocculation) • Clarification (Plain settling, Plate settlers, Solids contact, Dissolved air flotation, Filtration) • Rapid sand--direct mode (Coagulation, flocculation, Filtration, Slow sand filtration) • Diatomaceous earth filtration • Membrane filtration (Ultrafiltration, Nanofiltration, Reverse osmosis)
Bacteria, viruses, cyst removal	• Partial reduction--filtration (above) • Inactivation---disinfection (Chlorine, Chloramine, Chlorine dioxide, Ozone, UV)
Color	• Coagulation/rapid sand filtration • Adsorption (Granular activated carbon (GAC) media, Powdered activated carbon (PAC) addition, Synthetic resins/ion exchange) • Oxidation (Ozone, Chlorine, Potassium permanganate,

	Chlorine dioxide) • Nanofiltration
Taste and color control	• Oxidation (Ozone, Chlorine, Chlorine dioxide, Potassium permanganate) • BAC adsorption
Volatile organic reduction	• Air stripping (GAC adsorption, Combination of the above)
Disinfection by-product control	• Precursor reduction • Enhanced coagulation • GAC adsorption • Biologically activated carbon (BAC) media--preozonation • Nanofiltration • By-product removal (GAC adsorption, Air stripping partial)
Iron, manganese reduction/sequestering	• Filtration of precipitators formed by preoxidation • Sand and/or anthracite media • Green sand media • Proprietary media • Polyphosphate sequestering agent
Hardness reduction	• Lime softening (Ion exchange, Nanofiltration)
Inorganic, organic chemical reduction	• Ion exchange • Biologically activated carbon media • Adsorption • Reverse osmosis
Corrosion control	• Post-treatment (pH adjustment, Inhibitors)

Most Common Drinking Water Treatment Processes, are grouped in table below

Treatment measure	Quality improvement
Filtration (all)	• Particulate reduction • Bacteria, virus, cyst reduction
Coagulation, rapid sand filtration (additional)	• Precursors and by-product reduction • Color removal
Oxidation	• Pathogen inactivation • Partial organics reductions • Non- to biodegradable organics • Color removal • Taste and odor control • Iron and manganese reduction
GAC media	• Rapid sand filter particulate removal • Color removal • Precursor and by-product reduction • Additional reduction with preoxidation • Taste and odor control

Many systems must address the reduction or removal of less common or special contaminants In very general terms, treatment methods that may be considered for contaminants in the three categories mentioned above are as follows:

- *Inorganics.* Oxidation or chemical reaction to produce *innocuous* compounds or precipitates and/or ion-exchange following filtration.
- *Synthetic organics.* Herbicides and pesticides, most of which may be removed in GAC columns. Some contaminants may be preconditioned by strong oxidants.
- *Volatile organics.* Removed by air stripping and/or in GAC columns.

The most common types of household water treatment systems consist of:

- Filtration Systems

  A water filter is a device which removes impurities from water by means of a physical barrier, chemical, and/or biological process. Filtration of contaminants depends highly on the amount of contaminant, size of the contaminant particle, and the charge of the contaminant particle. Depending on the household's water needs, pretreatment before filtration may include the addition of coagulants and powdered activated carbon, adjustments in pH or chlorine concentration levels, and other pretreatment processes in order to protect the filter's membrane surface.

  Filtration types and solids loading capabilities may be categorized in general terms as follows:

  - Direct, slow sand, and diatomaceous earth filtration may be feasible for waters low in turbidity (5 ntu or less) and organic matter. Potential supply sources must also be stable, of high quality, and not subject to significant algal blooms or other major water quality changes.
  - Conventional clarification and rapid sand filter plants would be needed for source waters higher in turbidity and organic matter content, and those where higher coagulant dosages may be required.
  - The limitations of membrane filtration are more difficult to define. Closed-vessel applications would more likely be limited to source waters of higher quality. Immersed membranes can handle higher solids loading including that generated in precipitation and coagulation to improve solids removal.

