ENVIRONMENTAL ENGINEERING

WASTE MANAGEMENT, EFFLUENT TREATMENT AND EFFLUENT DISCHARGE PRACTICES

LECTURE CONTENT

EFFLUENT TREATMENT AND DISCHARGE	Effluent types, pollutants and effects Primary, secondary and tertiary treatment Physical, chemical and biological methods Equipment used in effluent treatment Advanced oxidation techniques Removal of specific pollutants
WASTE MANAGEMENT TECHNIQUES	Characteristics of industrial wastes Traditional treatment techniques Examples of industrial relevance Recent advances in wastewater treatment

INDUSTRIAL WASTEWATERS

SECTOR	POLLUTANT
Iron and steel	BOD, COD, oil, metals, acids, phenols, cyanide
Textiles and leather	BOD, solids, sulfates, chromium
Pulp and paper	BOD, COD, solids, chlorinated organic compounds
Petrochemicals and refineries	BOD, COD, mineral oils, phenols, chromium
Chemicals	COD, organic chemicals, heavy metals, SS, cyanide
Metal works	Chromium, nickel, zinc, cadmium, lead, iron and titanium compounds
Nonferrous metals	Fluorine, SS
Microelectronics	COD, organic chemicals
Mining	SS, metals, acids, salts
Food processing	SS, organics

POLLUTANTS AND EFFECTS

POLLUTANT	EFFECT
Biodegradable organic compounds	Microbial growth, toxicity, oxygen depletion
Suspended solids	Microbial growth, sludge blanket, turbidity
Coliform and other microorganisms	Health problems
pH	Toxicity to flora, fauna, humans
Oil and grease	Fouling, damages to flora and fauna
Nutrients (nitrogen, phosphorus)	Toxicity to aquatic life, eutrophication
Color	Aesthetics, inhibition of algal growth
Temperature	Toxicity to aquatic life
Surfactants	Toxicity to aquatic life, aesthetics
Mercaptans, chlorine, smelly compounds	Odors
Sulfides, sulfates	Toxicity, odor (H_2S), pH
Heavy metals, toxins, phenolics, cyanides	Toxicity to flora, fauna, humans

Quality Parameters for Industrial Wastewaters

Soluble organic materials	Oil and floating materials
Suspended solids	Color and turbidity
Priority organic pollutants	Odor
Priority heavy metals	Recalcitrant (refractory) compounds
Volatile organic compounds (VOCs)	Temperature
Nitrogen (typically as NH_4^+ or NO_3^-)	pH
Phosphorus (typically as phosphate)	Coliforms and other microorganisms

Characterization of Industrial Wastewaters

Category	Parameter
Physical	Solids content, odors, temperature, density, color, turbidity
Chemical	Organic/Inorganic material
Biological	

Physical Characteristics

Parameter	Details
Solids	• total, dissolved, suspended, volatile, fixed • TS, TSS, VSS, FSS, TVS, TDS, VDS, FDS, TFS • settleable, filterable, colloidal, soluble • MLSS, MLVSS
Odors	• Gases (H_2S) formed during anaerobic decomposition of organic matter in wastewater cause odors • Odors cause concern, stress and public reaction • H_2S, mercaptans, ammonia and chlorine cause odors • CH_4, CO_2 and O_2 are odorless

Characterization of Industrial Wastewaters ctd..

Chemical Characteristics

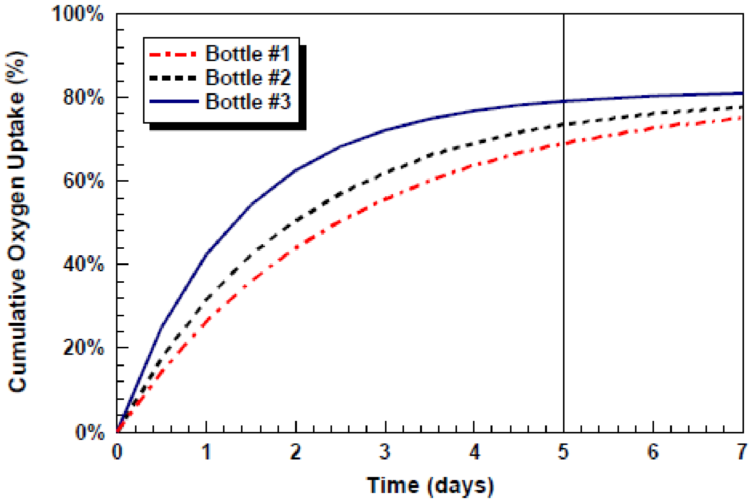
Parameter	Details
Organic material	• Total organic material • Proteins • Carbohydrates • Fats, oils, and grease • Pesticides • Phenols • Priority pollutants • Refractory pollutants • Surfactants • Volatile organic compounds
Inorganic material	• H^+ (pH) • Alkalinity • Heavy metals • Nitrate and nitrite • Ammonia • Phosphorous • Sulfate and sulfite • Sulfide • Chloride • Oxygen

Parameter	Method of Analysis
Organic material	• Gas chromatography • High performance liquid chromatography • Spectrophotometry (UV, visible, IR) • Mass spectroscopy • Gravimetric methods • Colorimetric methods
Inorganic material	• Atomic absorption • Ion selective electrodes • Ion chromatography • Gravimetric methods • Colorimetric methods

Determination of Organic Content

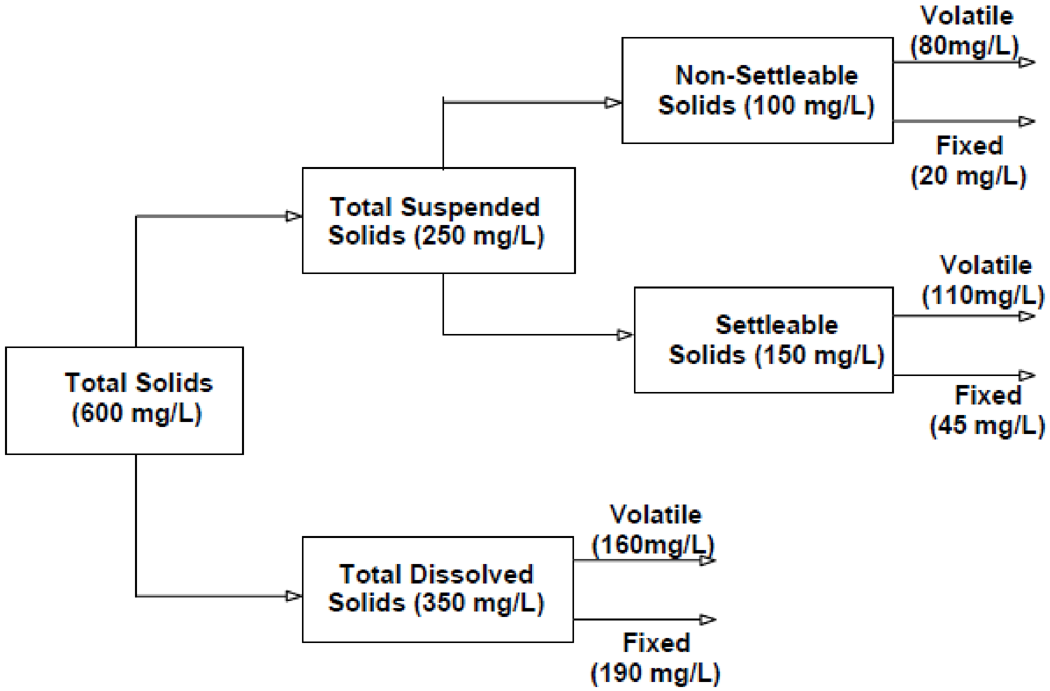
Parameter	Details	Detail
BOD	Biological oxygen demand (BOD_5, BOD_u and CBOD)	Amount of oxygen required to biologically oxidize organic material in wastewater
COD	Chemical oxygen demand	Amount of oxygen required to chemically oxidize organic material in wastewater
TOD	Total oxygen demand	Amount of oxygen required to oxidize organic material in wastewater by a high-temp. oxid. proc.
ThOD	Theoretical oxygen demand	Theoretical amount of oxygen necessary to oxidize all organic material in wastewater
TOC	Total organic carbon	Amount of organic carbon present in a known volume of wastewater as measured in a std. test
COD_{partox}	Partial oxidation parameter	Combination of TOC and COD data
AOSC	Average oxidation state of carbon	Combination of TOC and COD data

WASTEWATER CHARACTERIZATON



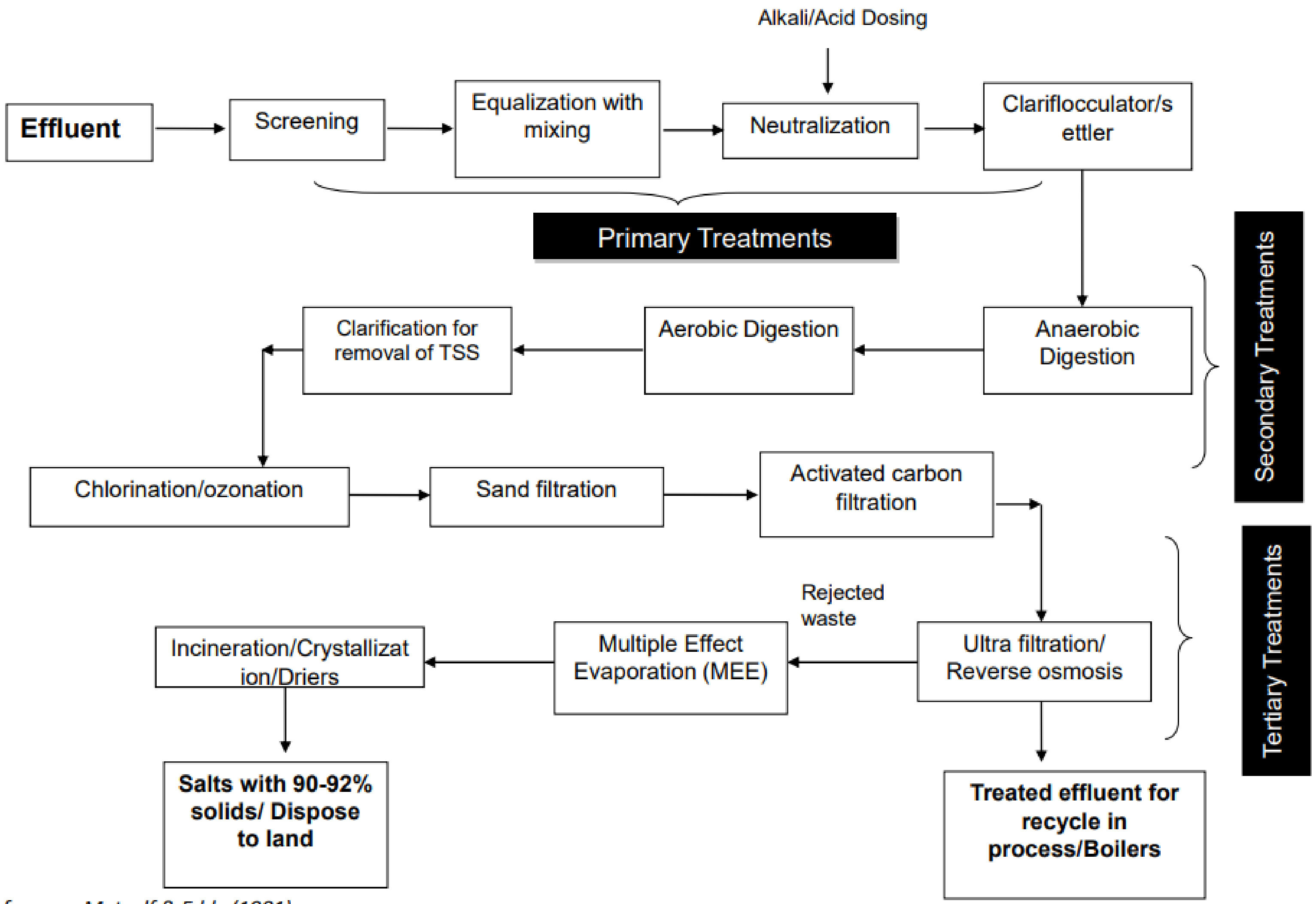
Biochemical Oxygen Demand

Chemical Oxygen Demand



Solids Content (TSS and TDS)

CETP IN INDUSTRY



Reference: Metcalf & Eddy (1991)

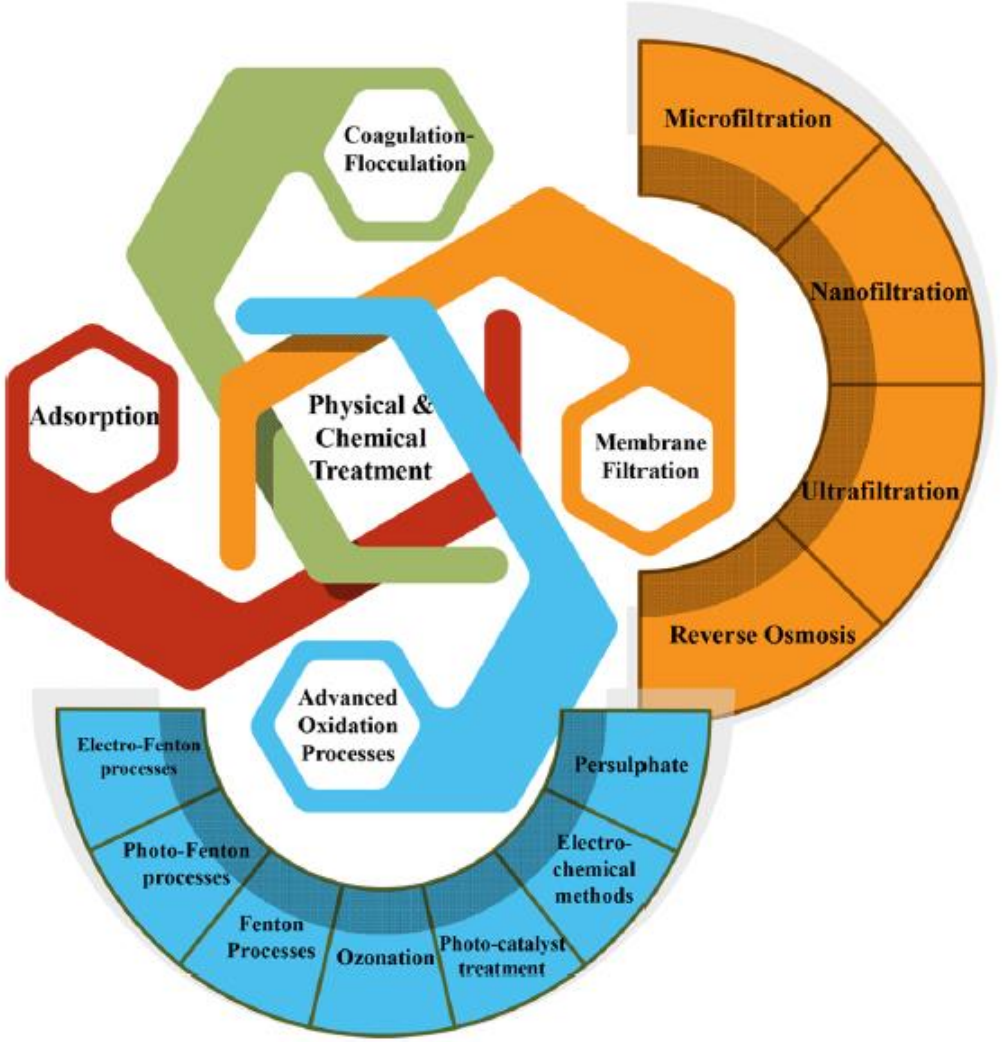
LEVELS OF WASTEWATER TREATMENT

	PRIMARY	SECONDARY	TERTIARY
PHYSICAL	Carbon adsorption Membrane filtration Reverse osmosis		Membrane filtration Reverse osmosis
CHEMICAL	Chemical precipitation Disinfection Dechlorination Oxidation	Chemical precipitation Disinfection Dechlorination	Chemical coagulation Flocculation and sedimentation Carbon adsorption Ion exchange
BIOLOGICAL		Activated-sludge processes Natural treatment systems Fixed-film reactors	Activated-sludge processes Natural treatment systems

