Water treatment

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Components of water treatment and waste treatment systems

Water supply systems consist of :

(1) Collection or intake works .

(2) Purification or treatment works.

(3) Transmission works .

(4) Distribution works.

Water systems can be supplied by surface water , ground water , or a combination of both.

Treatment facilities usually include the ability to :

1- Improve the physical characterestics of the water with regard to odor , taste , color , turbidity and hardness .

2- Remove or limit the concentration of toxic and nontoxic inorganic contaminations.

Toxic contaminants include Arsenic (As) , Barium (Ba) , Cadmium (Cd) , Chromium (Cr) , Fluoride (F) , Lead (Pb) , Mercury (Hg) , Nitrate (NO_3) , Selenium (Se) , and Silver (Ag) .

Treatment facilities usually include the ability to :

3- Remove or limit the concentration of toxic or carcinogenic :

Endrin , Lindane , Toxaphene ,

2,4-D, 5-TP (Silvex) , Methoxychlor , Trichloroethylene , Tetrachloroethylene , Carbontetrachloride , 1,1,1-Trichloroethane , Vinyl chloride , 1,2-Dichloroethane , Benzene , 1,1 Dichloroethane , and p-Dichlorobezene .

Treatment facilities usually include the ability to :

4- Eliminate disease-producing organisms .

5- Remove radioactive contaminants .

6- Add chemicals , such as Fluoride , that contribute to health .

Transmission components of a water supply system carry the water from the source to the treatment facilities and then to the community .

Treatment facilities usually include the ability to :

- The last stage of the water supply system is the distribution network in which water is supplied to individual consumers via a piping and reservoir system.
- Another type of community water treatment facility is required to treat wastewater before it is discharged to a surface water body .

Treatment facilities usually include the ability to :

- Wastewater systems serving communities collect , treat , and dispose of the water used for domestic or industrial purposes in the community .
- Treatment facilities for wastewater generally include the ability to remove putrescible material , stabilize degradable substances , remove organics , remove nutrients , and destroy disease-producing organisms .

Treatment facilities usually include the ability to :

- The ability of an indiviual treatment facility to accomplish these tasks effectively varies enormously , depending on plant design , maintenance , operator training , and the occurance of natural disasters such as floods and earthquakes .

Treatment technologies appropriate for meeting drinking water regulations :

1- Removal of inorganic substances .

2- Coagulation :

Chemical coagulation occurs when floc-forming chemicals are added to water to destabilize suspended or colloidal solids .

Treatment technologies appropriate for meeting drinking water regulations :

- Colloidal material won't settle out , because the particles have negative charges on their surfaces and thereby repel other particles.
- In this condition , the particles can't collide to form larger particles , called flocs , which would settle.

Water and waste treatment processes

Process	General Use or Capability	Advantages	Disadvantages
Coagulation, sedimentation, and filtration	Reduction in suspended solids by 90-98%	Low cost Simplicity	Large area required Does not remove dissolved salts or dissolved organics
Softening	Reduction in hardness level by 95-100%	Relatively low in cost for low hardness waters Simplicity	Requires frequent regeneration Chemical regeneration need increases linearly with hardness Does not remove dissolved organics
Ion exchange	Reduction of dissolved salts by 95-100%	Can reach very low levels of salinity	Does not remove dissolved organics Requires regeneration chemical which adds to waste loading
Biological treatment	Reduction of organic loading by 50-90%	Low in cost	Subject to upsets and variations Cannot remove more than 90% of organic loading which is subject to biological degradation
Carbon columns	Reduction of adsorbable organic loading by 95-100%	Effective way to remove small quantities of organics	Relatively expensive regeneration Removes only specific organics
Evaporation	Removal of dissolved solids and suspended solids	Well demonstrated Can handle wide range of applications	High energy use
Reverse osmosis	Reduction of nearly all contaminants by 90-95%	Simple Low energy utilization	Membrane subject to fouling or deterioration if not properly operated Not effective on very low molecular weight organics Generally requires some form of pretreatment Limited chemical compatibility

Treatment technologies appropriate for meeting drinking water regulations :

- By adding coagulants , the negative forces can be neutralized so that the particles become unstable , collide , and then settle .

3- Lime softening :

Lime softening reduces hardness by applying hydrated lime ($Ca(OH)_2$) to water to precipetate Calcium Carbonate ($CaCO_3$) , Magnesium Hydroxide ($Mg(OH)_2$), or both .

Treatment technologies appropriate for meeting drinking water regulations

- Calcium and Magnesium hardness and Carbon dioxide are precipitated as Calcium carbonate , but most waters contain alkalinity in the bicarbonate form.
- Thus , in the presence of Carbon dioxide (CO_2) is almost always present in groundwater.

Treatment technologies appropriate for meeting drinking water regulations

- The precipitation of Calcium carbonate and Magnesium hydroxide necessiates the conversion of Carbon dioxide and bicarbonate

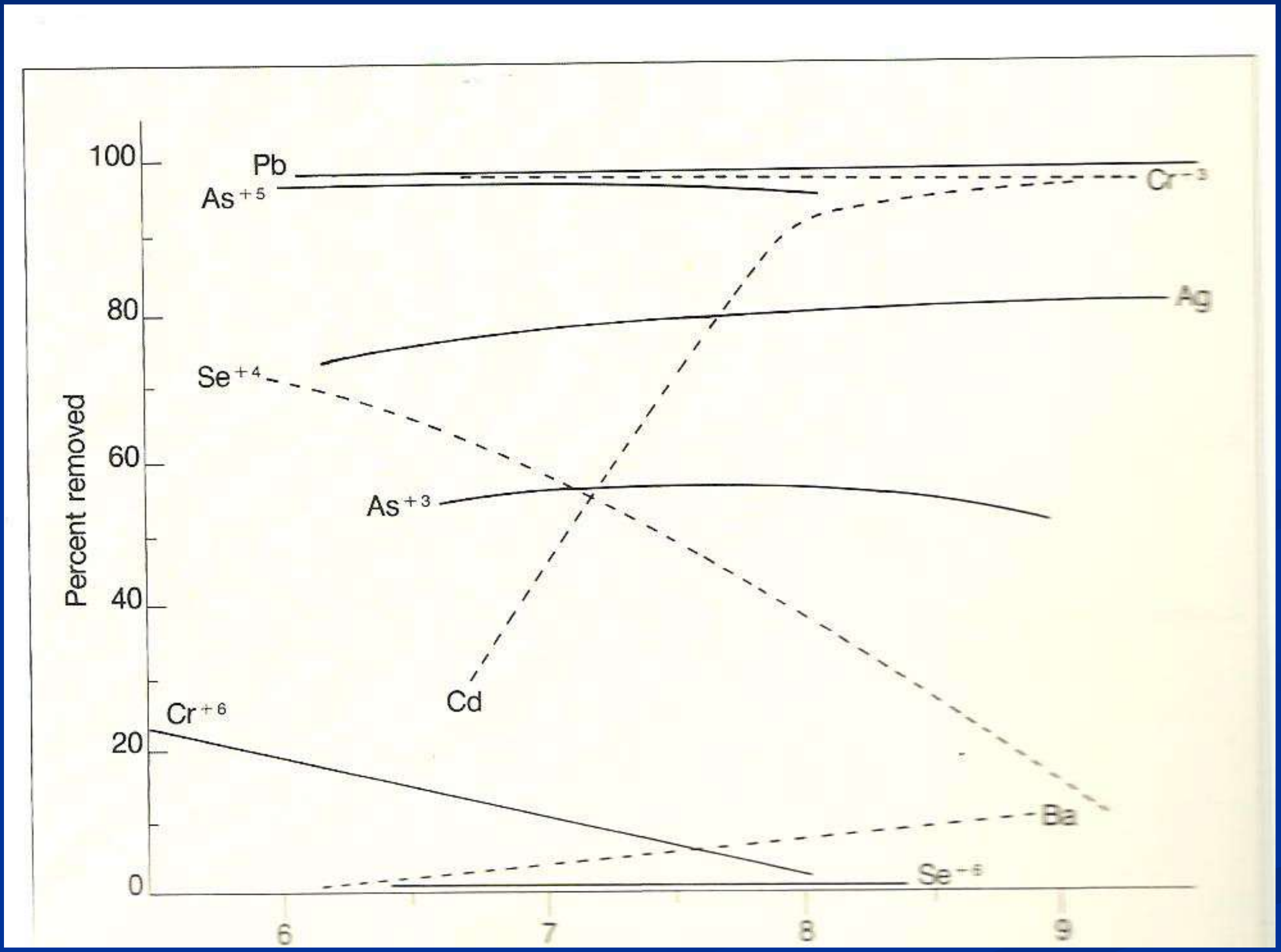
  (HCO_3) to Carbonate .

$$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2CaCO_3 + 2H_2O$$

$$CO_2 + Ca(OH)_2 \longrightarrow CaCO_3 + H_2O$$

$$\mathbf{Mg(HCO_3)_2 + 2\ Ca(OH)_2 \longrightarrow Mg(OH)_2 + 2\ CaCO_3 + 2H_2O}$$

Removal of inorganic contaminants by iron coagulation



Treatment technologies appropriate for meeting drinking water regulations

- After coagulation or lime softening , inorganic materials are removed from water through sedimentation and filteration.

4- Ion Exchange :

Water is passed through a medium .

Usually a synthetic cation-exchange resin .

Treatment technologies appropriate for meeting drinking water regulations

- Sodium ions are exchanged for the contaminant ions.
- When all sodium ions are used , a brine solution is passed through the resin to regenerate it – that is , remove the Calcium , Magnesium , Iron , or other ions and replace them with Sodium ions .