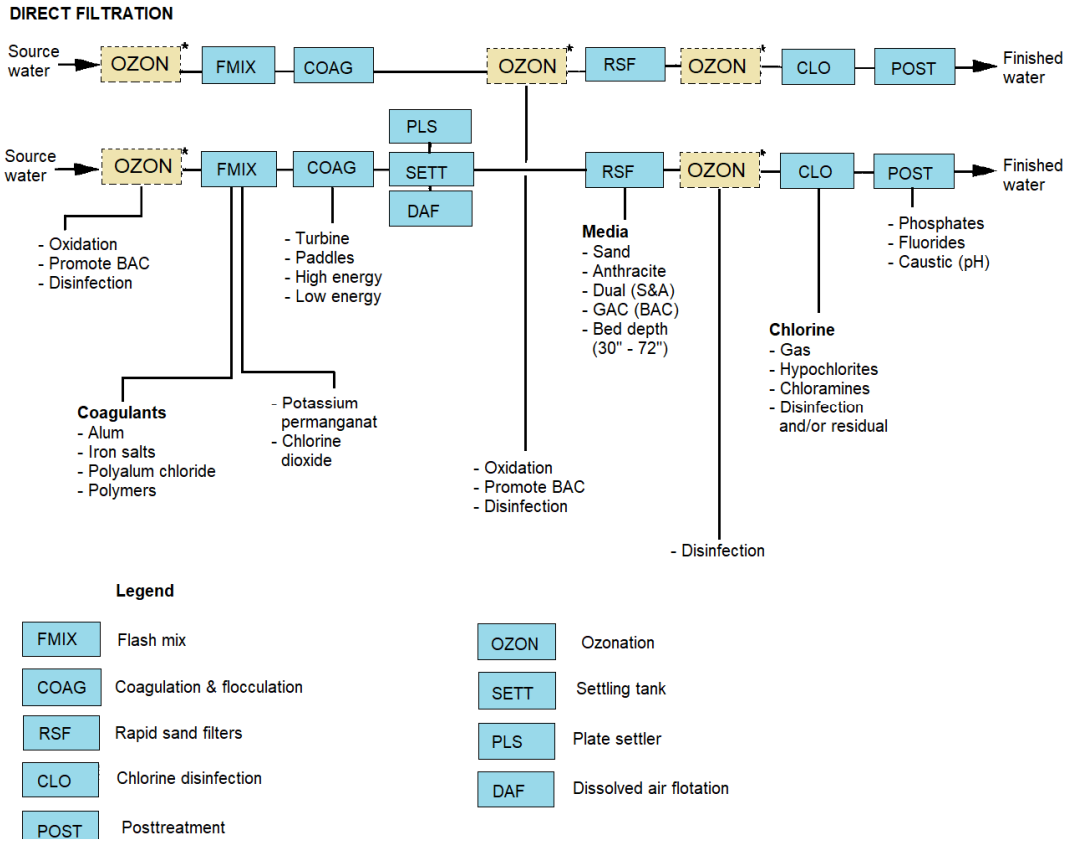

Figure 1. Baseline filtration options

- Water Softeners

  A water softener is a device that reduces the hardness of the water. A water softener typically uses sodium or potassium ions to replace calcium and magnesium ions, the ions that create “hardness.” Water Softeners use ion exchange technology for chemical or ion removal to reduce the amount of hardness (calcium, magnesium) in the water; they can also be designed to remove iron and manganese, heavy metals, some radioactivity, nitrates, arsenic, chromium, selenium, and sulfate. They do not protect against protozoa, bacteria, and viruses.

- Distillation Systems

  Distillation is a process in which impure water is boiled and the steam is collected and condensed in a separate container, leaving many of the solid contaminants behind. Distillation Systems have a very high effectiveness in removing protozoa (Cryptosporidium, Giardia), baceria (Campylobacter, Salmonella, Shigella, E. coli), viruses (Enteric, Hepatitis A, Norovirus, Rotavirus) and remove common chemical contaminants (including arsenic, barium, cadmium, chromium, lead, nitrate, sodium, sulfate, and many organic chemicals)

- Disinfection
  Disinfection is a physical or chemical process in which pathogenic microorganisms are deactivated or killed. Examples of chemical disinfectants are chlorine, chlorine dioxide, and ozone. Examples of physical disinfectants include ultraviolet light, electronic radiation, and heat.

In a conventional water treatment plant (WTP), raw water undergoes a series of processes which include the units presedimentation, rapid mix, flocculation, sedimentation, filtration, and disinfection, with appropriate chemical feeds and residual treatment processes.