EQUIPMENT FOR ETP

TREATMENT STAGE	EQUIPMENT USED
PRE-TREATMENT	Bar screens (manual and automatic)
PRIMARY TREATMENT	Grit removal screens (manual and automatic) Coarse screens Oil skimmers Aerators (floating, fixed, diffused, spray)
SECONDARY TREATMENT	Clarifiers Thickeners Phase separators Dissolved air flotation units
TERTIARY TREATMENT	Media filtration Activated carbon purification Disinfection Softening Membrane-based purification Membrane bio-reactors

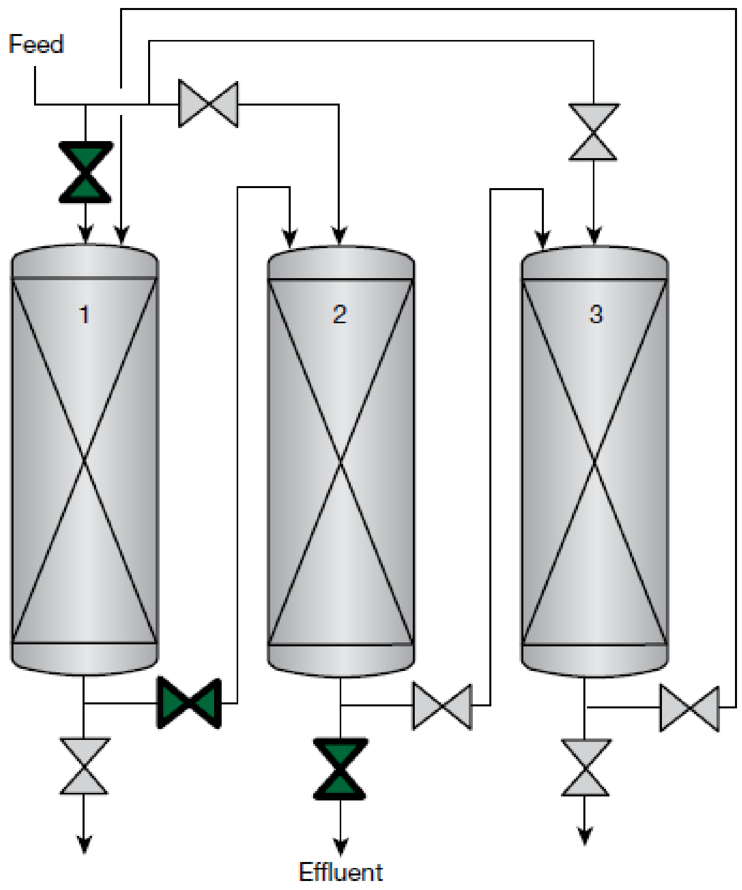
PHYSICAL AND CHEMICAL TREATMENTS



PHYSICAL WASTEWATER TREATMENT

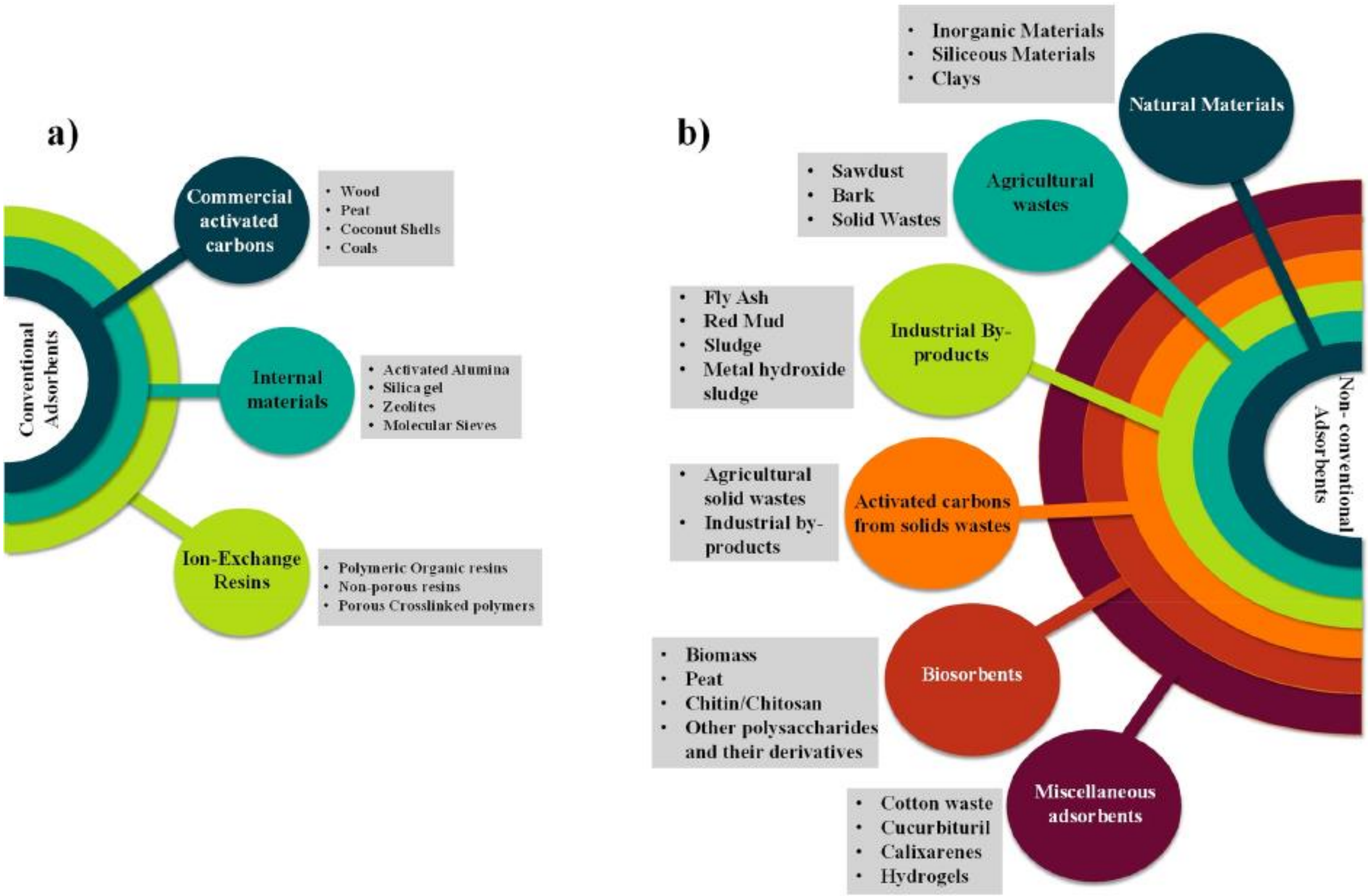
TECHNOLOGY	ADVANTAGES	DISADVANTAGES
Carbon adsorption	Reduces chlorine and PM Improves taste and odor Does not require electricity 95% efficiency	Cannot remove small particulates and some bacteria
Membrane filtration	Removes pyrogens, microorganisms, colloids Produces high-quality water Regenerable, low cost Easy to operate 94% efficiency	Requires mechanical devices Does not remove dissolved inorganics
Reverse osmosis	Filters 0.5-µm 500-nm particles 94% efficiency	Expensive maintenance requirement

ADSORPTION PROCESS

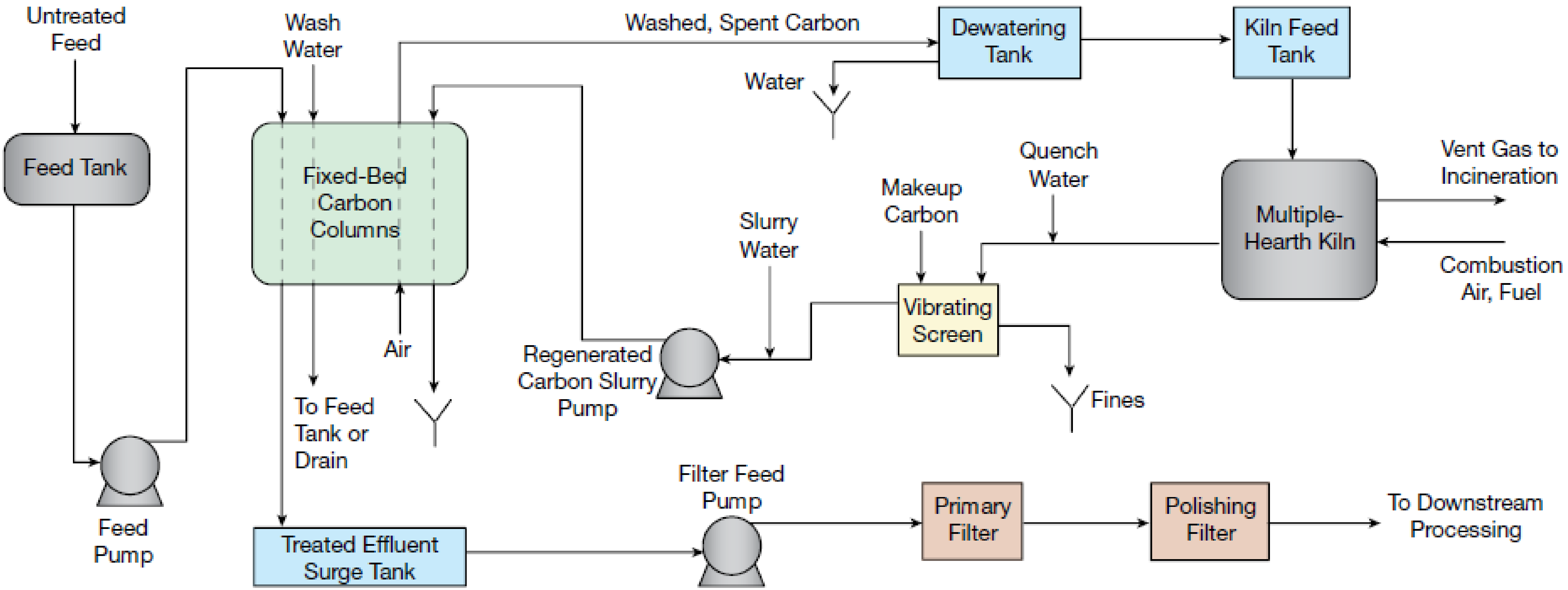


In this three-column arrangement, Column 1 and Column 2 serve as the lead and guard, respectively, while Column 3 is on regeneration or standby. Valves in bold are open, the others are closed.

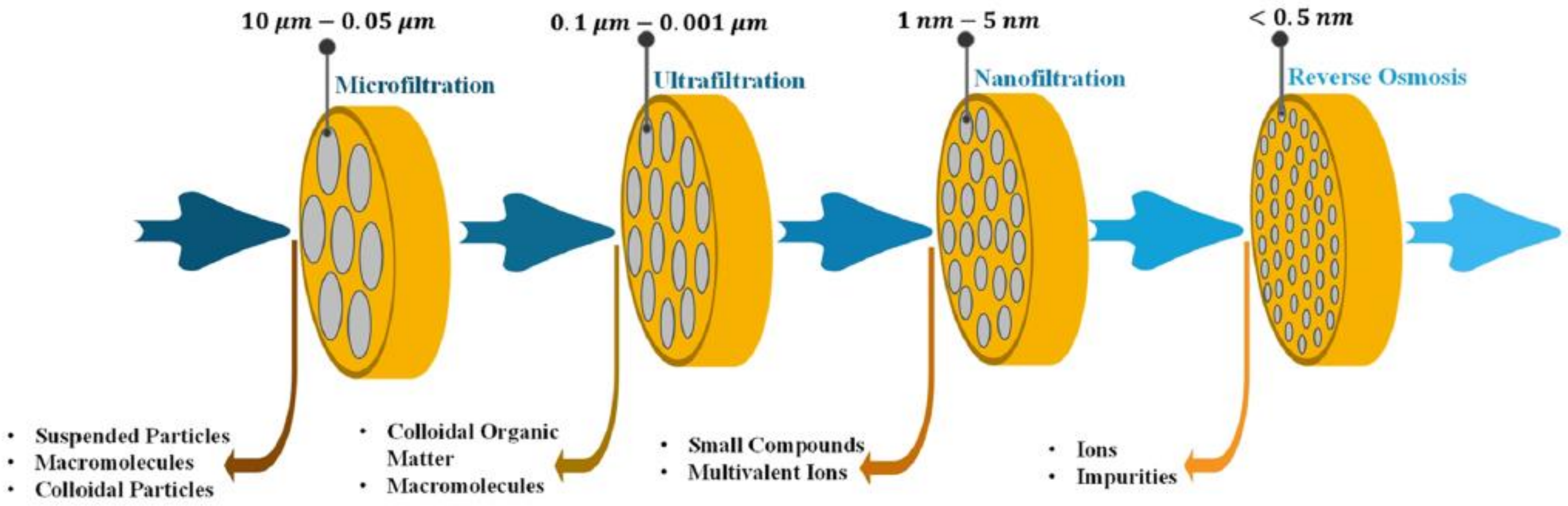
TYPES OF ADSORBENTS



ACTIVATED CARBON LIQUID TREATMENT



MEMBRANE CHARACTERISTICS



MEMBRANE SEPARATIONS

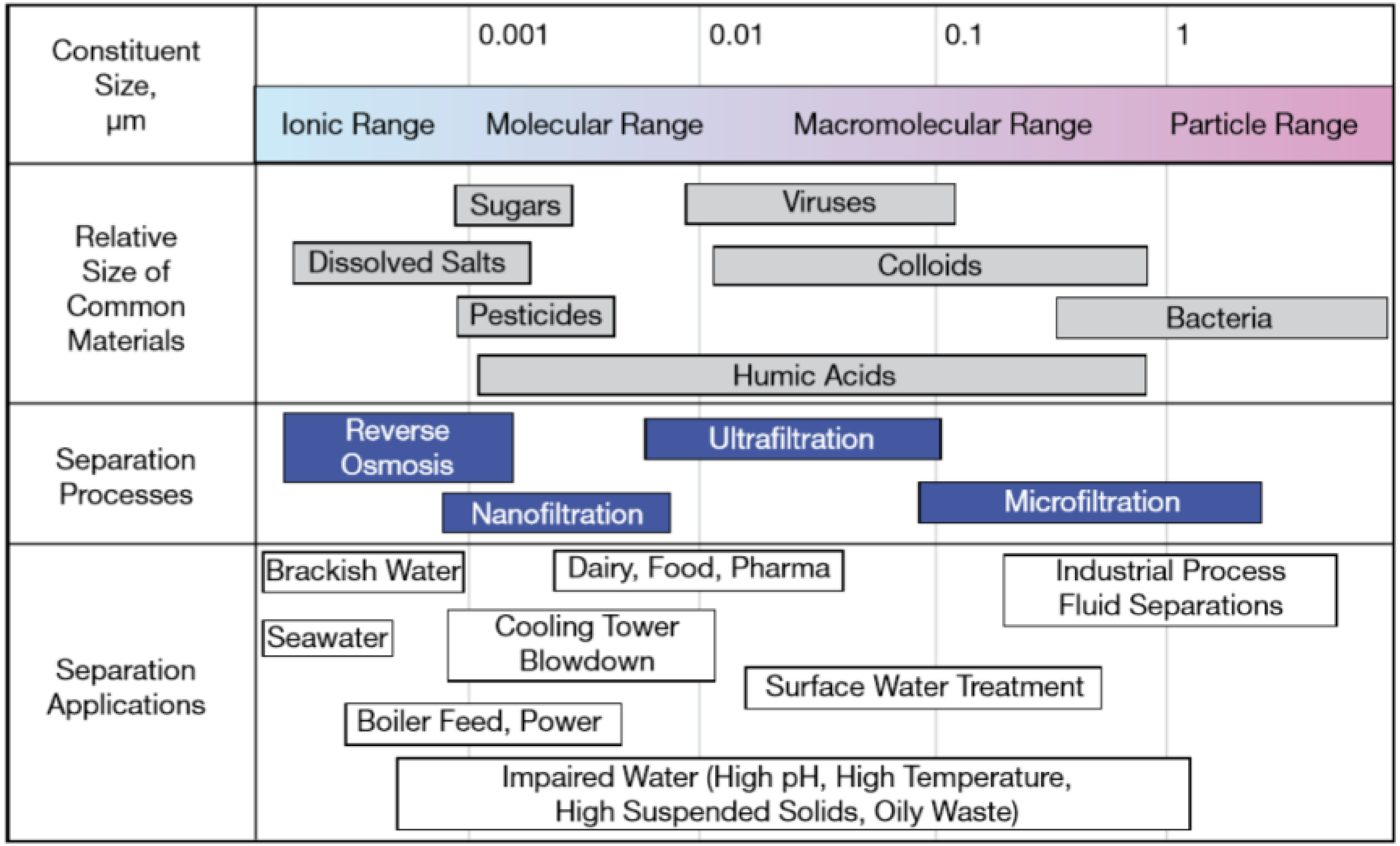


Table 1. The chemical potential gradient, or driving force, in membrane separation processes can arise from a pressure, concentration, or temperature difference.	
Driving Force	**Membrane Process**
Pressure Difference	Reverse Osmosis, Nanofiltration, Ultrafiltration, Microfiltration
Concentration Difference	Pervaporation (PV)
Temperature Difference	Membrane Distillation (MD)