Most effective treatment methods for removal of inorganic contaminants

Contaminant	Most Effective Methods
Arsenic	Ferric sulfate coagulation, pH 6-8
As^{+3}	Alum coagulation, pH 6-7
	Excess lime softening
	Oxidation before treatment required
As^{+5}	Ferric sulfate coagulation, pH 6-8
	Alum coagulation, pH 6-7
	Excess lime softening
Barium (Ba)	Lime softening, pH 10-11
	Ion exchange
Cadmium	Ferric sulfate coagulation, above pH 8
Cd	Lime softening
	Excess lime softening
Chromium	Ferric sulfate coagulation, pH 6-9
Cr^{+3}	Alum coagulation, pH 7-9
	Excess lime softening
Cr^{+6}	Ferrous sulfate coagulation, pH 7-9.5
Fluoride (F)	Ion exchange with activated-alumina or bone-char media
Lead (Pb)	Ferric sulfate coagulation, pH 6-9
	Alum coagulation, pH 6-9
	Lime softening
	Excess lime softening
Mercury (Hg)	
Inorganic	Ferric sulfate coagulation, pH 7-8
Organic	Granular activated carbon
Nitrate (NO_3)	Ion exchange
Selenium	Ferric sulfate coagulation, pH 6-7
Se^{+4}	Ion exchange
	Reverse osmosis
Se^{+6}	Ion exchange
	Reverse osmosis
Silver (Ag)	Ferric sulfate coagulation, pH 7-9
	Alum coagulation, pH 6-8
	Lime softening
	Excess lime softening

Treatment technologies appropriate for meeting drinking water regulations

5- Reverse osmosis :

Osmosis is the spontaneous process in which water with a lower total dissolved solids content till pass through a semi-permeable membrane into a solution containing a higher concentration of dissolved solids .

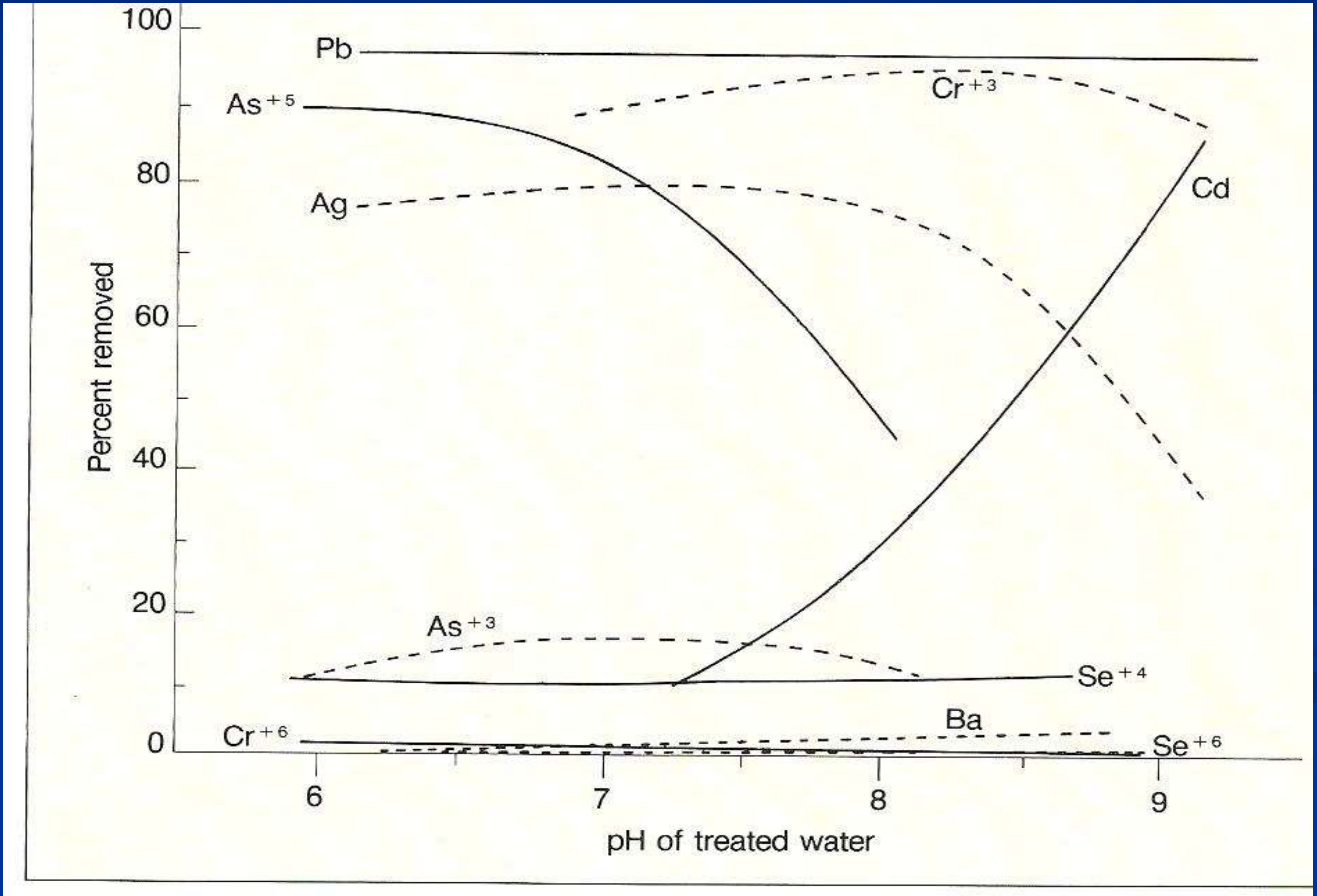
Treatment technologies appropriate for meeting drinking water regulations

- Flow continues until the osmotic pressure on the less concentrated side and the liquid head on the concentrated side balance each other .
- At this point , an equilibrium is reached so that the quantity of water passing through the membrane is equal in both directions .

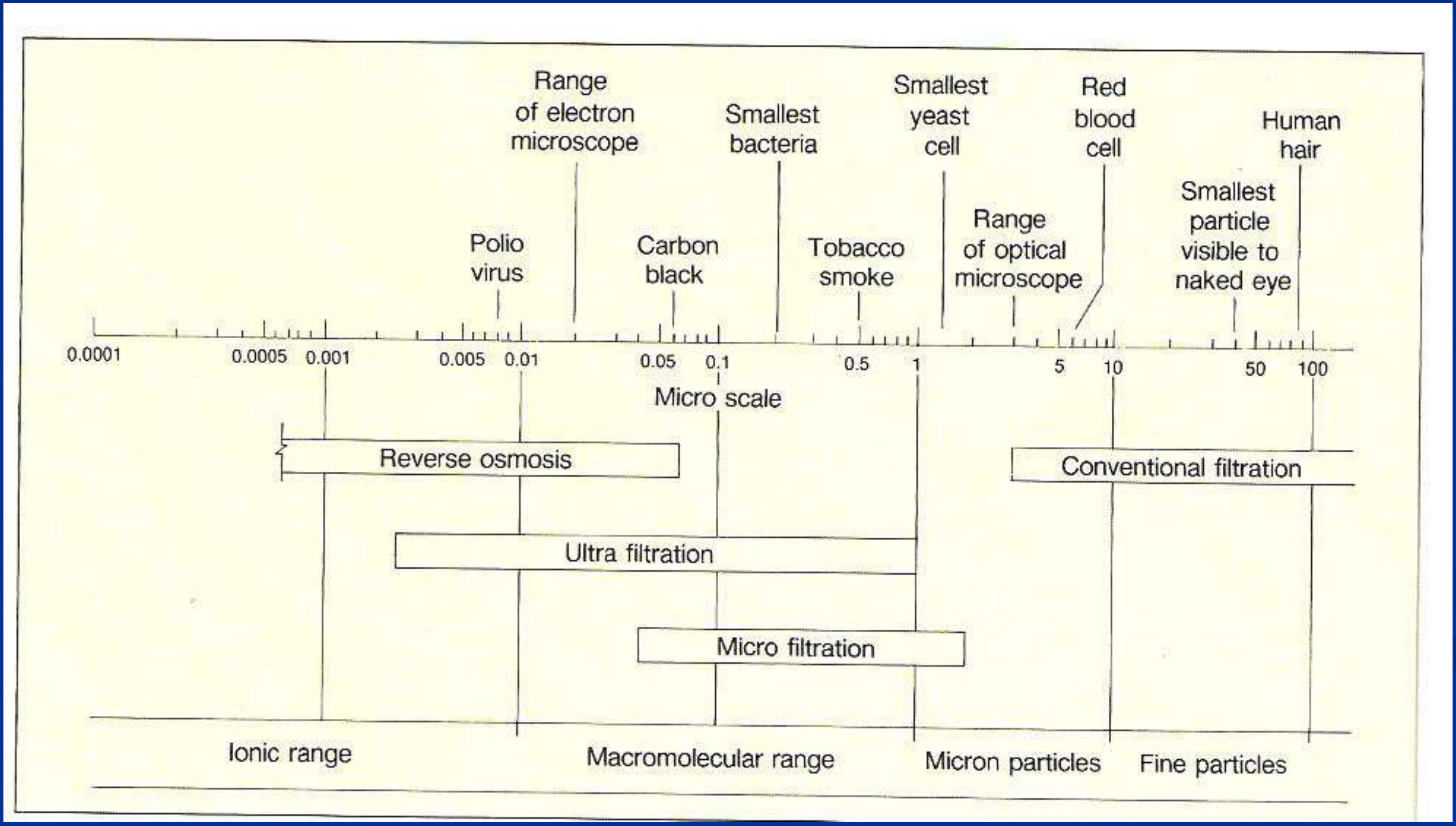
Treatment technologies appropriate for meeting drinking water regulations

- If the pressure equilibrium is changed by applying pump pressure to the concentrated solution , flow is reversed across the permeable membrane ; this is called reverse osmosis.
- A reverse osmosis system consists of semi permeable membrane elements mounted in the pressurs tubes , high-pressure water pump , pressure gauges , temperature gauge , and flow meters .