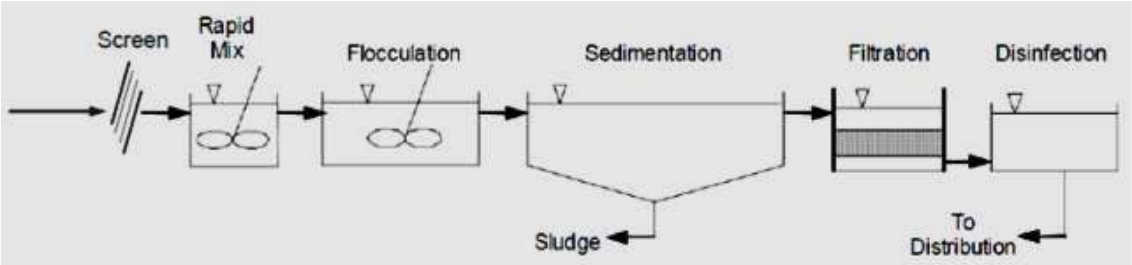

Figure 2. WTP layout

- Intake and screening
- Coagulation (rapid mix)
- Flocculation
- Clarification/sedimentation
- Filtration
- Chlorination/disinfection
- Residual management

The WTP to be designed will include a review of alternate treatment technologies that can treat dieldrin and TOC

- Ozonation (a more advanced disinfection method)
- Active Carbon Filtration (a more advanced adsorption filtration method)
- Nanofiltration (a Reverse Osmosis method)

Water may be treated differently in different communities depending on the quality of the water that enters the treatment plant. Typically, surface water requires more treatment and filtration than ground water because lakes, rivers, and streams contain more sediment and pollutants and are more likely to be contaminated than ground water. Some water supplies may also contain disinfections by-products, inorganic chemicals, organic chemicals, and radionuclides. Specialized methods for controlling formation or removing them can also be part of water treatment.

Consideration of viable options would also be critical to provide a flexible facility arrangement in which additions and modifications may be made for future treatment requirements. These other issues may include the following (not necessarily in order of importance):

- Construction cost
- Annual operation costs
- Site area required
- Complexity of operation (required capability of operating staff and laboratory monitoring)
- Operation risk (most common causes, if any, of treatment failure)
- Flexibility of plant arrangement for future changes
- Waste disposal options

DEFINITION

Absorption - The process in which one substance penetrates into the body of another substance, termed the absorbent. An example is the absorption of water into soil.

Acidity - The quantitative capacity of a water or water solution to neutralize an alkali or base. It is usually measured by titration with a standard solution of sodium hydroxide, and expressed in ppm or mg/L of its calcium carbonate equivalent.

Activated Alumina - A medium made by treating aluminum ore so that it becomes porous and highly adsorptive. Activated alumina will remove several contaminants including fluoride, arsenic, and selenium. It requires periodic cleaning with a regenerant such as alum, acid and/or caustic.

Activated Carbon - A water treatment medium, found in block, granulated, or powdered form, which is produced by heating carbonaceous materials, such as coal, wood, or coconut shells, in the absence of air, creating a highly porous adsorbent material. Activated carbon is commonly used for dechlorination, organic chemical reduction and radon reduction, and is recognized by the US EPA as the best available technology for reduction of organic chemicals from drinking water.

Activated Silica - A negatively charged colloidal substance generally formed by combining a dilute sodium silicate solution with a dilute acidic solution (or other activant). Generally used as a coagulant aid.

Activated Sludge - a suspended growth process for removing organic matter from sewage by saturating it with air and microorganisms that can break down the organic matter.

Adsorbate - Any substance that is or can be adsorbed. The liquid, gas or solid substance which is adsorbed as molecules, atoms, or ions.

Adsorbent - A water treatment medium, usually solid, capable of the adsorption of liquids, gases, and/or suspended matter. Activated alumina and activated carbon are common adsorbents used in water processing.

Adsorption - The physical process occurring when liquids, gases, or suspended matters adhere to the surfaces of, or in the pores of, an adsorbent media such as

activated carbon. Adsorption is a physical process which occurs without chemical reaction.

Aeration - The process in which air is brought into intimate contact with water, often by spraying water through air, or by bubbling air through water. Aeration may be used to add oxygen to the water for the oxidation of matter such as iron, or to cause the release of dissolved gases such as carbon dioxide or hydrogen sulfide from the water.

Aeration Tank - a chamber for injecting air and oxygen into water.