Table 2. Microporous and nonporous (dense) membranes employ different mechanisms of separation.		
Morphology	**Separation Mechanism**	**Membrane Process**
Microporous	Size Exclusion	Ultrafiltration, Microfiltration
Nonporous (dense)	Solution-Diffusion	Reverse Osmosis, Nanofiltration, Pervaporation, Gas Separation

Table 3. Characteristics of commercial pressure-driven membranes *(7)*.				
	Reverse Osmosis	**Nanofiltration**	**Ultrafiltration**	**Microfiltration**
Membrane	Asymmetric, Thin-Film Composite	Asymmetric, Thin-Film Composite	Asymmetric	Symmetric, Asymmetric
Pore Size	Nonporous	Nonporous	0.002–0.1 µm	0.1–10 µm
Total Thickness	150 mm	150–250 mm	150–250 mm	10–150 mm
Thin Film	1 mm or less	1 mm or less	—	—
Rejected Components	HMWC, LMWC, Sodium Chloride, Glucose, Amino Acid	HMWC, Mono-, Di-, and Oligosaccharaides, Multivalent Ions	Macromolecules, Proteins, Virus, Polysaccharides	Particles, Clay, Bacteria
Membrane Material(s)	Polymeric (thin-film composite and integrally skinned)	Polymeric (thin-film composite and integrally skinned)	Polymeric, Ceramic	Polymeric, Ceramic
Membrane Module	Spiral-Wound, Plate-and-Frame	Spiral-Wound, Plate-and-Frame	Spiral-Wound, Hollow-Fiber, Plate-and-Frame	Hollow Fiber
Operating Pressure	5–84 bar (100–1,000 psi)	3.5–16 bar (50–225 psi)	1–7 bar (15–100 psi)	0.7–3.5 bar (10–50 psi)

HMWC: high-molecular-weight components (*e.g.,* protein molecules). LMWC: low-molecular-weight components (*e.g.,* NaCl).

Table 4. Membrane separation is used in a wide range of commercial applications *(7)*.

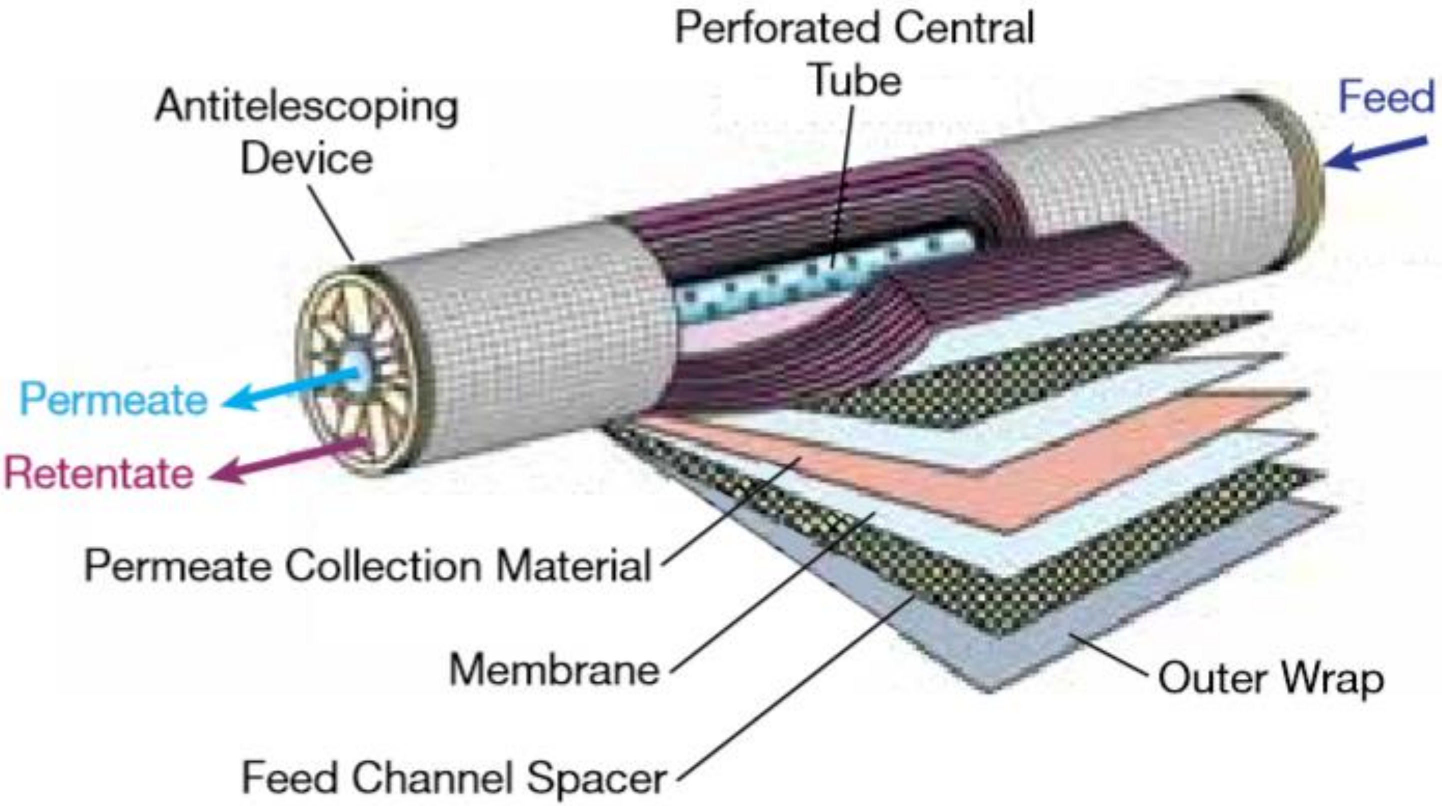
	Feed	Permeate	Concentrate
Reverse Osmosis	Water	Low-salinity water	Salty water
	Whey	Low-BOD permeate	Whey concentrate
	Dyeing effluent	Clean water	BOD, salt, chemicals, waste products
Nanofiltration	Water	Softened water	Waste product
	Antibiotics	Salty waste product	Desalted, concentrated antibiotics
	Whey	Salty wastewater	Desalted whey concentrate
	Dyeing effluent	Clean, salty water	BOD/COD, color
Ultrafiltration	Water	Clarified water	Waste product
	Oil emulsion	Oil-free water (≤10 ppm)	Highly concentrated oil emulsion
	Enzymes	Waste product	High-value product
	Washing effluent	Clarified water	Dirty water (waste product)
	Bio-gas waste	Clarified liquid for discharge	Microbes to be recycled
	Milk	Lactose solution	Protein concentrate for cheese production
	Antibiotics	Clarified fermentation broth	Waste product
	Carrageenan	Waste product	Concentrated carrageenan
Microfiltration	Water	Clarified water	Waste product
	Fruit juice	Clear juice	Waste product (suspended solids, micro-organisms, and undesirable proteins)
	Wine	Clear wine	Waste product (fine fruit particles, spent yeast, bacteria, soil, debris, and fining agents)
	Therapeutic proteins	High-value product	Waste product
	Amino acid	Clarified fermentation broth	Waste product

Biological oxygen demand (BOD): a measure of the amount of oxygen that is consumed by bacteria during the decomposition of organic matter. Chemical oxygen demand (COD): a measure of the amount of oxygen that is consumed in the chemical decomposition of organic matter and oxidation of inorganic matter. Both BOD and COD are standard methods for indirect measurement of the amount of contaminants (that can be oxidized biologically or chemically) in a wastewater sample.

Table 5. Commonly used polymers for membrane separation processes.	
Polymer	**Membrane Type**
Polyamide	RO, NF, UF, MF
Cellulose acetate (CA)	RO, UF, MF
Polysulfone (PS)	UF, MF
Polyether sulfone (PES)	NF, UF, MF
Polyvinylidene fluoride (PVDF)	UF, MF
Polyimide (PI)	NF
Polyetherimide (PEI)	UF, MF, GS
Polyethylene (PE)	UF, MF
Polypropylene (PP)	UF, MF
Polyacrylonitrile (PAN)	UF, MF, PV
Polyethylene terephthalate (PET)	MF
Polydimethylsiloxane (PDMS)	NF, PV, GS
GS: gas separation. PV: pervaporation.	

Reverse Osmosis in WWTPs

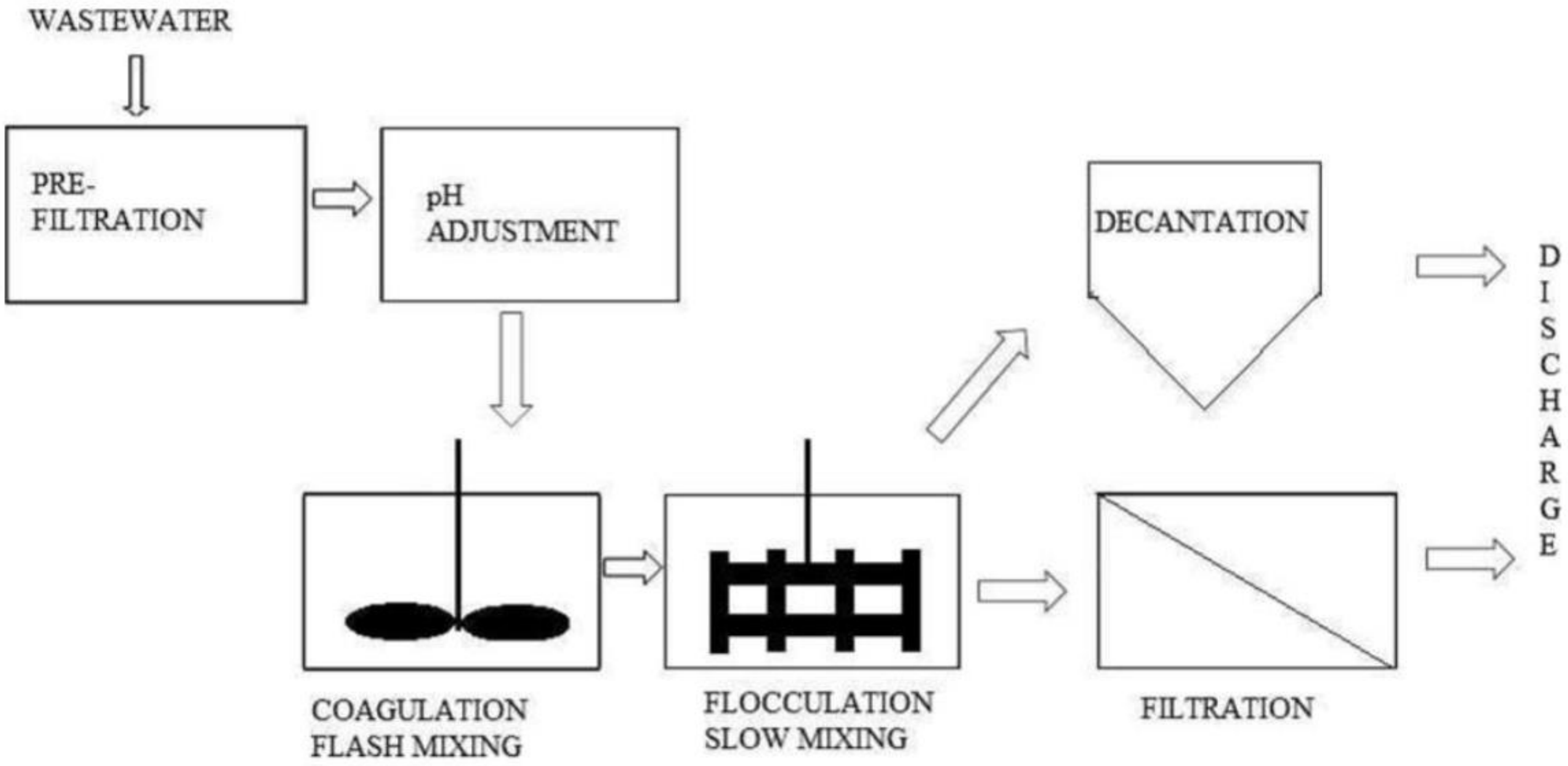
SPIRAL-WOUND MEMBRANE MODULE



CHEMICAL WASTEWATER TREATMENT

TECHNOLOGY	ADVANTAGES	DISADVANTAGES
Precipitation, Coagulation, Flocculation	Removes dissolved toxic metals 80-90% efficiency for removal of TSS	High cost of reagents Requires system controls Requires operator involvement
Chlorine dioxide	Highly effective against most pathogens Provides residual protection for drinking water Cost-effective Around 50% efficiency for removal of TSS	Forms trihalomethanes as byproducts Requires special operator training Not effective against *Cryptosporidium*
UV radiation	Effective sanitizing treatment 99% efficiency for bacteria and virus removal	Low dosage may be inadequate Turbidity and TSS makes UV ineffective
Ion exchange	Very low operating cost Long resin life 90-98% efficiency	Organic matter or Fe^{3+} ions in water can foul the resin