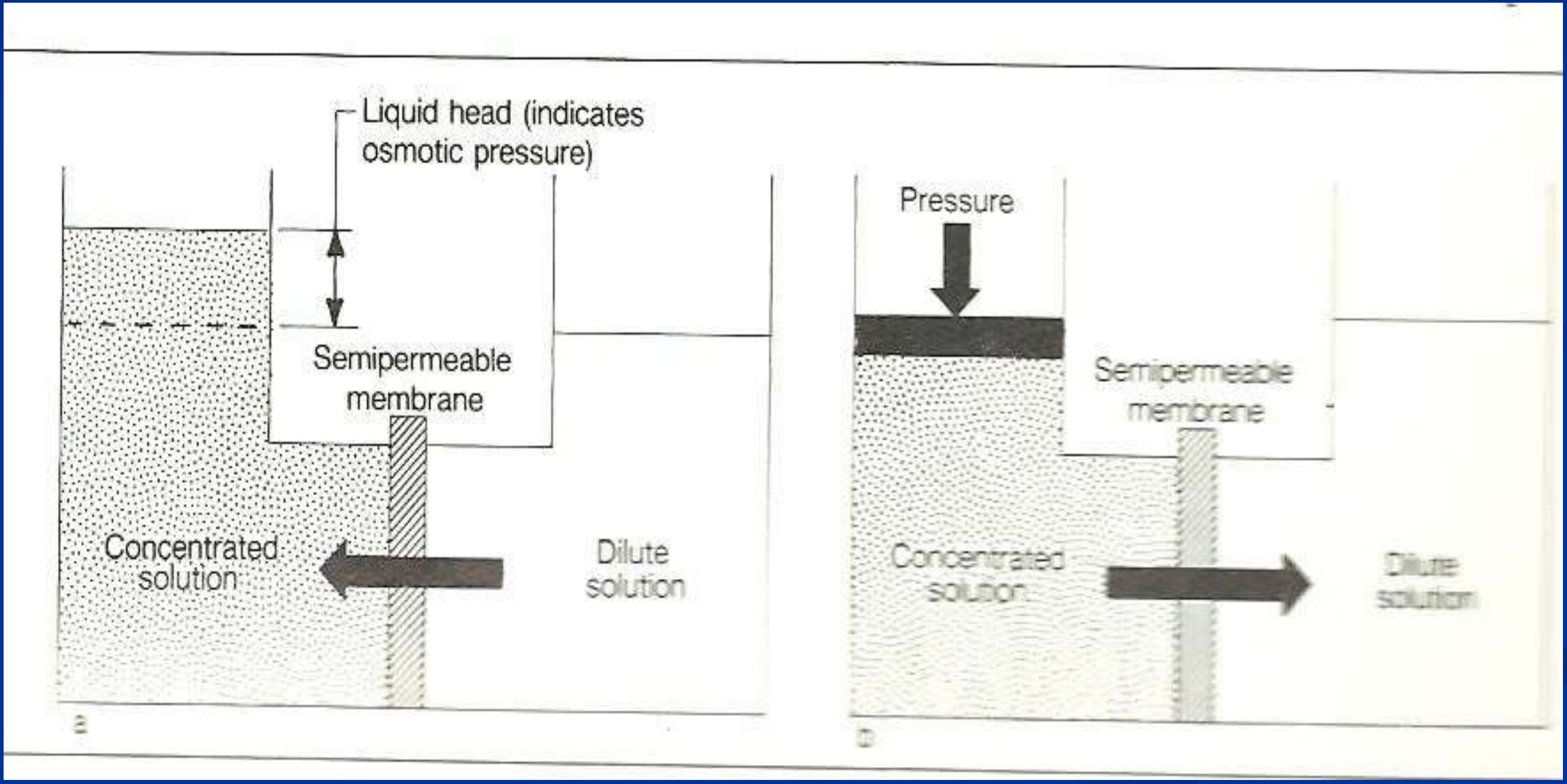
Removal of inorganic contaminants by alum coagulation



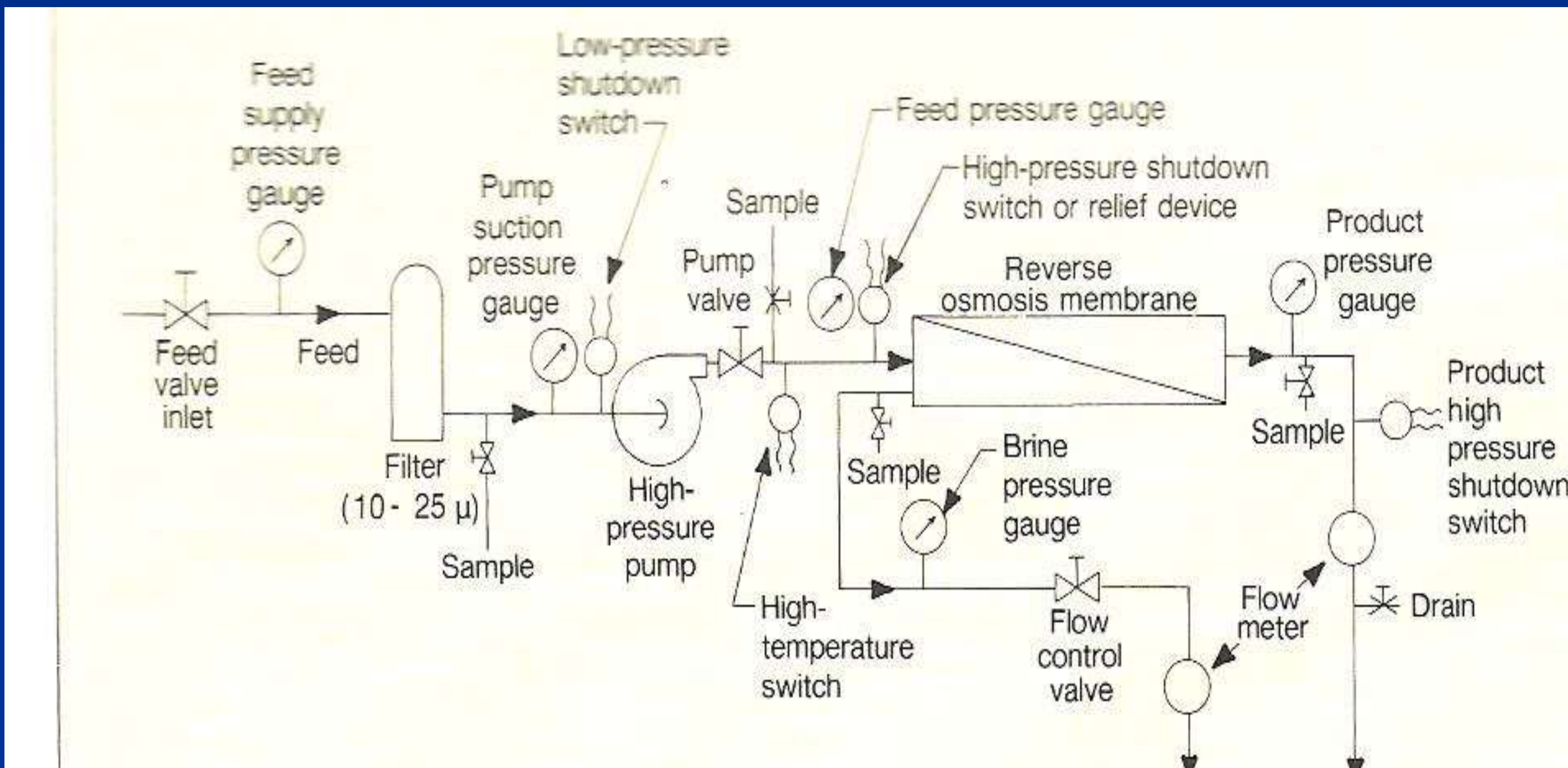
Approximate operating ranges of solids/liquids separation devices in treating water