Alkali - A substance which creates a bitter taste and a slippery feel when dissolved in water and will turn red litmus paper blue. An alkali has a pH greater than seven and is the opposite of an acid. Highly alkaline waters tend to cause drying of the skin. Alkalis may include the soluble hydroxide, carbonate, and bicarbonate salts of calcium, magnesium, potassium, and sodium. A hydroxide alkali may also be called a base.

Alum - The common name for aluminum sulfate [$Al_2(SO_4)_3$ $14H_2O$] which is often used as a coagulant in water treatment.

Anion - A negatively charged ion in solution, such as bicarbonate, chloride, or sulfate. An anion [such as chloride (Cl-)] may result from the dissociation of a salt, acid, or alkali.

Anion Exchange - An ion exchange process in which anions in solution are exchanged for other anions from an ion exchanger. In demineralization, for example, bicarbonate, chloride and sulfate anions are removed from solution in exchange for a chemically equivalent number of hydroxide anions from the anion exchange resin.

Anode - The positive pole of an electrolytic system. The metal which goes into solution in a galvanic cell. Anodes of metals such as magnesium and zinc are sometimes installed in water heaters or other tanks to deliberately establish galvanic cells to control corrosion of the tank through the sacrifice of the anode.

Automatic water softener (or Automatic Filter)- A water softener (or filter) that is equipped with a clock timer, meter, or sensor which automatically initiates the backwash and/or regeneration process at the preset intervals of time. A predetermined number of gallons of water usage or as determined by a sensor. All operations, including bypass of treated or untreated water (depending upon design),

backwashing, brining, rinsing, and returning the unit to service are performed automatically.

Back Pressure - Pressure which creates resistance against the flow of water.

Backwash - The upflow or counter-current flow of water through a filter or ion-exchange medium, lifting the mineral bed and flushing away to the drain the particles of foreign matter that have been filtered from the water supply during the service cycle.

Bacteria - Unicellular microorganisms which typically reproduce by cell division. Although usually classed as plants, bacteria contain no chlorophyll. Many different types of bacterial organisms are often found in drinking water. Most municipally treated water is essentially bacteria free due to the addition of chlorine. Some forms of cyst type viruses have a degree of immunity to chlorine due to the cocoon-like shell around the virus. These types of organisms such as Giardia Cyst, Giardia Lamblia, and Cryptosporidium have a physical size of three to seven microns and can be effectively removed by sub-micron filtration. Some bacteria are helpful to man, others harmful.

Bar Screen - composed of parallel bars that remove larger objects from wastewater

Base - An alkali that releases hydroxyl ions when dissolved in water. Bases reset with acids to form a neutral salt and water. In general they taste bitter rather than sour, and feel slippery and reverse the color changes produced by acids in indicators. For example, they turn litmus paper blue.

Batch Operation - The utilization of ion exchange resins to treat a solution in a container wherein the removal of ions is accomplished by agitation of the solution and subsequent decanting of the treated liquid.

BOD (Biochemical Oxygen Demand) - a measure of oxygen consumed in biological processes that break down organic matter in water.

Brackish Water - Water containing bacteria between 1.000 and 15,000 ppm of dissolved solids.

Brine - A strong solution of salt(s), such as the sodium chloride or potassium brine used in the regeneration of ion exchange water softeners, but also applied to the mixed sodium, calcium and magnesium chloride waste solution from regeneration.

Buffer - A chemical which causes a solution to resist changes in pH, or to shift the pH to a specific value.

Bypass - A connection or a valve system that allows untreated water to flow to a water system while a softener or filter is being regenerated, backwashed or serviced; also applied to a special water line installed to provide untreated water to a particular tap, such as a sill cock.

Caustic Soda - The common name for sodium hydroxide and often used as a regenerant of anion resin in deionization systems.

Channeling - The flow of water or regenerant taking the line of least resistance through a media bed, as opposed to the usual distributed flow through all passages of the bed. Channeling may be due to fouling of the bed, poor distribution design, low flow rates, or insufficient backwash.

Chloramines - Chemical complexes formed from the reaction between ammonia and chlorine being used to disinfect many municipal water supplies. Does not combine with organics to form triclomethanes.

Chlorinator - A mechanical device specifically designed to feed chlorine gas or pellets, or solutions such as hypochlorides, into a water supply in proportion to the flow of water.