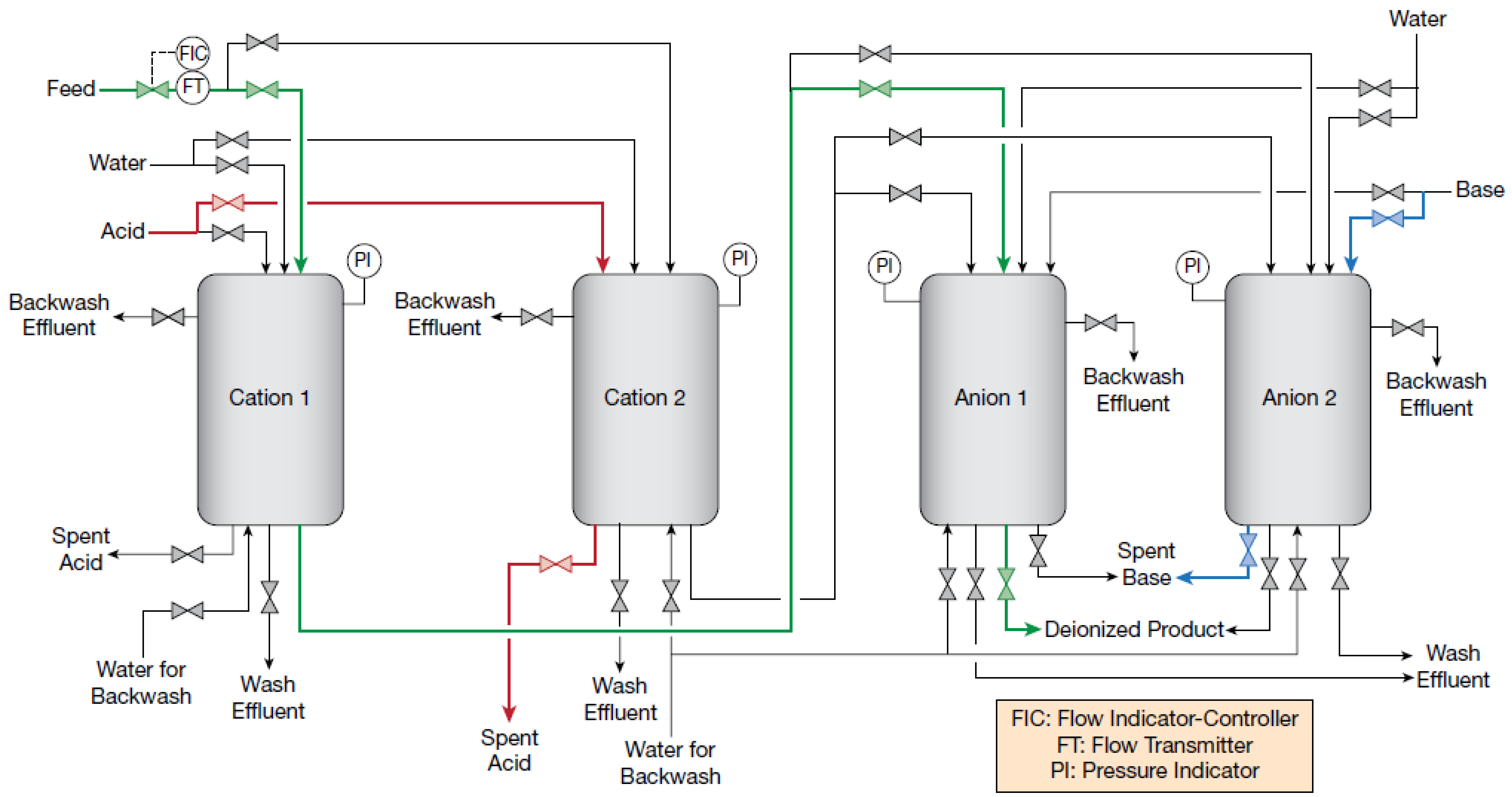
COAGULATION-FLOCCULATION



ION EXCHANGE RESINS

	Strong Acid	Strong Base	Weak Acid	Weak Base
Functional Group	Sulfonic Acid ($-SO_3H$)	Quaternary Ammonium ($-NR_4OH$; R is usually CH_3)	Carboxyl (COOH)	Most Common: Tertiary Amine ($-N(CH_3)_3$)
Operating pH	Entire Range	Entire Range	Above 6	Below 7
Able to Split Neutral Salts?	Yes	Yes	No	No
Amount of Regenerant Required (% of stoichiometric)	130	130	100	100
Reversible Swelling	≤10% ($Na^+ \rightarrow H^+$)	10–30% ($Cl^- \rightarrow OH^-$)	50–100% ($H^+ \rightarrow Na^+$)	20–50% (free base $\rightarrow Cl^-$)
Exchange Capacity, eq/L	1.5–2.5	0.5–1.5	3–5	1–3

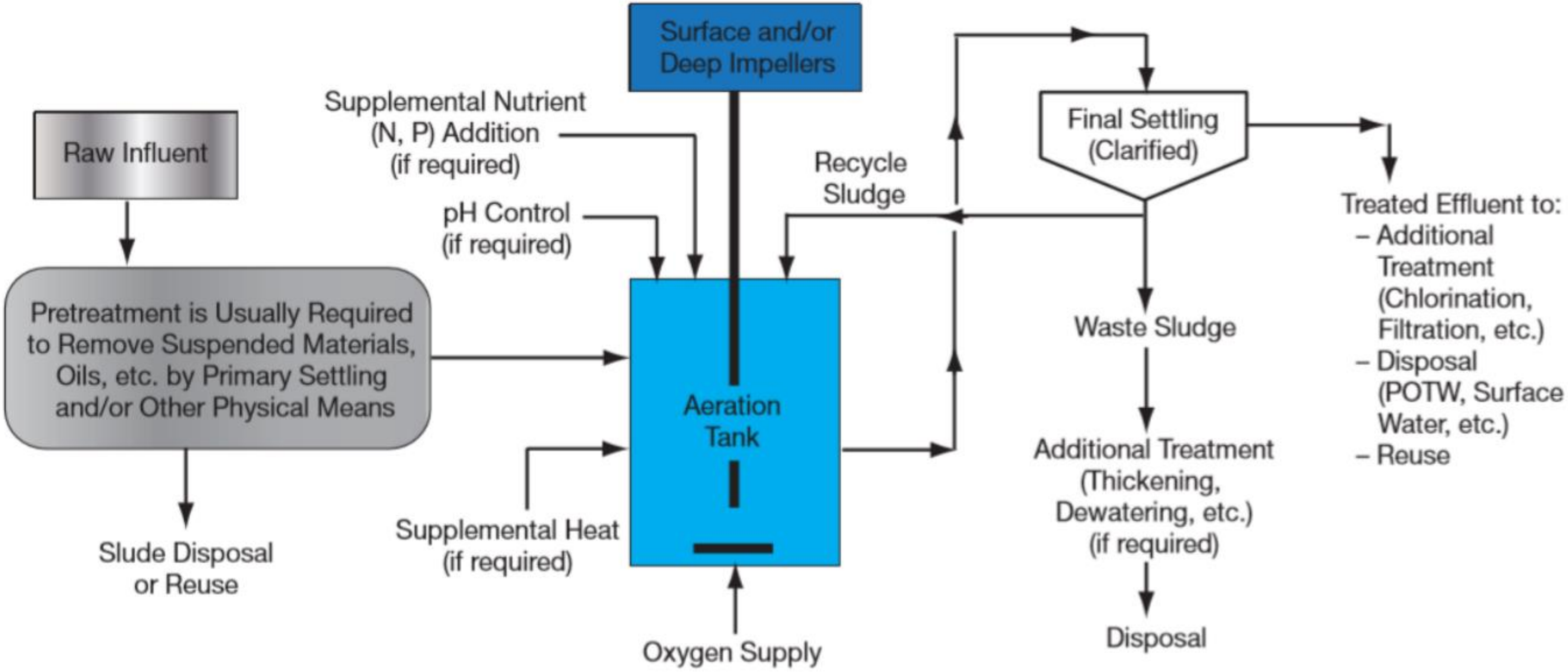
ION EXCHANGE PROCESS



BIOLOGICAL WASTEWATER TREATMENT

TECHNOLOGY	ADVANTAGES	DISADVANTAGES
Activated sludge	High efficiency Small footprint 90% efficiency for ammonia removal	High cost Requires sludge disposal area Requires technically skilled manpower
Stabilization ponds	Low capital cost Low operation and maintenance cost Low technical manpower requirement 80% efficiency for nitrogen removal	Requires a large land area May produce undesirable odors Very long treatment times
Facultative ponds	Performs aerobic and anaerobic activities 80% efficiency of BOD removal	Large algal growth High SS concentration Long retention time
Constructed wetlands	Natural wetlands act as bio-filters Removes sediments and heavy metals 70% efficiency for solids and bacteria removal	Excessive amounts of sediment can reduce performance over time

ACTIVATED SLUDGE PROCESS



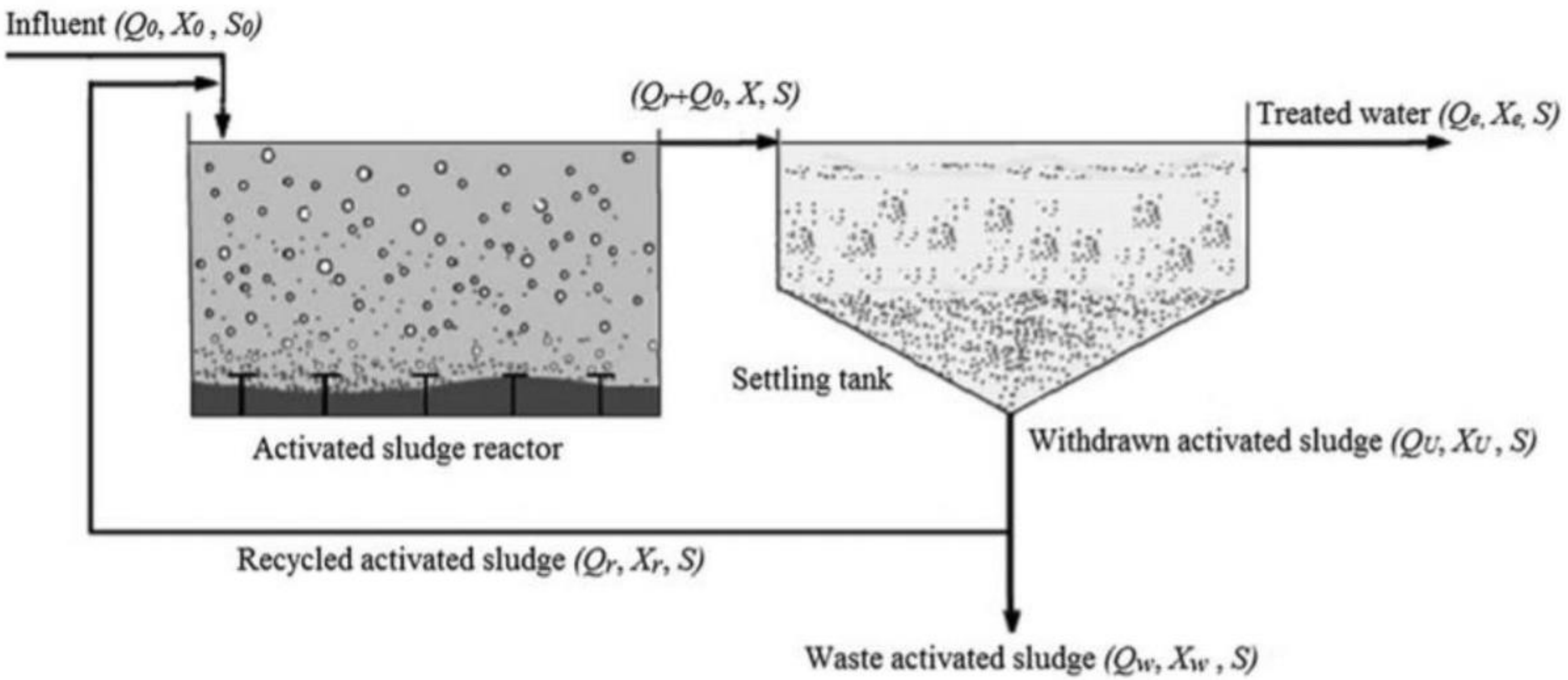
ACTIVATED SLUDGE PROCESS

CHEMICAL	CONCENTRATION, ppm	TYPICAL REMOVAL
Phenolics	1000 to 1000	>99%
PAHs	0.01 to 1	>95%
Oil & Grease	10 to 100	40 to 92%
TOC	500 to 3000	>90%
Ammonia (-N)	10 to 1000	>95%
Cyanide, Thiocyanide	1 to 1000	40 to 98%
Metals (As, Hg, Zn)	0.5	Settles with sludge
Benzene, Toluene, Xylene	5 to 1000	>99%

WASTEWATER FEATURES	DESIGN VARIABLES
Flow rate	Hydraulic retention time
Water quality	Sludge retention time
Toxic or inhibitory compounds	Recycle ratio (r)
	Optimum HRT, SRT & r
	Oxygen requirements
	Bacterial growth and decay factors
	Sludge settling factors

ACTIVATED SLUDGE PROCESS

PROBLEM	PROBABLE CAUSE	REMEDY
Low or high pH in the aeration basin	Extremely high or low pH in influent No biological activity	Add acid or alkali to the aeration tank Reduce phenols and oils, or add P and DO in the aeration tank
Low DO concentration in the aeration tank	Influent feed rate is too high or influent has slug of organics MLTSS concentration is too high	Reduce feed until DO concentration goes above 1 mg/L Lower SRT by wasting more sludge
High TSS concentration in water	Presence of unwanted bacteria Clarifier is overloaded	Increase DO or reduce influent organics by reducing feed flow rate Determine whether recycle ratio and feed rates are properly set



Technological sketch of a typical activated sludge plant

Referring to Fig. 1, the overall mass balance equation for the plant with respect to the microorganisms and the substrate can be written as follows:

$$V_r(dX/dt) = Q_0X_0 - Q_wX_w - Q_eX_e + V_r r'_g \quad (1a)$$

$$V_r(dS/dt) = Q_0S_0 - Q_wS - Q_eS + V_r r_{su} \quad (1b)$$

where V_r (m^3) is the reactor volume, r'_g is the net growth rate of the microorganisms (kg/m^3 day), r_{su} is the substrate utilization rate (kg/m^3 day) and t is the time (d).

Following Monod kinetics of growth rate for the microorganisms r'_g can be expressed as follows (Metcalf and Eddy 1998):

$$r'_g = -Yr_{su} - k_dX \quad (2)$$

where Y (kg/kg) is the maximum yield coefficient (defined as the ratio of the mass of the new cells formed to the mass of the substrate consumed, measured during any finite period of logarithmic growth), k_d is the endogenous decay coefficient (d^{-1}).

If all the food in the system is converted to biomass, relationship between food utilization rate (dS/dt) and biomass utilization rate (dX/dt) can be written as follows:

$$-\frac{\mathrm{d}S}{\mathrm{d}t} = \frac{1}{Y}\frac{\mathrm{d}X}{\mathrm{d}t}. \tag{3}$$

Combining Eqs. (1–3) for steady state condition, we obtain

$$\theta = \frac{1}{k_\mathrm{d}}\left[\frac{Y(S_0 - S)}{X} - \frac{\beta(1+\alpha)}{\alpha+\beta}\right] \text{ with } \alpha = Q_\mathrm{r}/Q_0, \tag{4}$$

and $\beta = Q_\mathrm{w}/Q_0$ and $\theta = V_\mathrm{r}/Q_0$

where θ is the hydraulic retention time, α is the sludge recycle ratio and β is the sludge waste ratio.

Equation (4) gives the required volume of the activated sludge reactor for given value of the operating parameters α, β, S_0 and S, and the assumed sludge concentration X in the reactor. This equation clearly indicates that with an increase in the activated sludge concentration in the reactor, the volume of the reactor required to achieve assigned treatment level decreases.