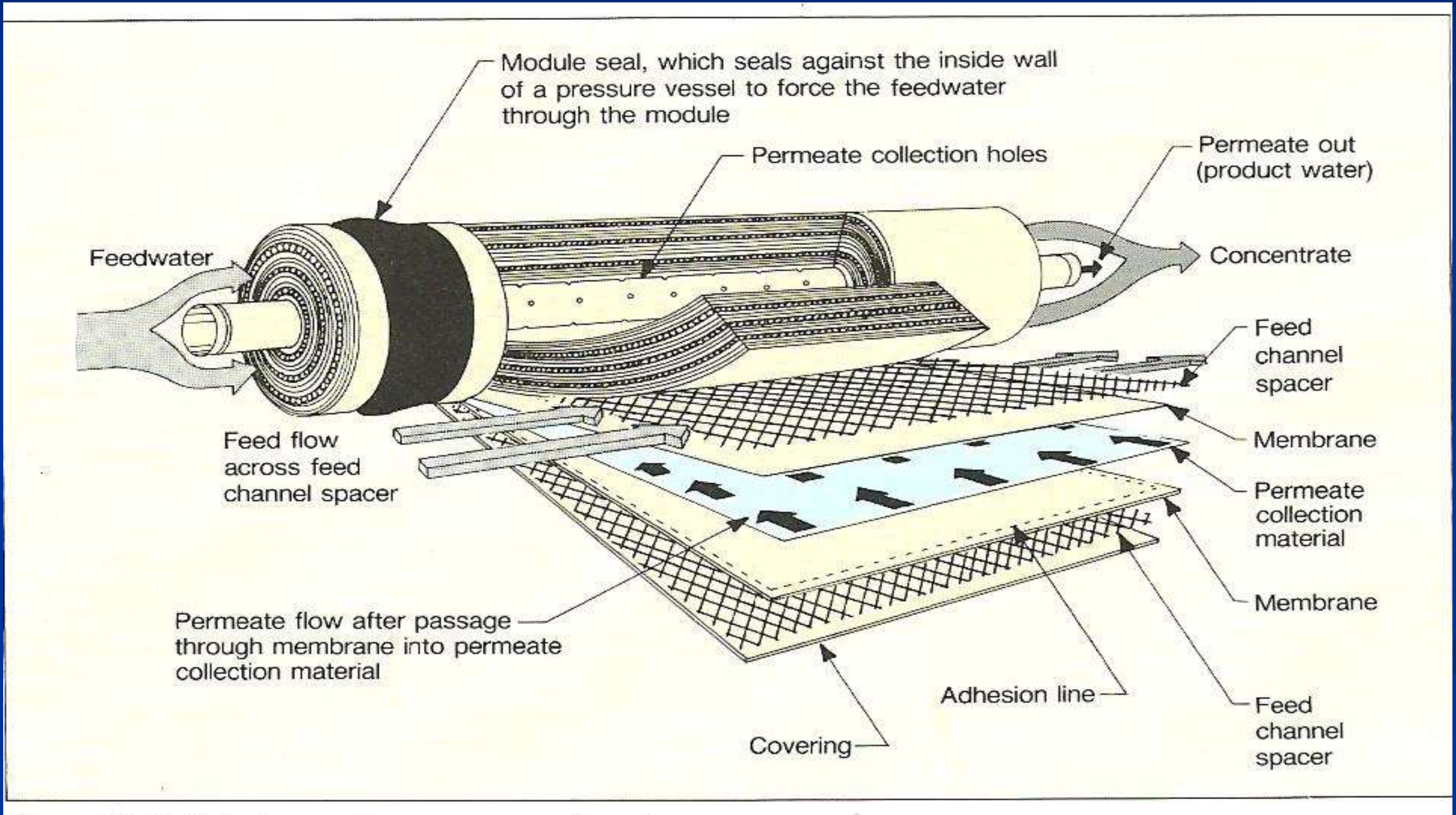
a)Osmosis b)reverse osmosis



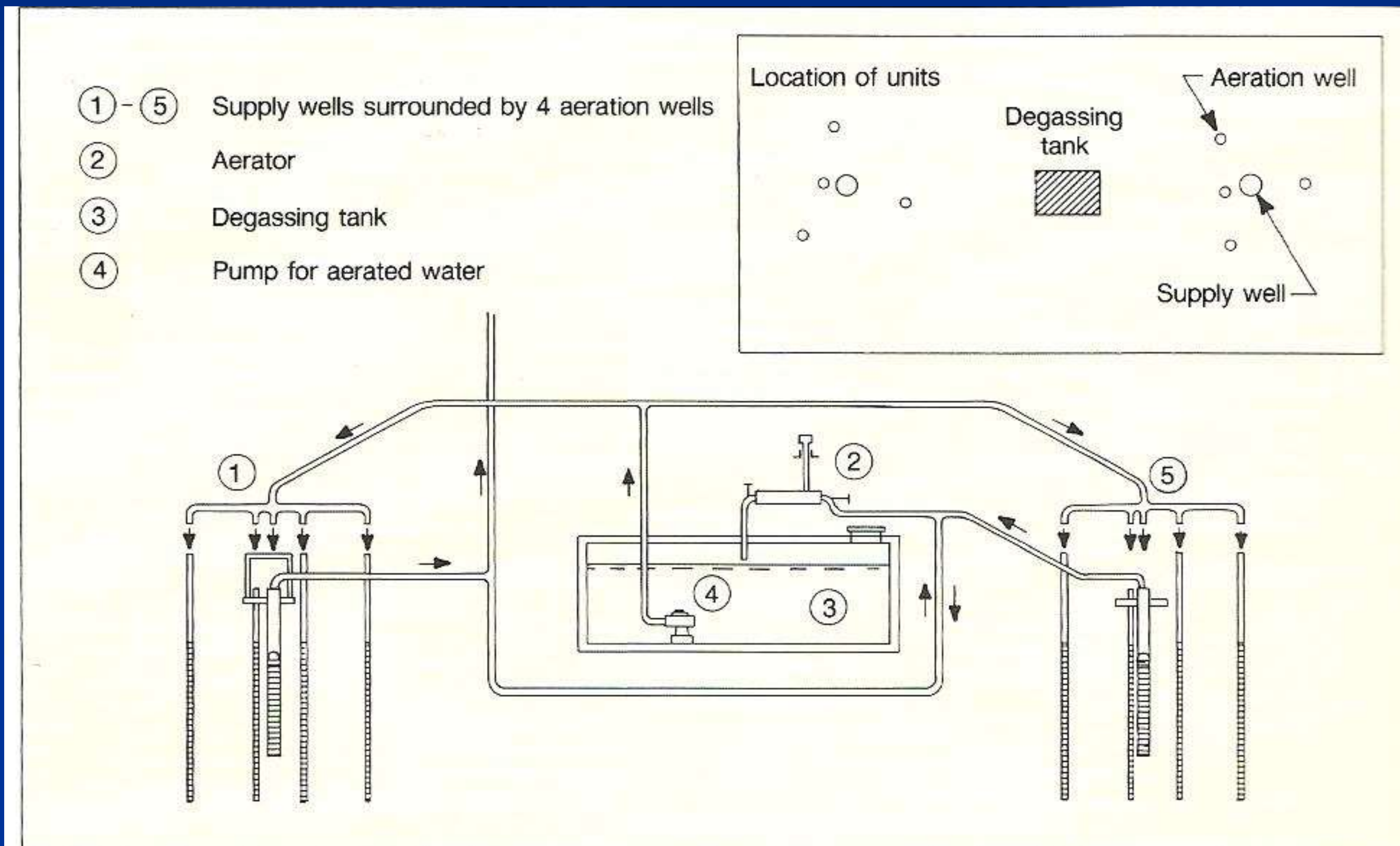
Flow schematic of reverse osmosis system



Spiral wound reverse osmosis unit



Vyredox plant with two supply wells , aeration wells , and oxygenator building



Analysis of brackish water before and after treatment by reverse osmosis

Contaminant	Feedwater	Pretreated Feedwater	Concentrate (Rejected Water)	Permeate (Product Water)
	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ
Calcium	61	61	303	0.2
Magnesium	24	24	119	0.1
Sodium	78	78	379	2.4
Potassium	4	4	19	0.1
Ammonia	0	0	0	0
Carbonate	0	0	0	0
Bicarbonate	129	24	115	2.0
Sulfate	201	284	1,414	0.2
Chloride	73	73	348	3.9
Nitrate	0	0	1	0
Fluoride	0	0	1	0
Silica	10	10	47	0.8
Total	581	558	2,747	8.1
Total dissolved solids	516	546	2,689	7.8
pH	7.8	5.7	6.4	4.6
Carbon dioxide	3	80	80	78
pHs		8.8	7.2	

Water analysis of Sea water treated by reverse osmosis

Contaminant	Feedwater	Pretreated Feedwater	Concentrate (Rejected Water)	Permeate (Product Water)
	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ
Calcium	418	418	642	0.4
Magnesium	1,330	1,330	2,044	1.4
Sodium	11,035	11,035	16,885	144.6
Potassium	397	397	607	5.2
Ammonia	0	0	0	0
Carbonate	0	0	0	0
Bicarbonate	146	146	224	0.8
Sulfate	2,769	2,769	4,256	0.3
Chloride	19,841	19,841	30,374	233.6
Nitrate	0	0	0	0
Fluoride	1	1	2	0
Silica	0	0	0	0
Total	35,937	35,937	55,034	386.3
Total dissolved solids	35,864	35,864	54,922	386
pH	8.2	8.2	8.4	5.9
Carbon dioxide	2	2	2	2
pHs		8.2	8.0	

Treatment technologies appropriate for meeting drinking water regulations

- The spiral-wound design involves a membrane unit that consists of two layers of membrane formed around a permeate carrier , which in turn is wound around a perforated tube .

6- In-situ treatment methods to remove Iron and Manganese from ground water .
(Vyredox method)

Treatment technologies appropriate for meeting drinking water regulations

7- Removal of turbidity :

- Turbidity refers to solids and organic matter that don't settle out of water.
- Groundwater is rarely turbid , unlike surface water which often contains suspended solids and colloidal or soluble organic matter

Treatment technologies appropriate for meeting drinking water regulations

- Turbidity is measured by how much light is transmitted or scattered when a beam of light is passed through a water sample .

A) Jackson turbidity unit (JTU) .

B) Nephelometric turbidity units (NTU) .

Treatment technologies appropriate for meeting drinking water regulations

8- Removal of coli form organisms :

- Microbes can be controlled by using oxidizing or no oxidizing biocides.
- Chlorine is a strong oxidizing agent that reacts with many impurities in water .
- The chlorine demand of a specific water is the amount of chlorine required to react with these impurities .

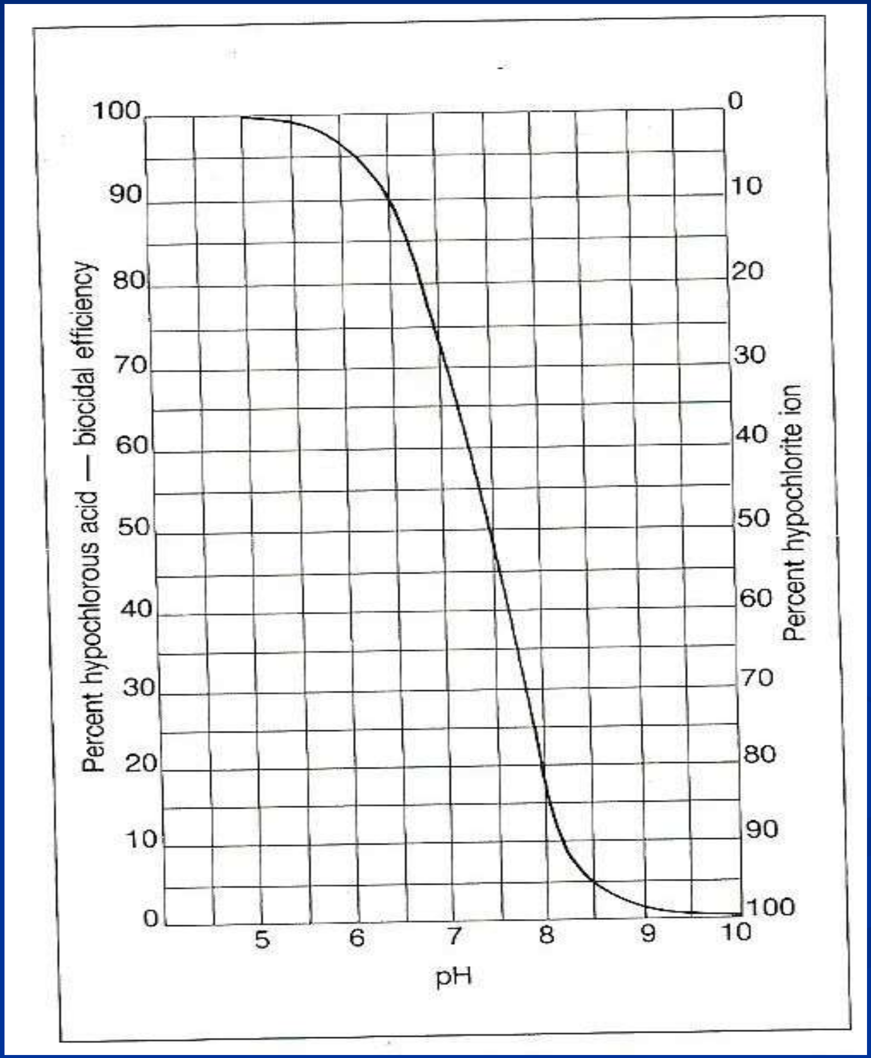
Treatment technologies appropriate for meeting drinking water regulations

- Chlorine not used immediately is called the chlorine residual .
- Breakpoint chlorination occurs when the addition of a volume of chlorines satisfies the chlorine demand and produces a free chlorine residual .