Chlorine - Widely used in the disinfection of water and as an oxidizing agent for organic matter, iron, hydrogen sulfide, etc. It is available as a gas, as a liquid in sodium, hypochlorite, or as a solid in calcium hypochlorite. In water chlorine reacts with organics to form trihalomethanes (THM) which can cause cancer.

Clarifier - known as a settling tank, removes solids from wastewater by gravity settling or by coagulation.

Coagulant - A material such as alum, which will form a gelatinous precipitate in water, and gather finely divided particles into larger ones which can then be removed by settling and/or filtration.

Coagulant chemicals - inorganic or organic chemicals that, when added to water at an optimum dosage, cause particle destabilization. Most coagulants are cationic when dissolved in water and include chemicals such as alum, ferric salts, lime, and cationic organic polymers.

Coagulation - the process in which chemicals are added to water, causing a reduction of the forces tending to keep particles apart. Particles in source water are in a stable condition

Contact Time - The actual time which water remains in contact with an oxidizer, regenerant, or water conditioning media within a water treatment system. The amount of contact time determines the effectiveness of the system. Also called retention time.

Contamination - The addition of any physical, chemical, biological or radiological substance to water which reduces the value of the water, or interferes with its intended use.

Degassing - The removal of dissolved gasses from water such as carbon dioxide, methane, hydrogen sulfide, and oxygen. This can by done by subjecting the water to below atmospheric pressure, or by passing air through the water at atmospheric pressure.

Desalination - The removal of dissolved inorganic solids (salts) from a solution such as water to make it free of dissolved salts. Typically accomplished by reverse osmosis, distillation, or electrodialysis.

Diffused Air - a technique by which air under pressure is forced into sewage in an aeration tank. The air is pumped into the tank through a perforated pipe and moves as bubbles through the sewage.

Direct filtration - a treatment train that includes coagulation, flocculation, and filtration, but excludes a separate sedimentation process. With direct filtration, all suspended solids are removed by filtration.

Dissolved Oxygen (DO) - the amount of free oxygen in solution in water, or wastewater effluent. Adequate concentrations of dissolved oxygen are necessary for fish and other aquatic organisms to live and to prevent offensive odors.

Drinking Water Standards - National Primary Drinking Water Standards are established by the U.S. Environmental Protection Agency (EPA) are health related and establish the maximum contaminant levels (MCL's) for regulated substances in drinking water. A MCL is the highest permissible level of a contaminant allowed in water delivered to the consumer's tap. These standards relate to public water systems. National Secondary Drinking Water Standards are also issued by the EPA

and pertain to aesthetic characteristics of water and are recommended only. Drinking Water Standards

Efficiency - The effectiveness of the operational performance of an ion exchanger. Efficiency in the adsorption of ions is expressed as the quantity of regenerant required to effect the removal of a specified unit weight of adsorbed material, e.g., pounds of acid per kilogram of salt removed.

Effluent - The outflow of a water treatment device. Sometimes used to mean the product water of a given water conditioning device or system.

Electrodialysis - A dialysis process using semi-permeable membranes.

Electrolyte - A chemical compound which dissociates or ionizes in water to produce a solution which will conduct an electric current. Could be an acid, base, or salt.

Exhaustion - The state of the adsorbent such as activated carbon, a water softener, or a deionizer that is no longer capable of the removal of a specific pollutant or of useful ion exchange. The exhaustion point is determined arbitrarily in terms of: (a) the presence or increase of an adsorbent contaminant as chlorine; (b) a value in parts per million of ions in the effluent solution; (c) the reduction in quality of the effluent water determined by a conductivity bridge which measures the resistance of the water to the flow of an electric current.

Filtration - The process of passing water through a porous substance to remove solids in suspension. Available as media beds in tanks or as cartridge type devices

Fines - Smaller than the specified size or particles of ion exchange or filtration materials. An excess of fines can create undesirable pressure drop in the system.

Floc - a clump of solids formed in sewage by biological or chemical action.

Flocculants - Materials added to water which can cause gelatinous clouds of precipitate to enclose fine particles of foreign material in order to settle or filter them from the water.

Flocculation - the agglomeration of small particles and colloids to form settleable or filterable particles (flocs). Flocculation begins immediately after destabilization in the zone of decaying mixing energy following rapid mixing, or as a result of the turbulence of transporting flow.