From the mathematical viewpoint, the sludge concentration X may assume any value higher than zero, resulting in positive, negative or zero reactor volume. But for ensuring proper environment for biochemical reaction in the reactor, some restrictions must be imposed to X in order to maintain the 'food to microorganism ratio' F/M in the reactor in a defined range. The restriction is given by the following relation:

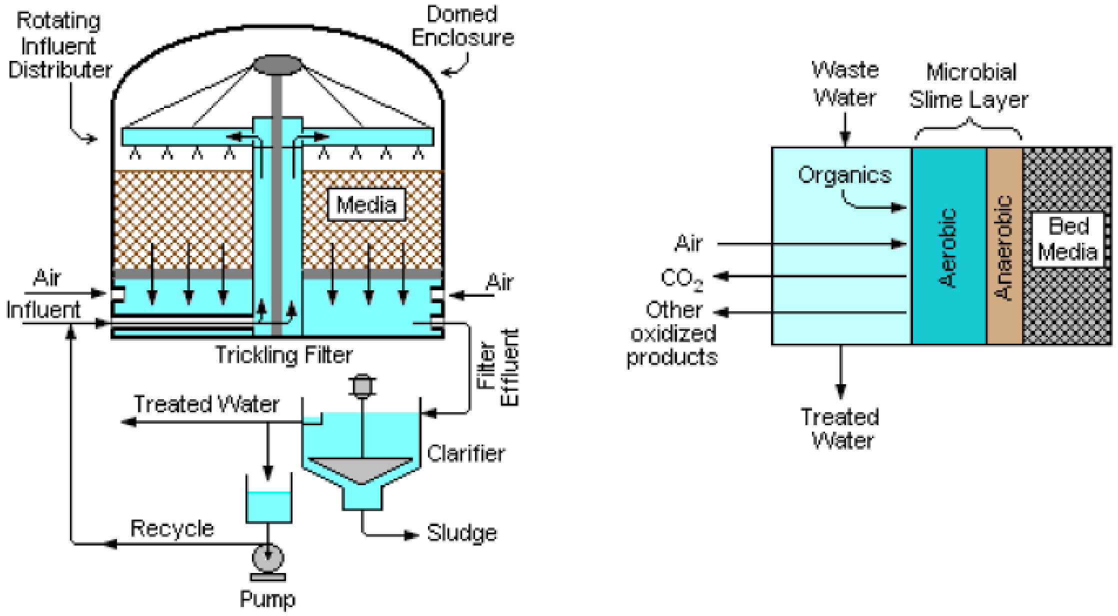
$$f_{\min} \leq F/M = \frac{S_0}{\theta X} \leq f_{\max} \tag{5}$$

where f_i is some assigned value to F/M ratio. The F/M ratio is usually recommended to be in the range of (0.2, 1.0) (Metcalf and Eddy 1998). Combining Eq. (4) and Equation/Inequality (5), we obtain

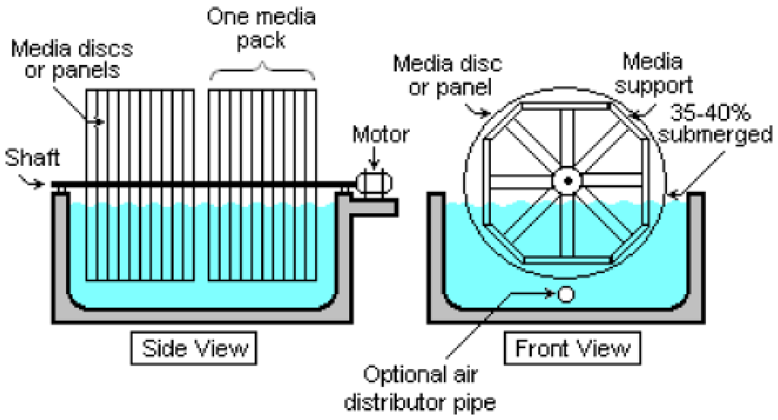
$$\begin{aligned}&\frac{\alpha+\beta}{\beta(1+\alpha)}\left[Y(S_0-S)-\frac{S_0k_d}{f_{\min}}\right]\\&\leq X \leq \frac{\alpha+\beta}{\beta(1+\alpha)}\left[Y(S_0-S)-\frac{S_0k_d}{f_{\max}}\right]\end{aligned} \tag{6}$$

with

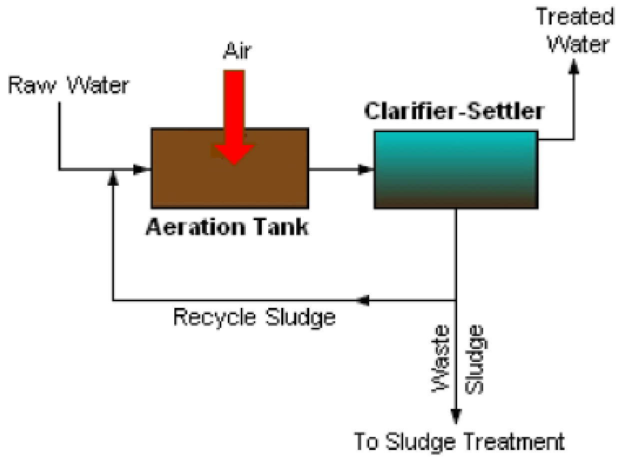
$$\begin{aligned}X_{\min} &= \frac{\alpha+\beta}{\beta(1+\alpha)}\left[Y(S_0-S)-\frac{S_0k_d}{f_{\min}}\right] \text{ and } X_{\max}\\&= \frac{\alpha+\beta}{\beta(1+\alpha)}\left[Y(S_0-S)-\frac{S_0k_d}{f_{\max}}\right],\end{aligned} \tag{6a}$$



Trickle-bed filter



Rotating biological contactor



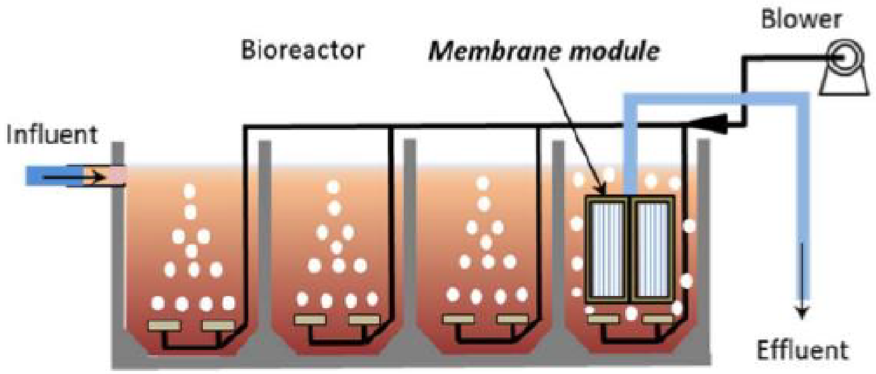
Activated sludge process

FUTURE FOCUS

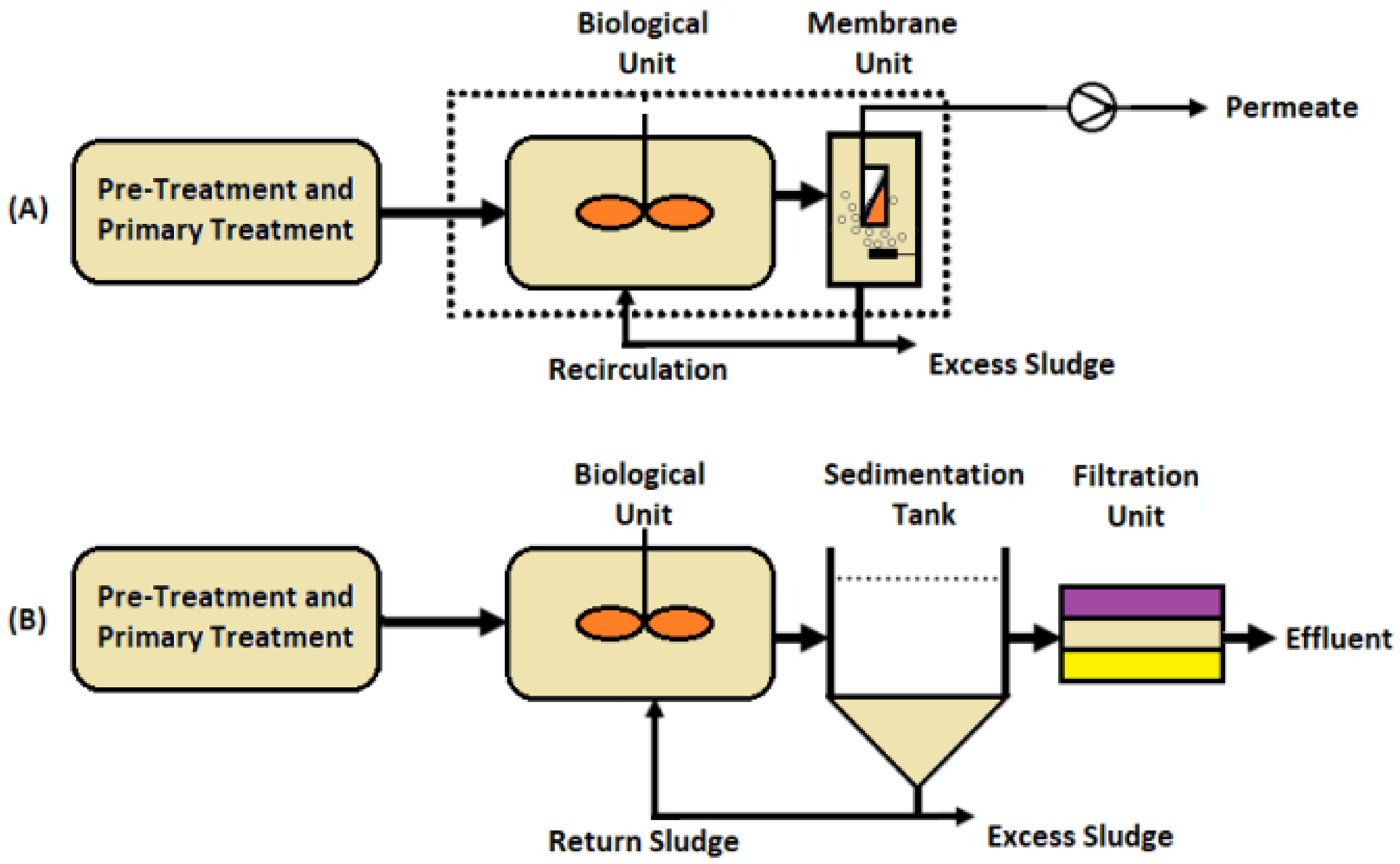
Membrane bioreactor (MBR) process

The MBR process combines microporous membranes for solid-liquid separation with a suspended-growth activated-sludge bioreactor. Such a design obviates the need for an external filter or secondary clarifiers.

MBR technology is becoming increasingly competitive, and products are available for domestic, municipal and industrial applications. European countries currently have the largest number of full-scale MBR plants.



MEMBRANE BIOREACTOR



Anaerobic Digestion

- It is a biological treatment in absence of air or elemental oxygen.

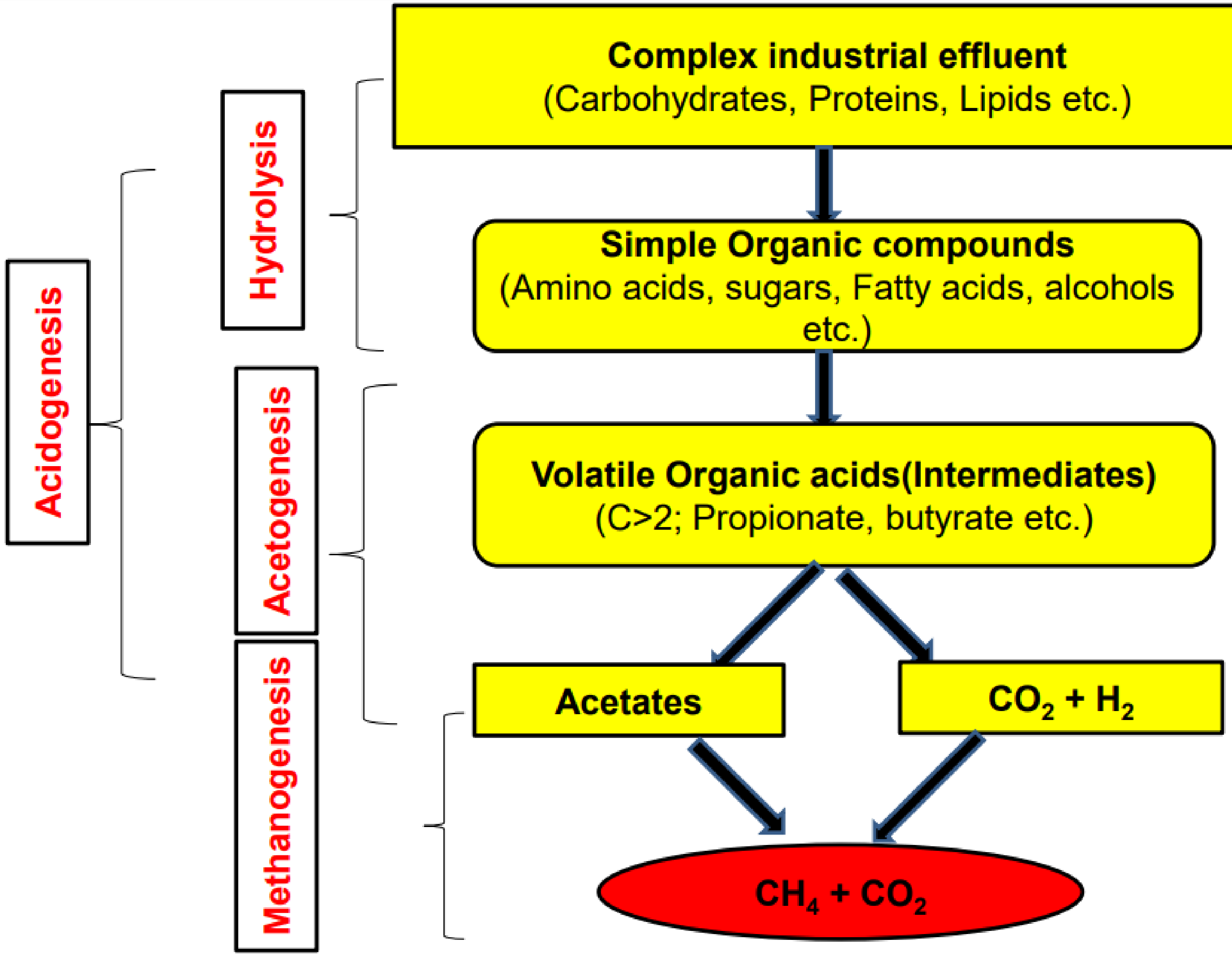
$$\textit{Organic materials} + \textit{Nutrients} \xrightarrow{\textit{Anaerobic microbes}} CH_4 + CO_2 + \textit{Biomass (10\%)}$$

- **Examples:** Cow dung, activated sludge from previous process, selective methanogens such as Methanobacterium formicium, Methanococcus frisius etc.

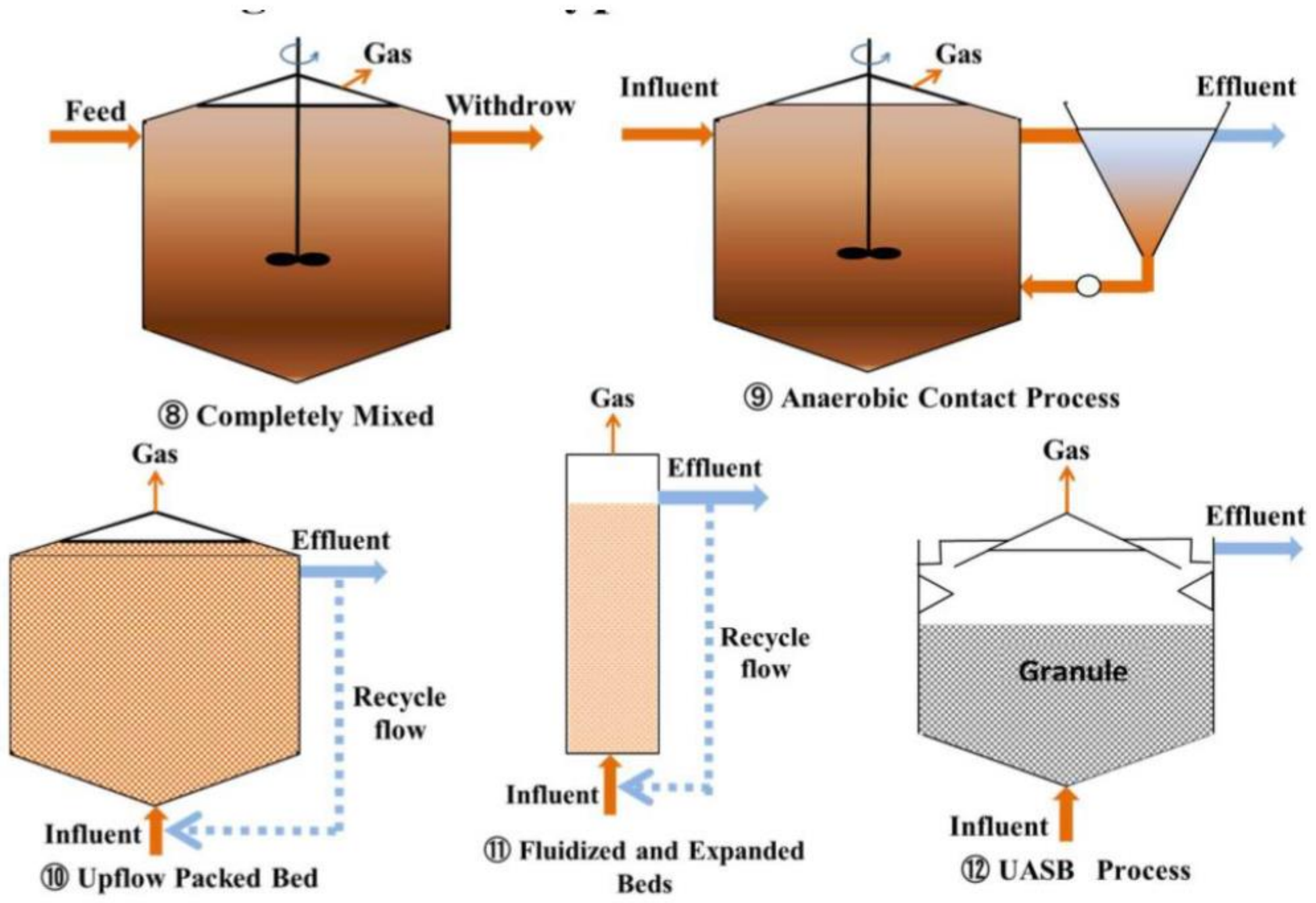
- **Conditions for efficient anaerobic treatment:**

✓ No air/O_2 exposure
✓ Maintain pH between 6.8-7.8
✓ No rapid changes in temperature.
✓ No toxic/refractory components present in the influent.
✓ Enough nutrients (N & P) and trace metals especially, Fe, Co, Ni etc.