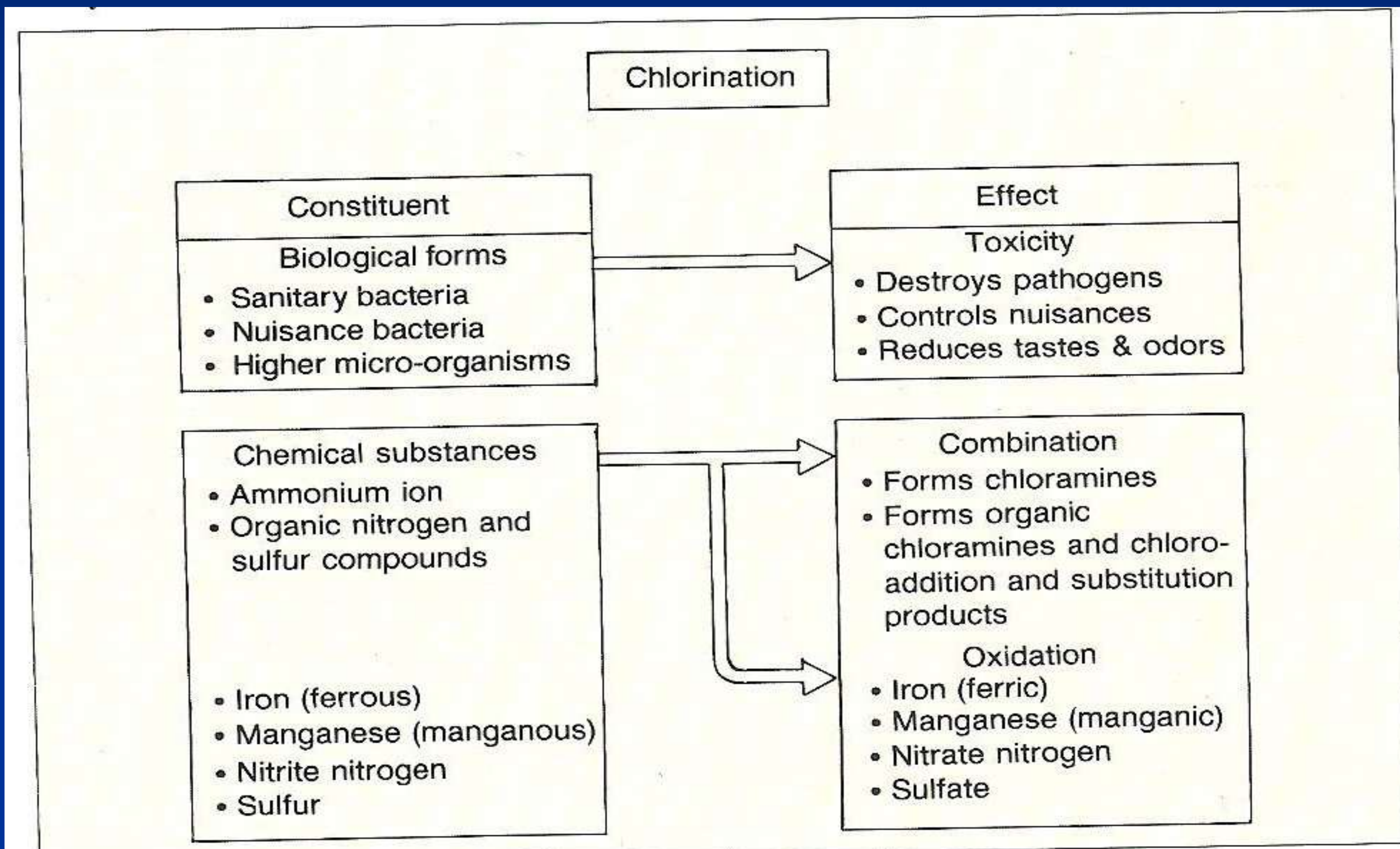
Typical Micro-Organisms and their associated problems

Type of Organism	Type of Problem
Bacteria	
Slime-forming bacteria	Form dense, sticky slime with subsequent fouling. Water flows can be impeded and promotion of other organism growth occurs.
Spore-forming bacteria	Become inert when their environment becomes hostile to them. However, growth recurs whenever the environment becomes suitable again. Difficult to control if complete kill is required. However, most processes are not affected by spore formers when the organism is in the spore form.
Iron-depositing bacteria	Cause the oxidation and subsequent deposition of insoluble iron from soluble iron.
Nitrifying bacteria	Generate nitric acid from ammonia contamination. Can cause severe corrosion.
Sulfate-reducing bacteria	Generate sulfides from sulfates and can cause serious localized corrosion.
Anaerobic corrosive bacteria	Create corrosive localized environments by secreting corrosive wastes. They are always found underneath other deposits in oxygen-deficient locations.
Fungi	
Yeasts and molds	Cause the degradation of wood in contact with the water system. Cause spots on paper products.
Algae	Grow in unlit areas in dense fibrous mats. Can cause plugging of distribution holes on cooling-tower decks or dense growths on reservoirs and evaporation ponds.
Protozoa	Grow in almost any water which is contaminated with bacteria; indicate poor disinfection.

The effect of PH on the bacterial ability of chlorine



Biological and chemical effects of chlorine in water



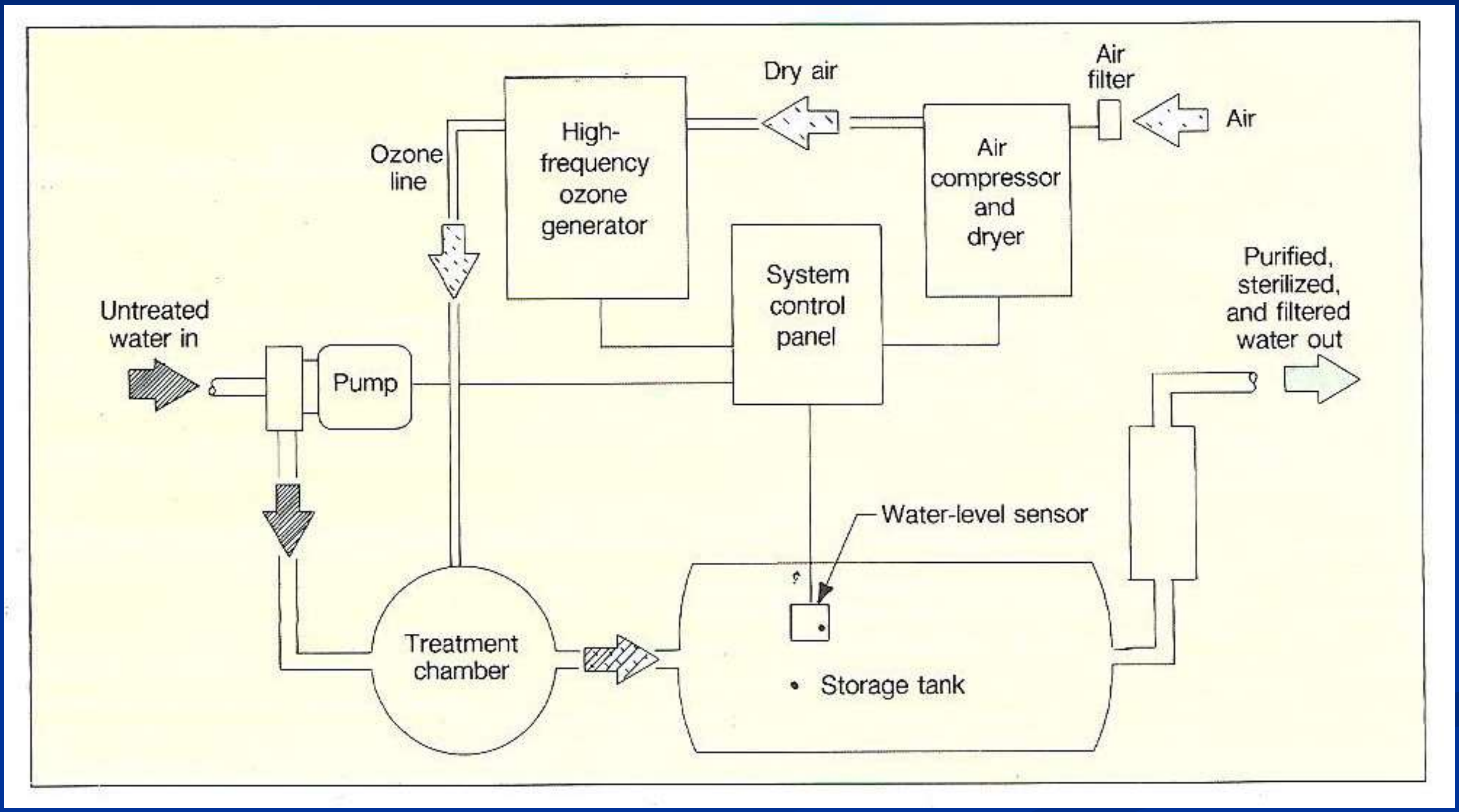
Treatment technologies appropriate for meeting drinking water regulations

9- Removal of organic contaminants .