Flocculation aids - chemicals used to assist in forming larger, denser particles that can be more easily removed by sedimentation or filtration. Cationic, anionic, or nonionic polymers are most often used in dosages of less than 1.0 mgFL.

Greensand - A natural mineral, primarily composed of complex silicates, which possess ion exchange properties. Greensand was the original material used in domestic and commercial water softeners and is the base product in the production of manganese greensand.

Hard water - Water with a total hardness of one grain per gallon or more, as calcium carbonate equivalent.

Hardness - A characteristic of natural water due to the presence of dissolved calcium and magnesium; water hardness is responsible for most scale formation in pipes and water heaters, and forms insoluble "curd" when it reacts with soaps. Hardness is usually expressed in grains per gallon, parts per million, or milligrams per liter, all as calcium carbonate equivalent. Temporary hardness, caused by the presence of magnesium of calcium bicarbonate, is so called because it may be removed by boiling the water to convert the bicarbonates to the insoluble carbonates. Calcium sulfate, magnesium sulfate, and the chlorides of these two metals cause permanent hardness.

Hardness Leakage - The presence in the effluent of the type of ions present in the water being treated. Leakage may be caused by incomplete regeneration, channeling, excessive service water, low temperature, high concentrations of sodium or interfering TDS in the feedwater.

Head loss - The reduction on liquid pressure associated with the passage of a solution through a bed of exchange material; a measure of the resistance of a resin bed to the glow of the liquid passing through it.

Hot Lime (soda softening)- Partially softens water by adding lime and soda ash at a water temperature of about 212 degrees Fahrenheit. It chemically precipitates calcium, magnesium, iron, and silica. It also drives away carbon dioxide.

ion Exchange - A reversible process in which ions are released from an insoluble permanent material in exchange for other ions in a surrounding solution; the direction of the exchange depends upon the affinities of the ion exchanger for the ions present and the concentration of the ions in the solution. The ion exchanger media is an insoluble permanent solid medium. for a product offering.

Lime Softening - Often used by municipalities for partial reduction of water hardness. After the addition of baked lime, soda ash is added to form an insoluble precipitate which is filtered from the water. This method leaves five or more grains of hardness.

Low-pressure membranes - hollow-fiber membrane systems that provide micro- or ultrafiltration. These systems have pore sizes that are 10 to 100 times smaller than those of primary protozoa of concern (i.e., Cryptosporidium and Giardia lamblia). The membrane is a thin layer of polymer capable of separating materials based on size and chemical properties. These membrane systems typically operate in the range of - 12 psi vacuum to 40 psi pressure.

Membrane – A selective barrier that allows the passage of certain constituents and retains other constituents.

Mineral - A term applied to inorganic substances, such as rocks and similar matter found in the earth's strata, as opposed to organic substances such as plant and animal matter. Minerals normally have definite chemical composition and crystal structure. The term is also applied to matter derived from minerals, such as the inorganic ions found in water. The term has been incorrectly applied to ion exchangers, even though most of the modern materials are organic ion exchange resins.

Mixing - commonly referred to as flash mixing, rapid mixing, or initial mixing. The purpose of rapid mixing is to provide a uniform dispersion of coagulant chemical throughout the influent water.

Nanofiltration - A membrane process that treats water between reverse osmosis and ultrafiltration the filtration/separation spectrum. It can remove particles in the 300 to 1,000 molecular weight range such as humic acid and organic color found in water. Nanofiltration may be used for selective removal of hardness ions.

Osmosis - A process of diffusion of a solvent such as water through a semi-permeable membrane which will transmit the solvent but impede most dissolved substances. The normal flow of solvent is from the dilute solution to the concentrated solution. Osmosis causes the stronger solution to become more diluted and tends to equalize the opposing solutions.

Osmotic Pressure - The pressure and potential energy difference that exists between solutions on either side of a semi-permeable membrane. This pressure is

caused by the tendency of water to flow in osmosis. Every 100 ppm (mg/L) of TDS produces about one pound per square inch of osmotic pressure. Osmotic pressure must first be overcome by water pressure in the reverse osmosis process.

Oxidation – process that involves aerobic bacteria breaking down organic matter and oxygen combining with chemicals in sewage.