ANAEROBIC TREATMENT



Reactor Configurations in Anaerobic Treatment



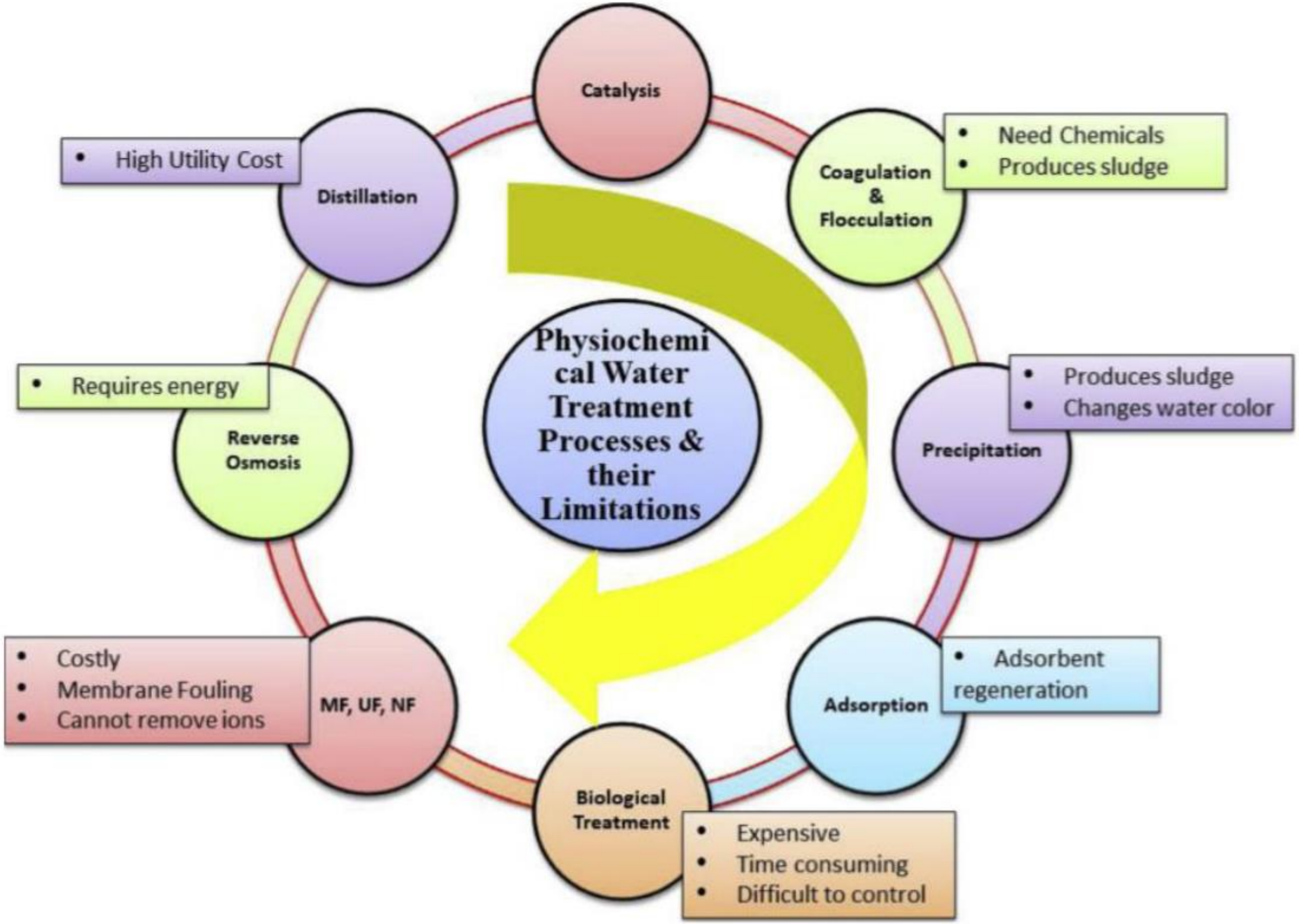
ANAEROBIC TREATMENT

ADVANTAGES	Low production of waste biological solids
	Low nutrient requirements
	Methane is a useful end-product
	Generally, a net energy producer
	High organic loading is possible
DISADVANTAGES	Low growth rate of microorganisms
	Odor production
	High buffer requirement of pH control
	Poor removal efficiency with dilute wastes

Comparison between Anaerobic and Aerobic processes

Parameter	Anaerobic	Aerobic
Organic loading rate	High (10-40 kg COD/m^3.day)	Low (0.5-1.5 kg COD/m^3.day)
Biomass yield	Low (0.05-0.15 kg VSS/kg COD)	High (0.35-0.45 kg VSS/kg COD)
Start-up time	Long time: 1-2 months for mesophilic 2-3 months for thermophilic	Short time 1-2 weeks
Solid retention time (SRT)	Longer SRT essential to retain the slow growing methanogens within reactor	4-10 days are enough for activated sludge process
Environmental Factor	Highly susceptible to the changes in environment	More robust to the changes in environment

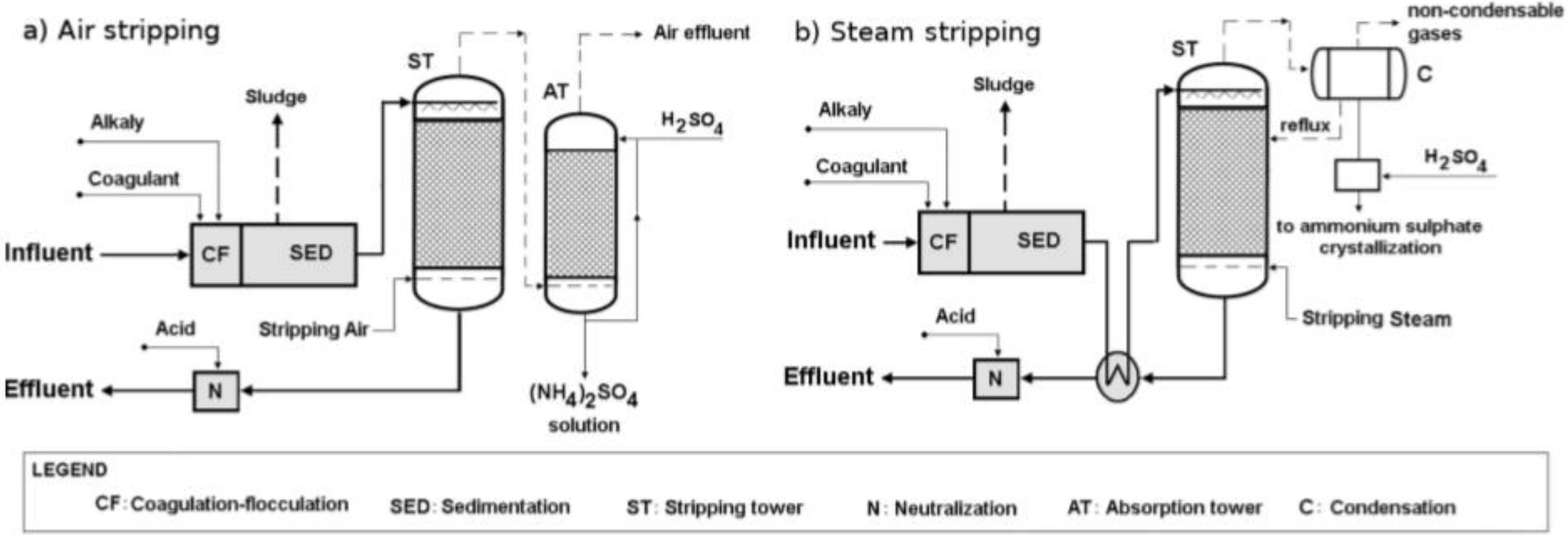
Conventional water treatment processes - Limitations



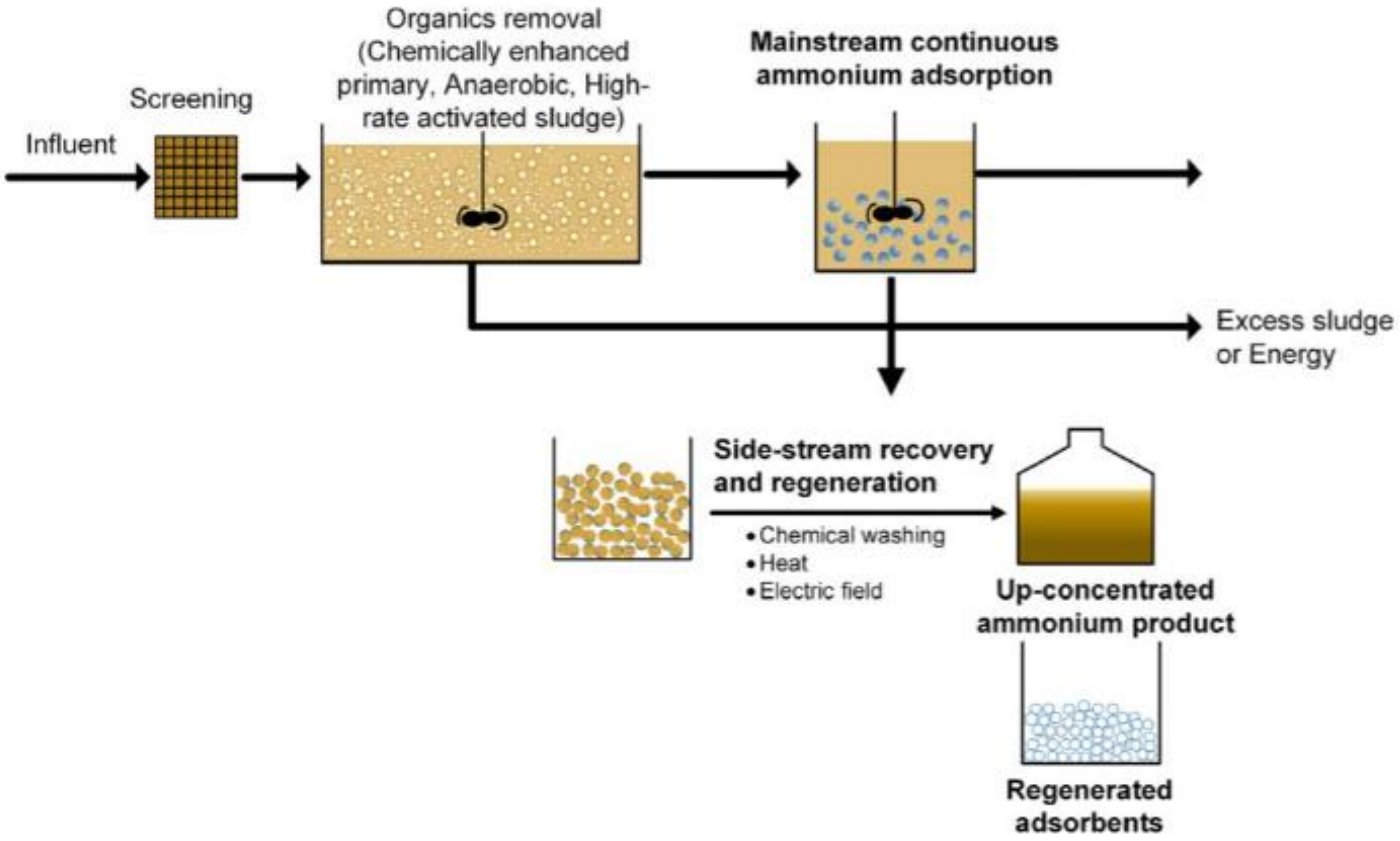
OTHER POLLUTANTS

POLLUTANT	REMOVAL STRATEGY
HEAVY METAL IONS	Chemical precipitation Adsorption and ion exchange Membrane filtration Coagulation and flocculation Flotation Electrochemical treatment
COLORANTS AND PIGMENTS	Coagulation Membrane separation Advanced oxidation processes Biological treatment
AMMONIA	Air/Steam stripping Biological treatment