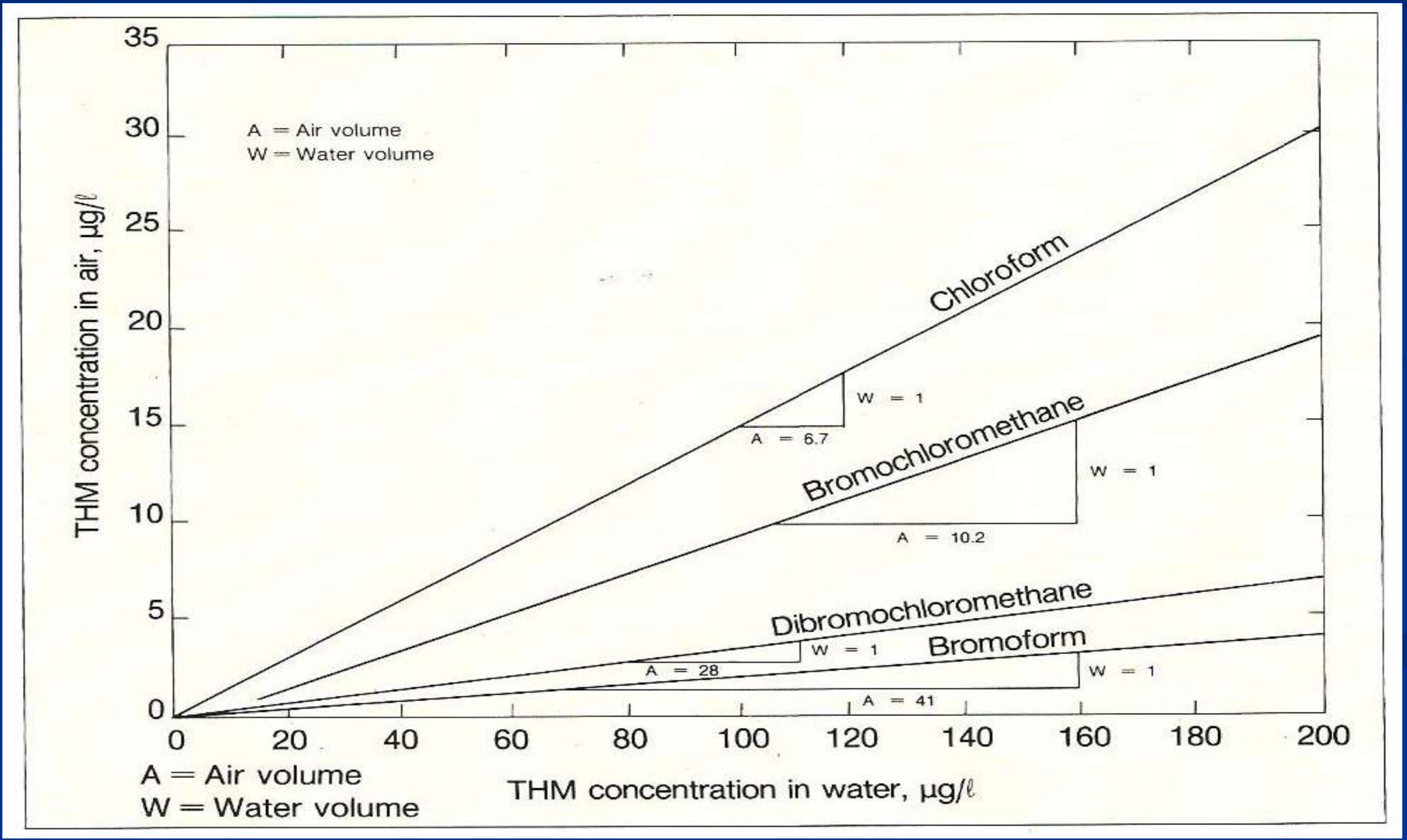
10- Aeration :

in the aeration process , water containing organic chemicals is mixed with air in a special chamber or tower which is filled with packing material that disperses the water to enhance air contact .

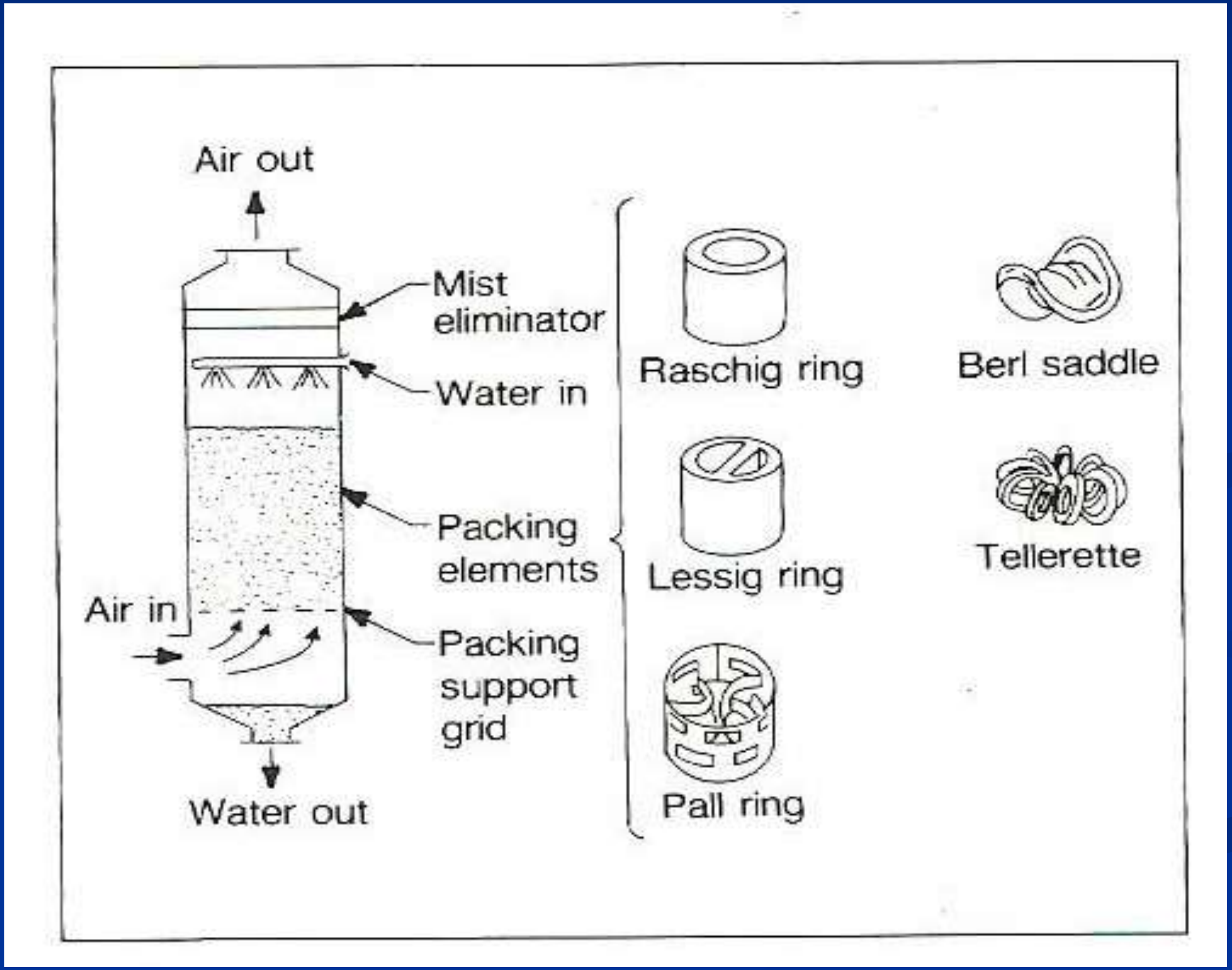
Flow diagram of ozone water treatment system



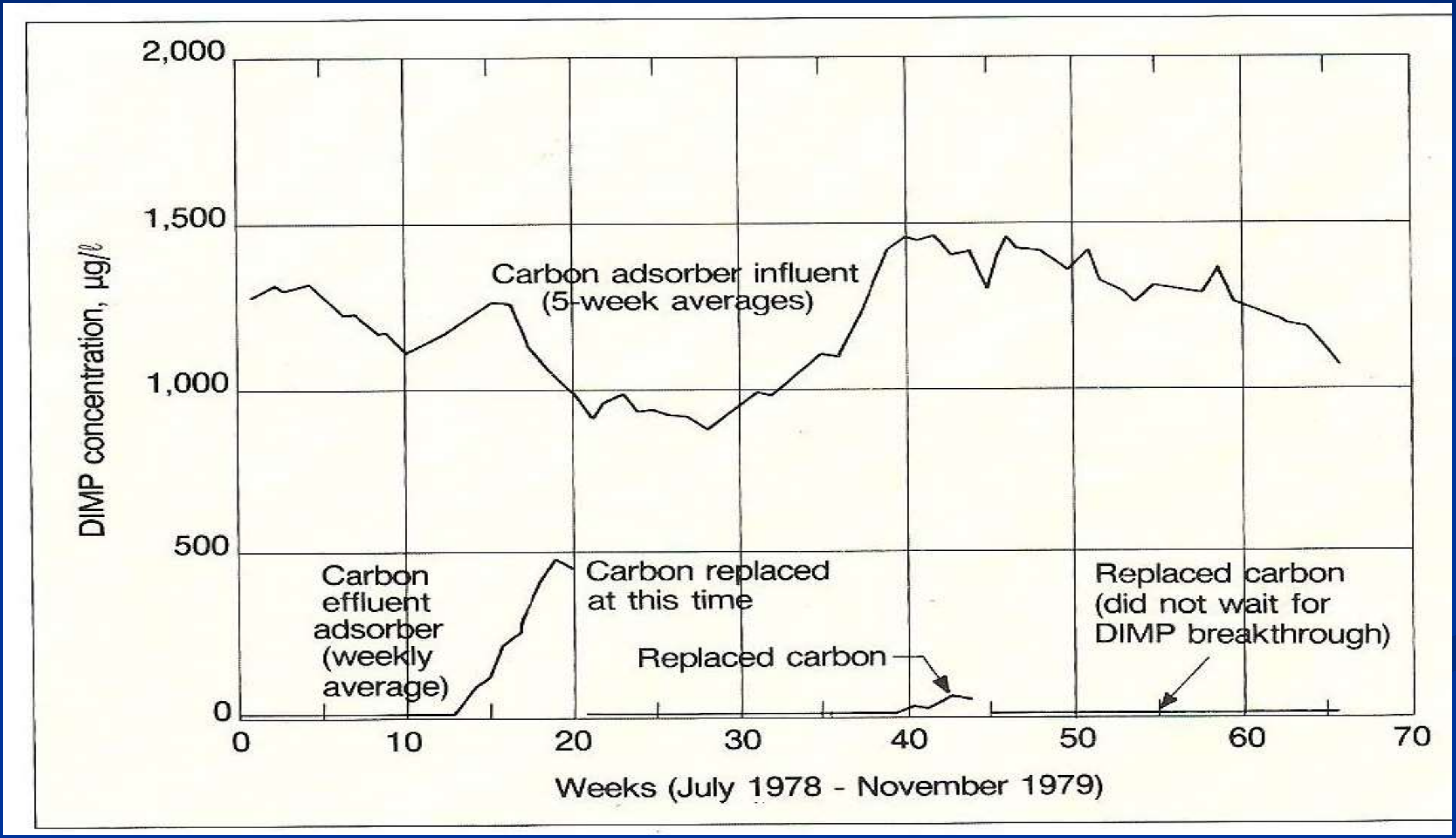
Theoretical equilibrium lines for four tri-halo-methanes