Ozone - An unstable form of oxygen (03), which can be generated by sending a high voltage electrical discharge through air or regular oxygen. It is a strong oxidizing agent and has been used in water conditioning as a disinfectant. It can be also produced by some types of ultraviolet lamps and during lightning storms.

Permeability – Permeation of a gas or vapor through solid substance.

Powdered Activated Carbon - Activated carbon in particle sizes predominantly smaller than 80 mesh.

Reverse osmosis (RO) - a water purification technology that uses a semipermeable membrane. This membrane technology is not properly a filtration method. In reverse osmosis, an applied pressure is used to overcome osmotic pressure, a colligative property, that is driven by chemical potential, a thermodynamic parameter. Reverse osmosis can remove many types of molecules and ions from solutions, and is used in both industrial processes and the production of potable water.

Sand Filter - A treatment device or structure for removing solid or colloidal material of a type that cannot be removed by sedimentation. Such filters can be gravity rapid-rate or enclosed pressure type

Sedimentation Tanks - wastewater treatment tanks in which floating wastes are skimmed off and settled solids are removed for disposal.

Solids contact clarifiers - proprietary devices that combine rapid mixing, flocculation, and sedimentation in one unit. These units provide separate coagulation and flocculation zones and are designed to cause contact between newly formed floc and settled solids.

Suspended Solids - the small particles suspended in water or wastewater.

Total Dissolved Solids - The weight of solids per unit volume of water which are in true solution, usually determined by the evaporation of a measured volume of filtered water, and determination of the residue weight. TDS is expressed as ppm per unit

volume of water. An electrical conductivity test provides only an estimate of the TDS since non-conductive substances cannot be measured by electrical means.

Ultrafiltration - A membrane type system that removes small colloids and large molecules from solutions. Ultrafiltration removes particles in size range between 0.002 to 0.1 micron range. The process falls between reverse osmosis and microfiltration as far as the size of particles removed is concerned.

NOMENCLATURE

a	Opening between bars, m
A_{across}	Area of channel, m²
A_{floc}	Area of flocculation tank, m²
$A_{opening}$	Area opening, m²
A_{screen}	Area of screen, m²
b	Thickness of the bars, m
D/W $_{ratio}$	Depth diameter ratio
d_s	Diameter of particles, mm
G	mean velocity gradient, /s
G_s	Specific gravity of particles
G_w	Specific gravity of water, m³/s
h_l	headloss through a clean coarse screen, mm
L/W_{ratio}	ratio length width ratio
$L_{channel}$	length of the channel, m
L_{screen}	length of the screen, m
n	Number of bars
Q	Annual Average Daily Flow, m³/s
$Q_{clarification}$	Flow rate per tank, m³/min
Q_{design}	Design Flow Rate, m³/s
Q_{1flash}	Discahrge one flash mixers, m³/min
V	clarification Volume per tank, m³
v_a	Velocity in approach channel, m/s
V_{flash}	Volume of flash mixers, m³
V_{floc}	Volume per tank, m³
$V_{floctotal}$	Volume total, m³
v_{sc}	velocity through the screen, m/s
$W_{channel}$	width of channel, m
W_{screen}	width of screen, m
θ	Angel inclination
μ	dynamic viscosity, Pa/s
$\rho_{coagulant}$	Density of coagulant, kg/m³

REFERENCES

1. American Water Works Association and American Society of Civil Engineers. Water Treatment Plant Design. McGraw-Hill. 2005
2. Frank R. Spellman. Handbook of Water and Wastewater Treatment Plant Operations. Taylor & Francis Group, LLC. 2014
3. Frank R. Spellman. Water Treatment Operations Math Concepts and Calculations. Taylor & Francis Group, LLC. 2014
4. Nicholas P. Cheremisinoff. Handbook Of Water And Wastewater Treatment Technologies. Butterworth-Heinemann. 2002
5. K Kolmetz et al, Kolmetz Handbook of Process Equipment Design, KLM Technology Group, Membrane Technology Engineering Design Guideline. 2014
6. K Kolmetz et al, Kolmetz Handbook of Process Equipment Design, KLM Technology Group, Waste Water Treatment Engineering Design Guideline. 2014
7. K Kolmetz et al, Kolmetz Handbook of Process Equipment Design, KLM Technology Group, Fluid Flow Piping Hydraulics Fluid Flow Line Sizing and Material Selection Engineering Design Guidline, 2018