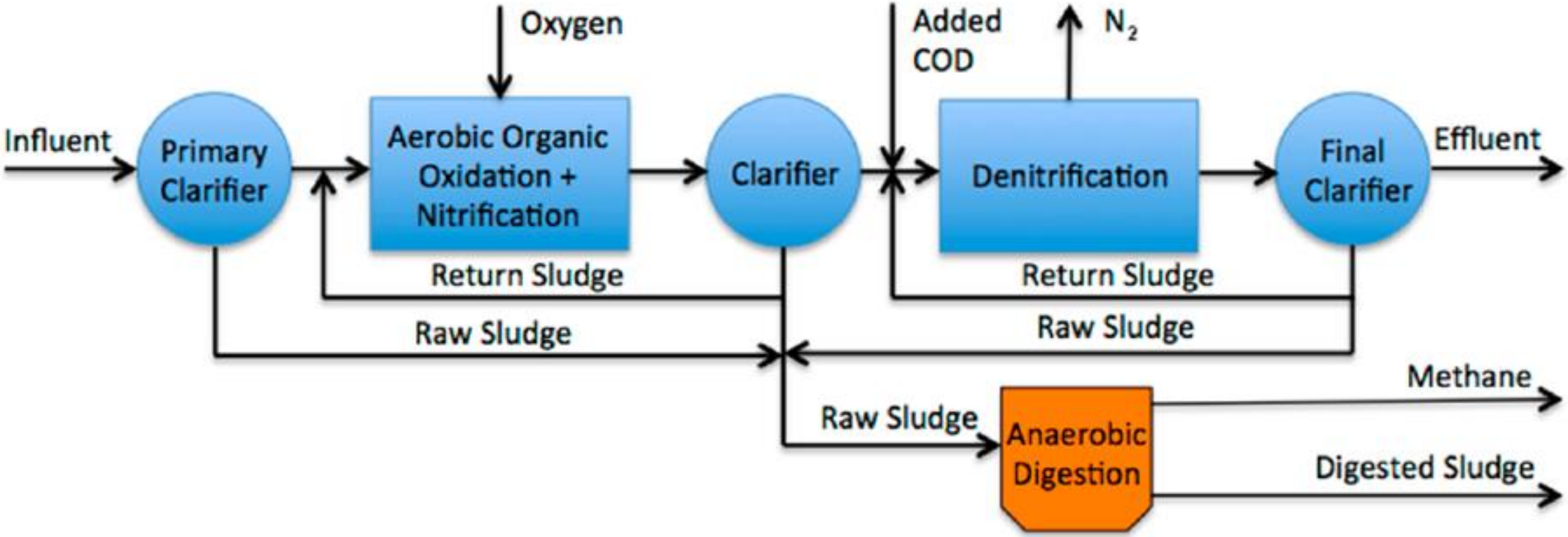
AMMONIACAL NITROGEN RECOVERY



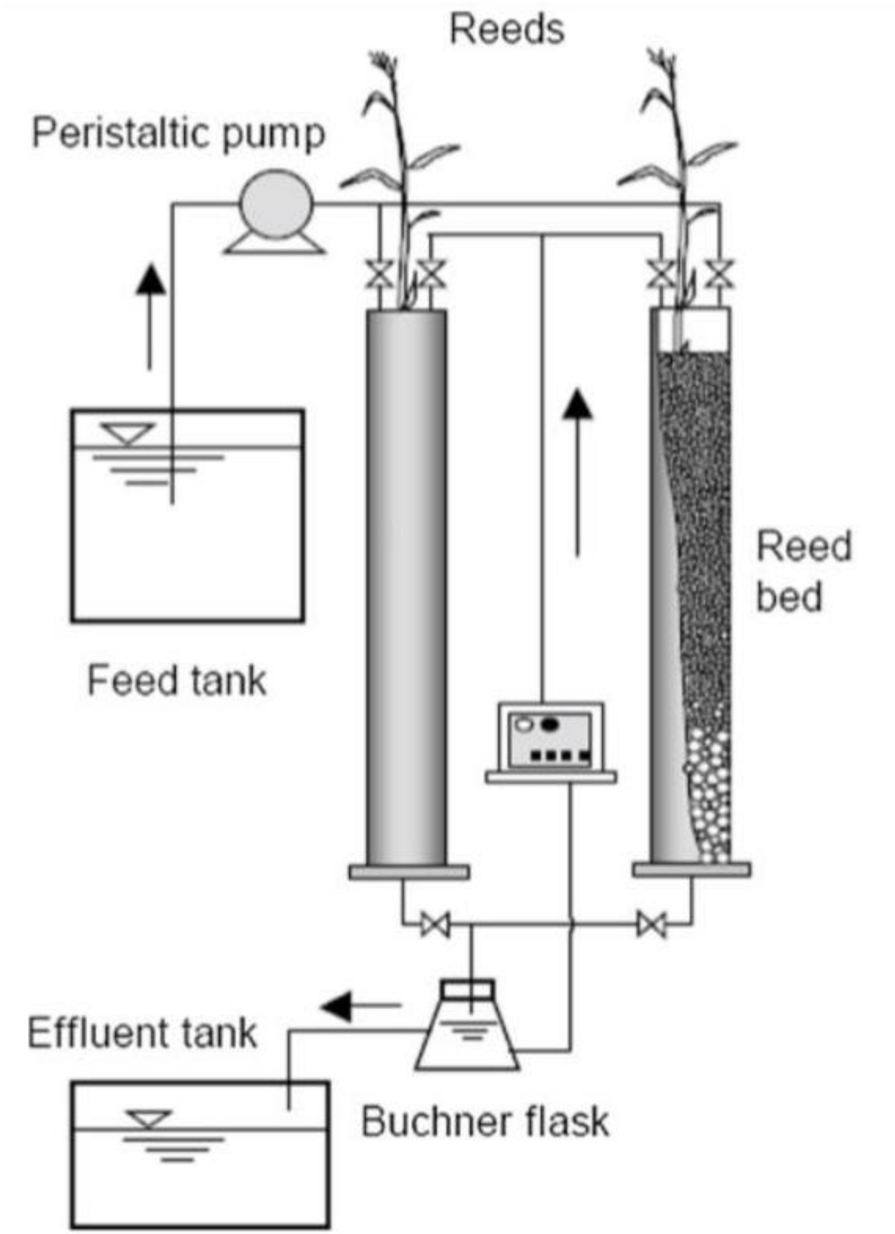
AMMONIACAL NITROGEN RECOVERY



NITRIFICATION / DENITRIFICATION FOR NITROGEN REMOVAL



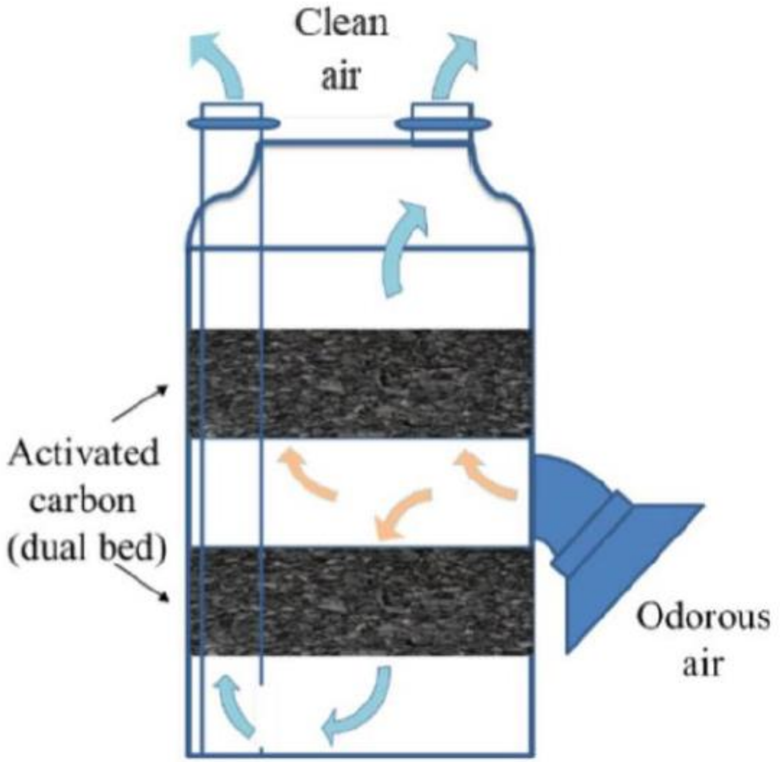
Reed bed system for ammonia removal process

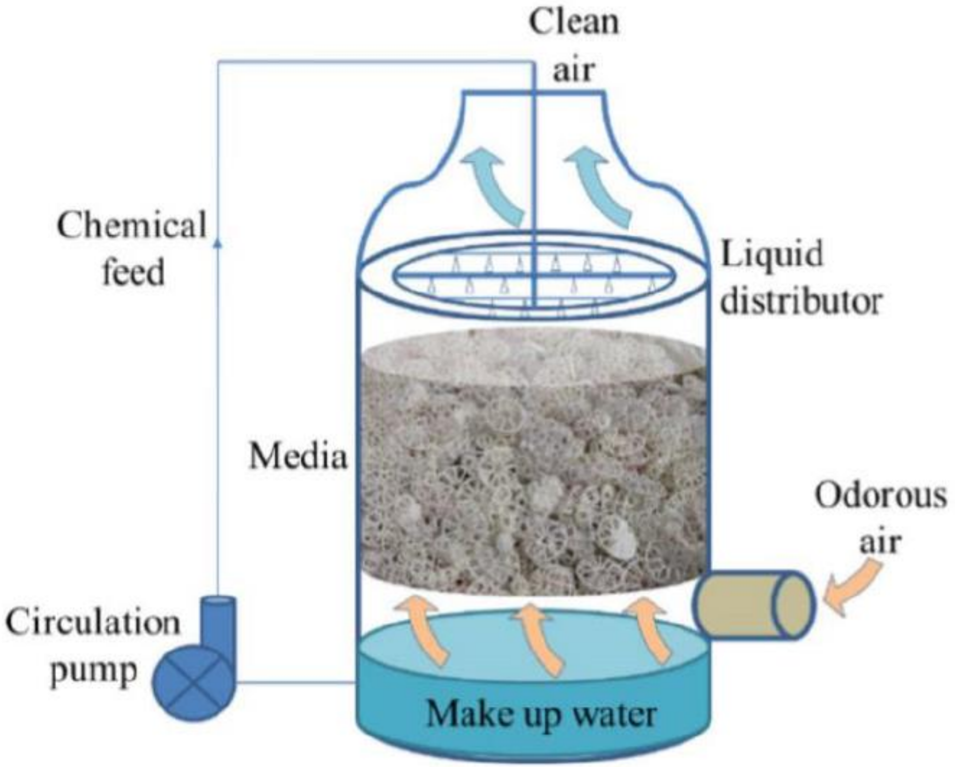


Odorous emissions from WWTPs

Compound	Odor description	Chemical formula	Odor threshold (ppb)
Ammonia	Sharp, pungent	NH_4	130–15300
Butanone	Sweet, minty, green apple	$CH_3C(O)CH_2CH_3$	270
Dimethyl sulfide	Decayed vegetables	$(CH_3)_2S$	0.12–0.4
Geosmin	Earthy, musty	$C_{12}H_{22}O$	4
Hydrogen sulfide	Rotten eggs	H_2S	0.5
Indole	Fecal, repulsive	C_8H_7N	0.3–1.4
Methyl mercaptan	Decayed cabbage, garlic	CH_4S	0.0014–18
Skatole	Fecal	C_9H_9N	0.006
Sulfur dioxide	Pungent, acidic	SO_2	9
Thiophenol	Garlic, stench	C_6H_6S	0.064

Physical/chemical abatement technologies: adsorption system (left), chemical scrubber (right)

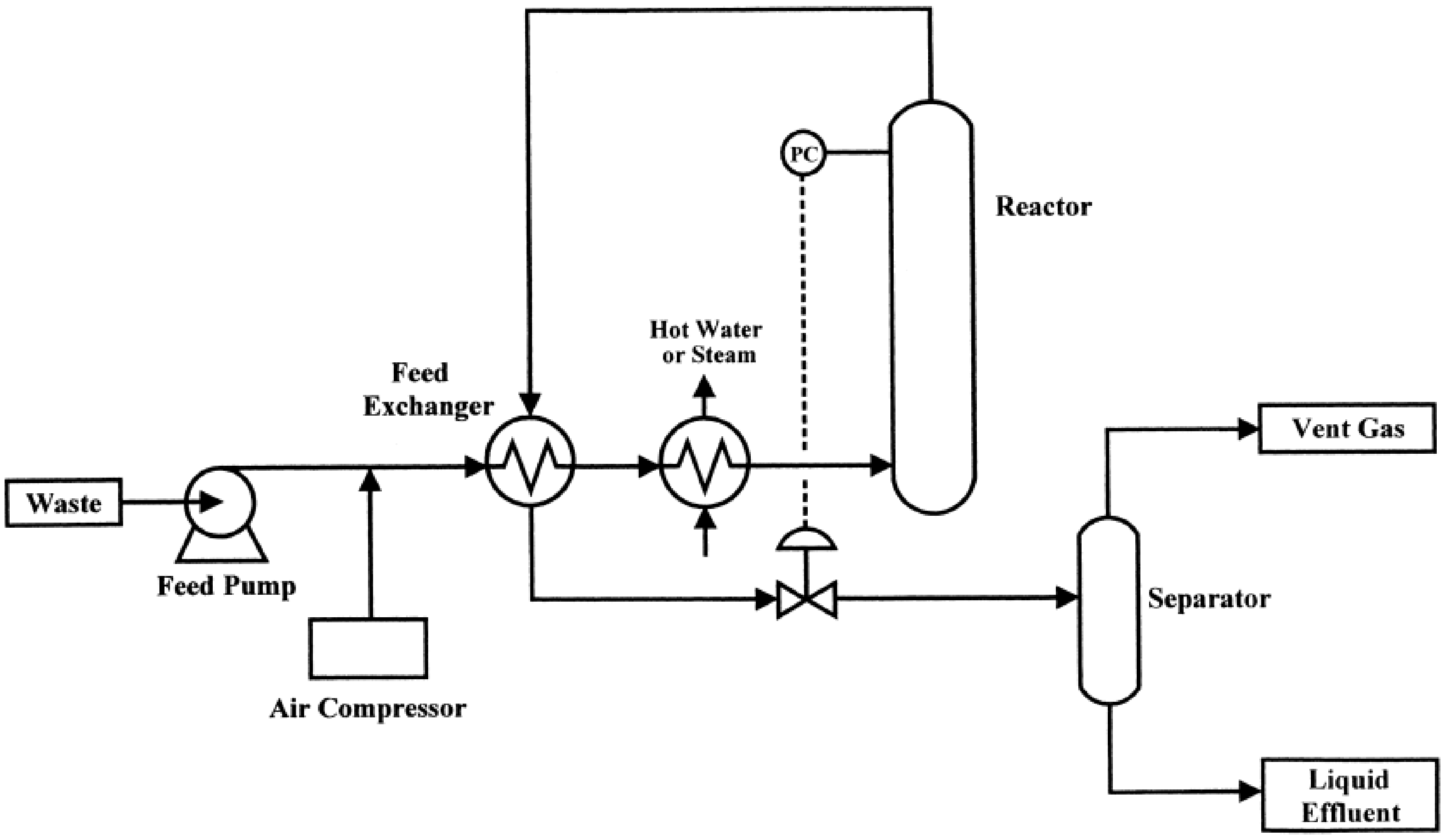




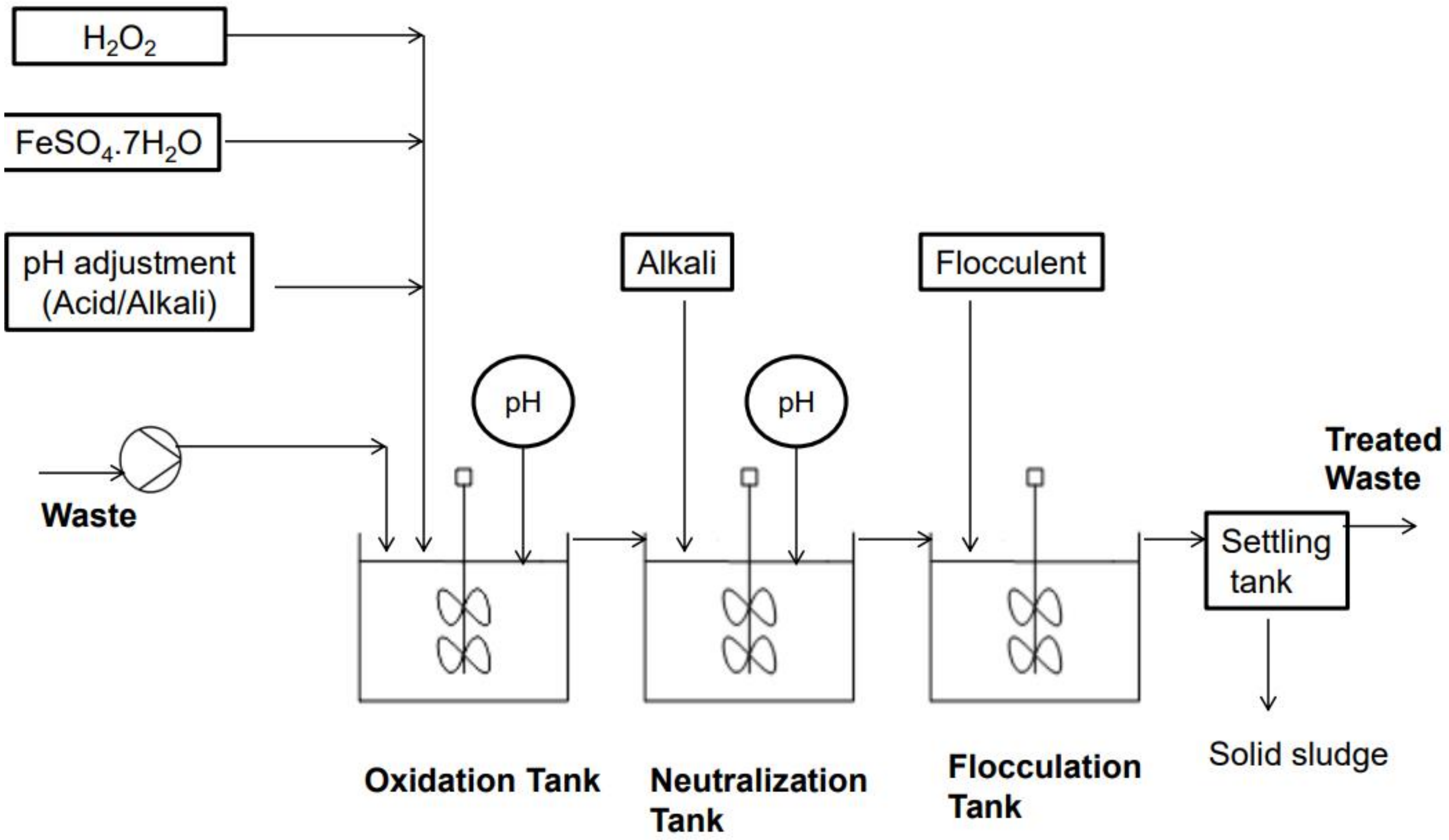
Advanced oxidation processes (AOP) for removal of organics from wastewater