Packed tower and types of packing



Performance of carbon beds



Treatment technologies appropriate for meeting drinking water regulations

- The ratios of air and water are shown for four tri-halo-methanes .
- The slope of the curve suggests the ease with which the contaminant can be removed by aeration in a countercurrent system .

Treatment technologies appropriate for meeting drinking water regulations

11- Adsorption :

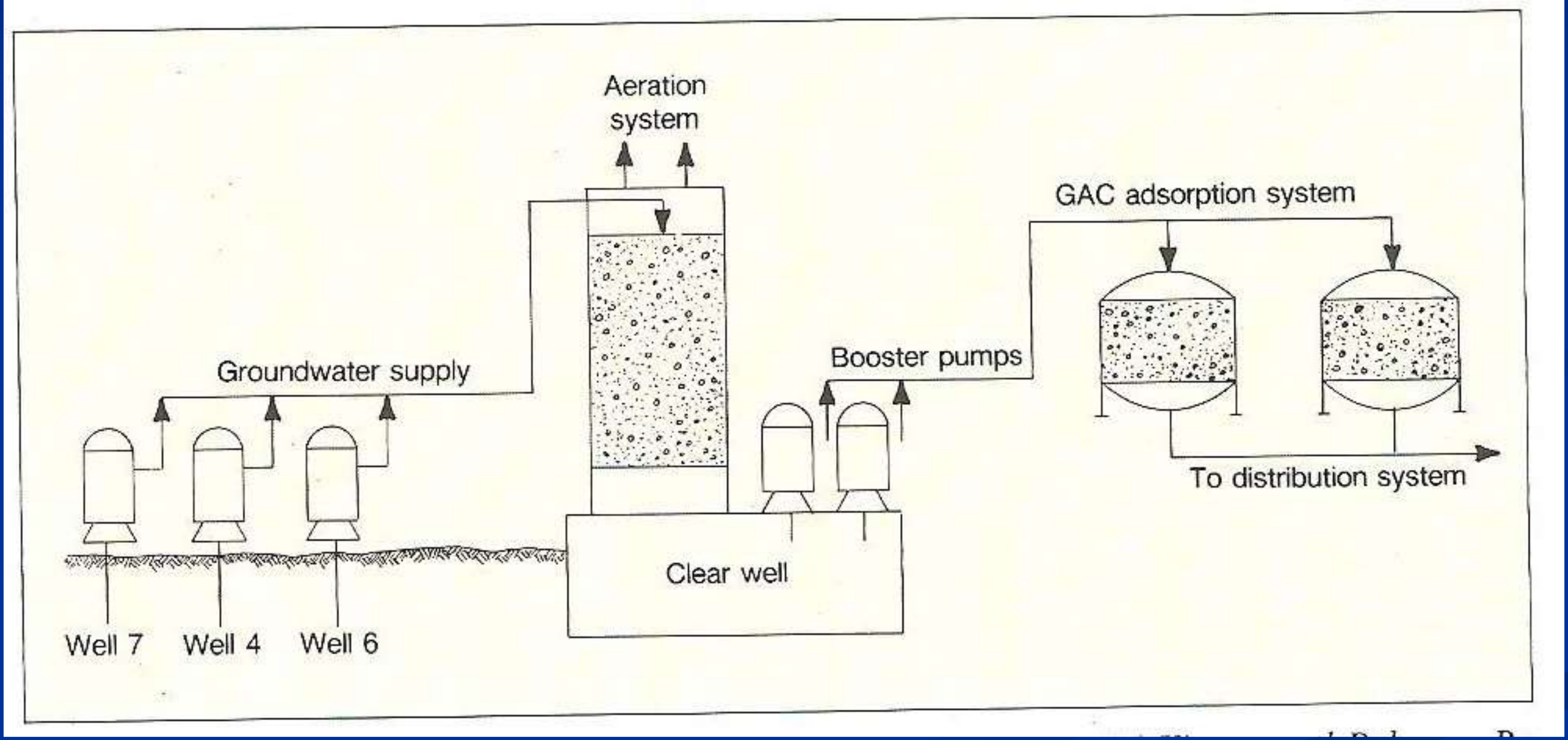
Two types of materials are used to adsorb organic contaminants – granular or powdered activated carbon and a synthetic carbon-based resin .

- ✓ The high cost of a synthetic resin has limited its use in comparison with activated carbon .

Treatment technologies appropriate for meeting drinking water regulations

- Granular activated carbon (GAC) is most often used in treatment systems , and provides huge numbers of sites (pores) where various organic contaminants can become affixed when contaminated water is based upward through a carbon bed .
- The water is usually in contact with the GAC for about 10 minutes .

Schematic of the Rockaway township treatment system



Treatment technologies appropriate for meeting drinking water regulations

- In time , the GAC is used up and the contaminant will break through .

12- Removal of radioactive contaminants .

13- Emergency treatment procedures for sudden contamination :

From time to time , sudden contamination of a water supply occurs.

Treatment technologies appropriate for meeting drinking water regulations

- The public must be notified immediately if the contaminated water is already in the distribution system.

14 - Point of use water treatment systems .

15 - Chlorination , Ozonation , and ultraviolet disinfection .

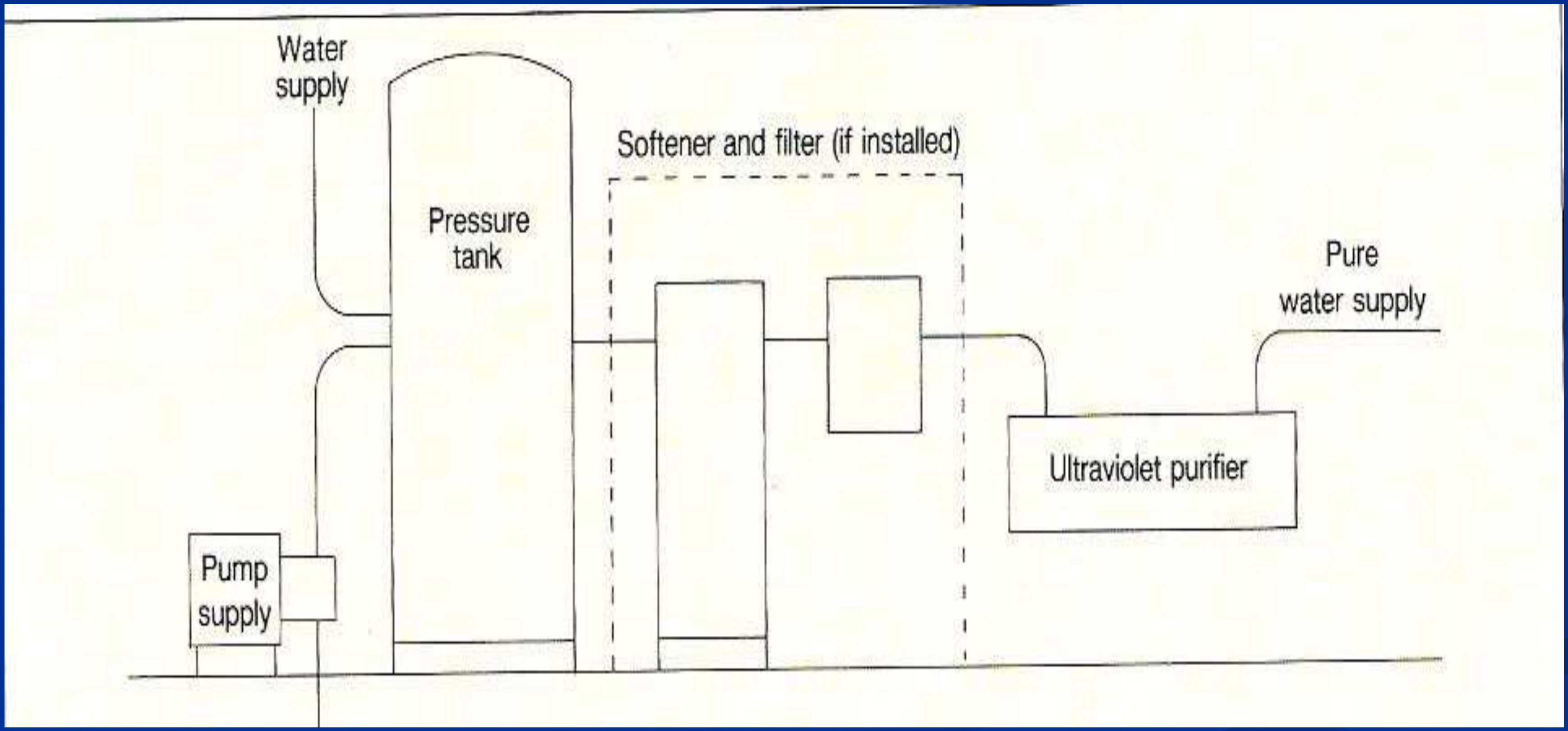
Processes for Effective Removal of Drinking water communities by Point of use systems

General Water Problem	Contaminants or Dissolved Solids	Processes: Cation Exchange	Chlorination	Sediment Cartridge Filter	Taste & Odor Cartridge Filter (Carbon)	Reverse Osmosis	Distiller (Vented)	Ultraviolet Disinfection
Particulates	Sand			x			x	
	Silt			x			x	
	Rust particles			x			x	
Inorganics	Arsenic	x				x	x	
	Barium	x				x	x	
	Cadmium	x				x	x	
	Calcium	x				x	x	
	Chromium					x	x	
	Copper	x				x	x	
	Iron	x				x	x	
	Lead	x				x	x	
	Magnesium					x	x	
	Manganese	x				x	x	
	Mercury	x				x	x	
	Radium 226 & 228					x	x	
	Selenium					x	x	
	Silver					x	x	
	Sodium					x	x	
	Strontium 90					x	x	
	Zinc	x				x	x	
	Chlorides					x	x	
	Chlorine				x		x	
	Fluorides						x	
	Nitrates						x	
	Sulfates					x	x	
	Sulfides					x	x	
Organics	Benzene				x	x	x	
	THM's				x	x	x	
	PCB's				x	x	x	
	Petroleum Solvents				x	x	x	
	Pesticides				x	x	x	
	Herbicides				x	x	x	
	Tannin (Humic Substances)					x	x	
	Odors				x	x	x	
	Swampy taste				x	x	x	
Biological	Algae		x			x	x	x
	Bacteria		x			x	x	x
	Viruses						x	x

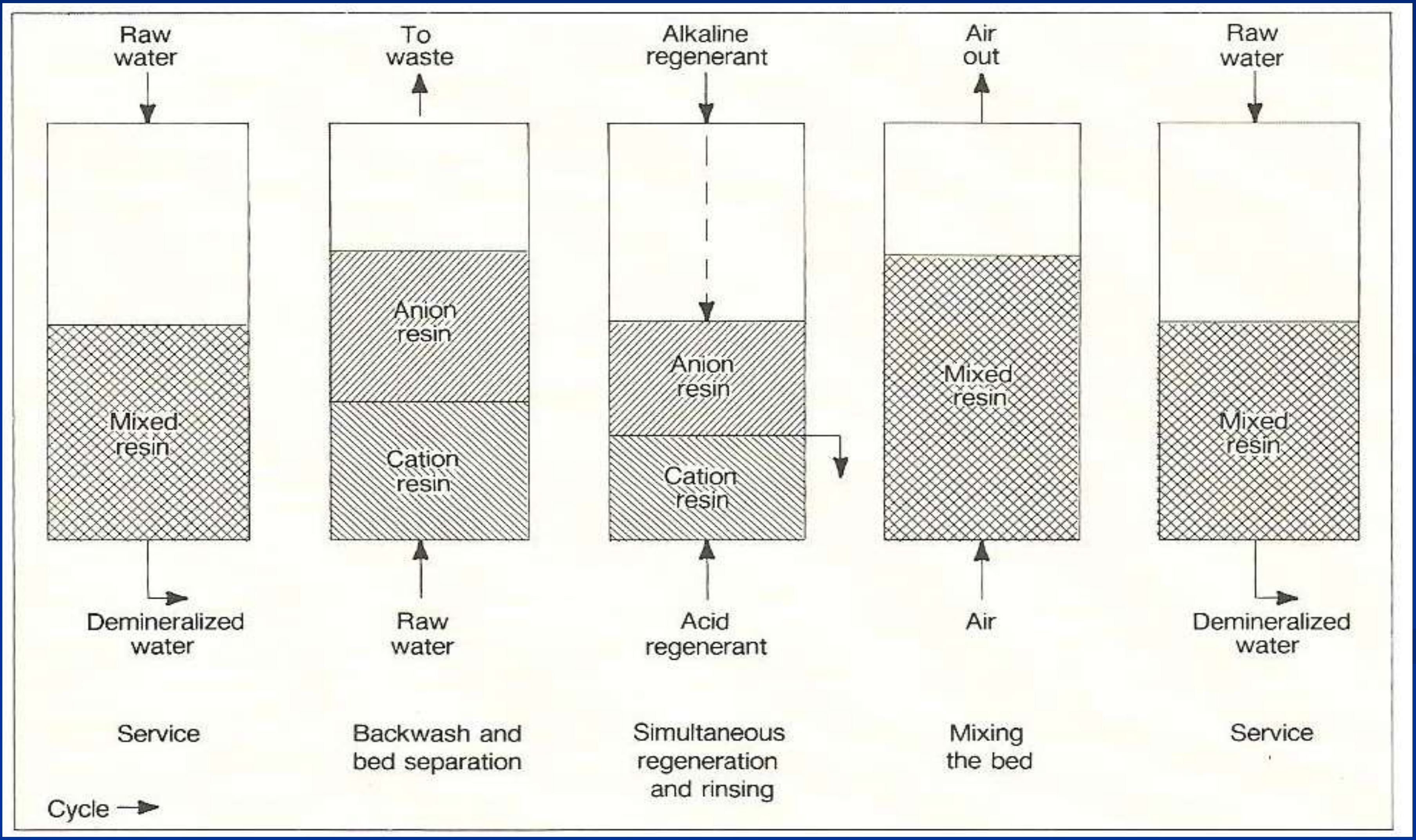
Treatment technologies appropriate for meeting drinking water regulations

- Ion Exchange .
- Domestic water conditioning .
- Filters .
- Distillation .
- Reverse osmosis .

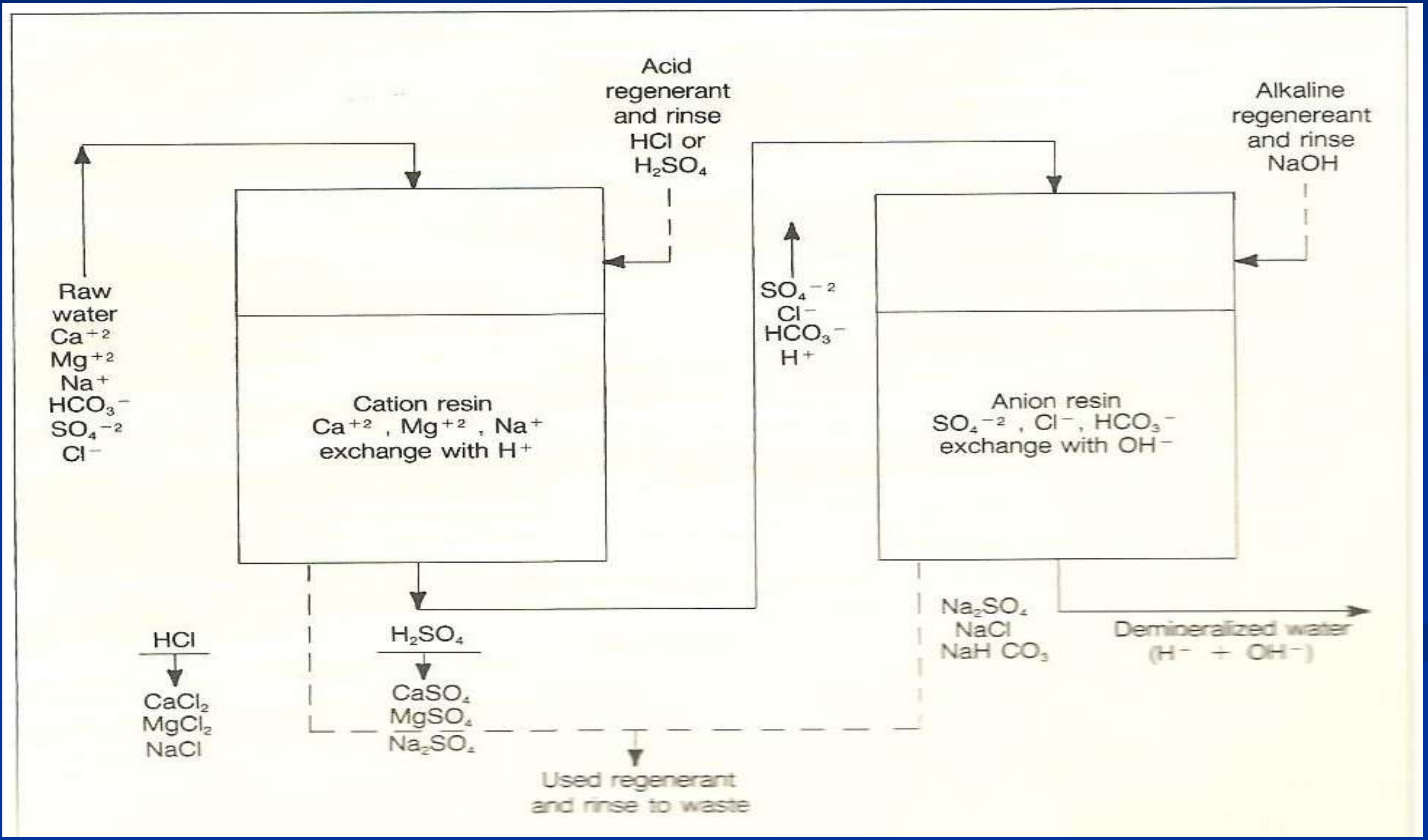
Typical residential water system



Mixed-bed ion Exchange and regeneration system



Two-bed ion exchange system



Hardness Classification for water

Hardness		Classification
mg/ℓ	Grains/gal	
0 - 9	0 - ½	Soft
9 - 60	½ - 3½	Slightly hard
60 - 120	3½ - 7	Moderately hard
120 - 180	7 - 10½	Hard
over 180	over 10½	Very hard

IoExchange Selectivity Decreasing Preference

Cation Exchanger	Anion Exchanger
Barium	Iodide
Strontium	Nitrate
Calcium	Bisulfate
Copper	Chloride
Zinc	Bicarbonate
Magnesium	Hydroxide
Titanium	Fluoride
Potassium	Bisilicate
Ammonia	
Sodium	
Hydrogen	

Thanks