These are done after primary treatment and prior to biological treatment

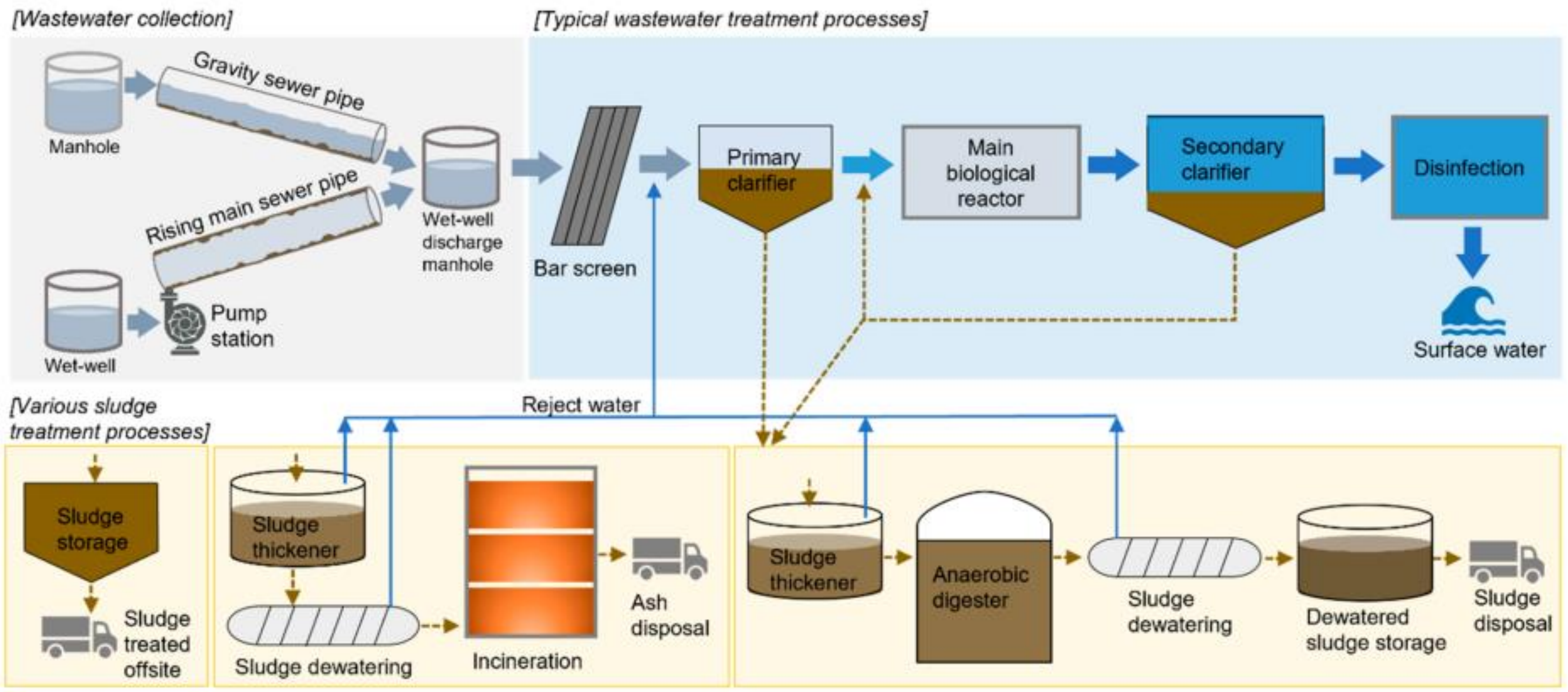
ADVANCED OXIDATION – WET OXIDATION



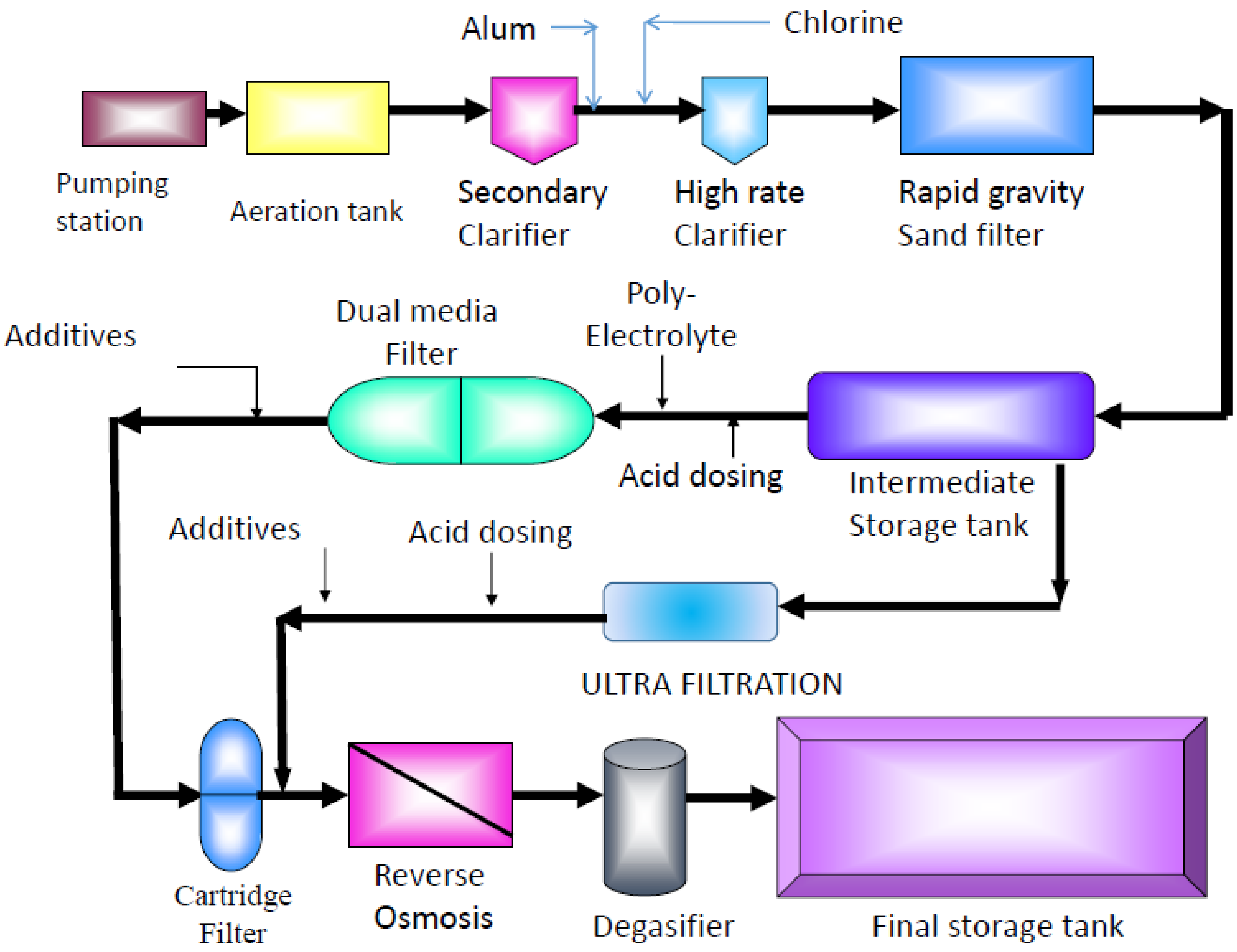
FENTON OXIDATION



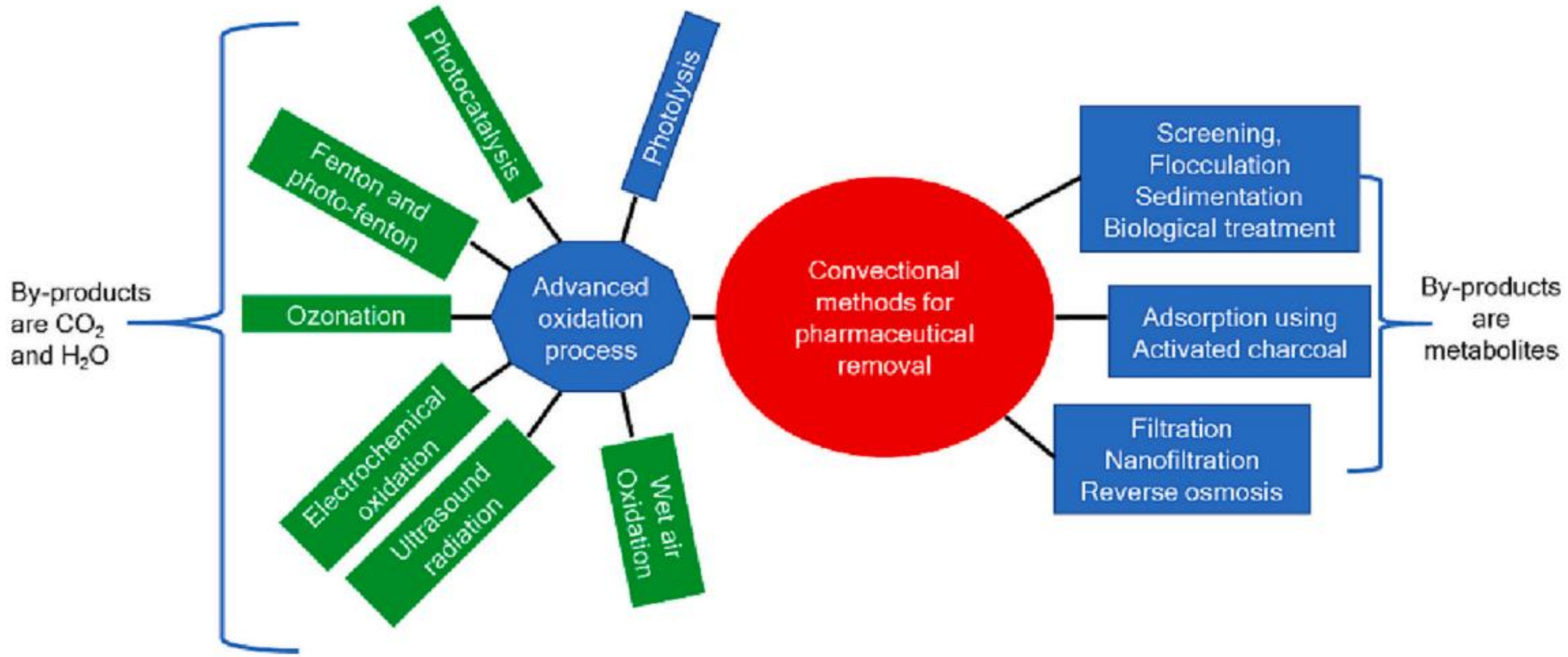
EXAMPLES – MUNICIPAL WASTEWATER



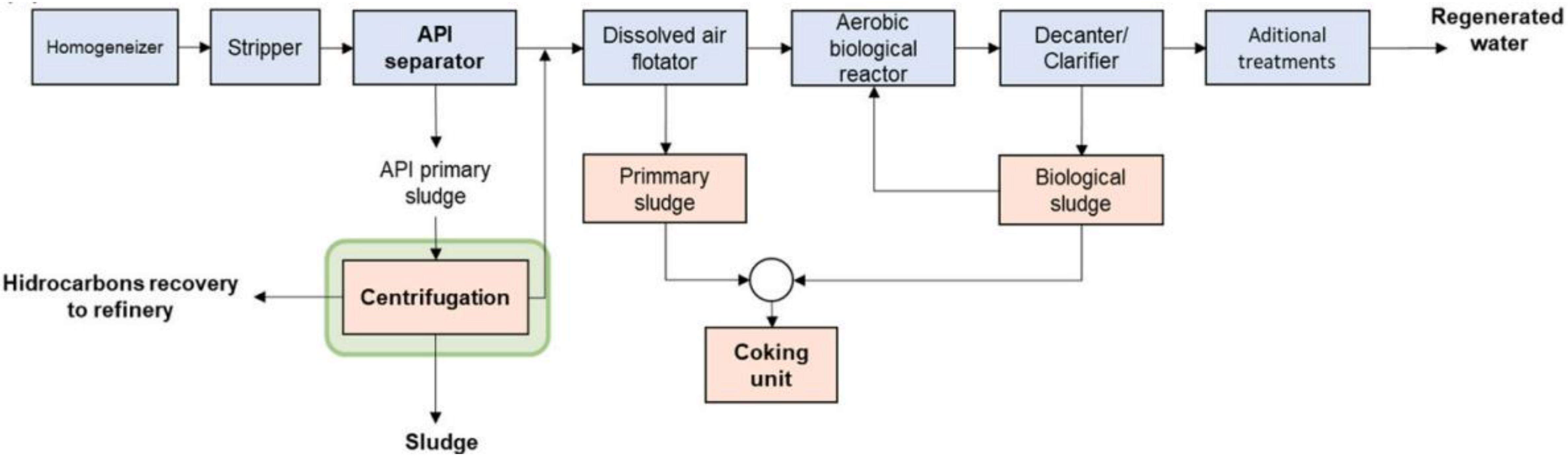
SEWAGE TREATMENT PLANT



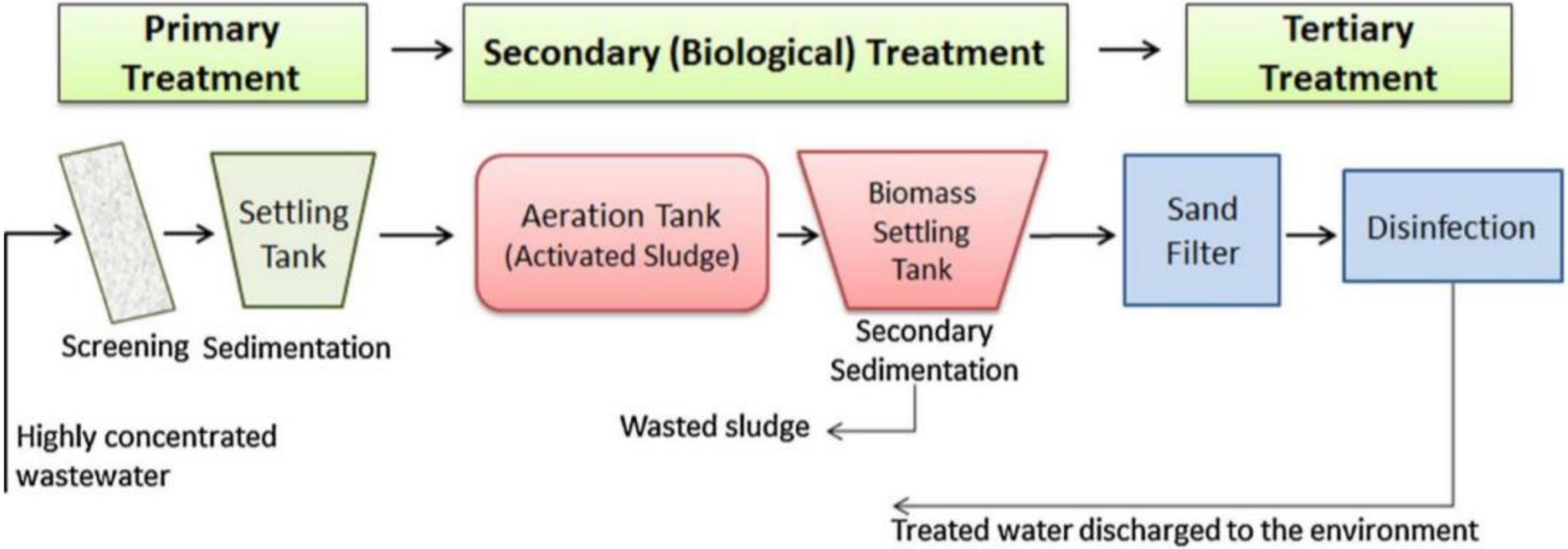
PHARMACEUTICAL WASTEWATER



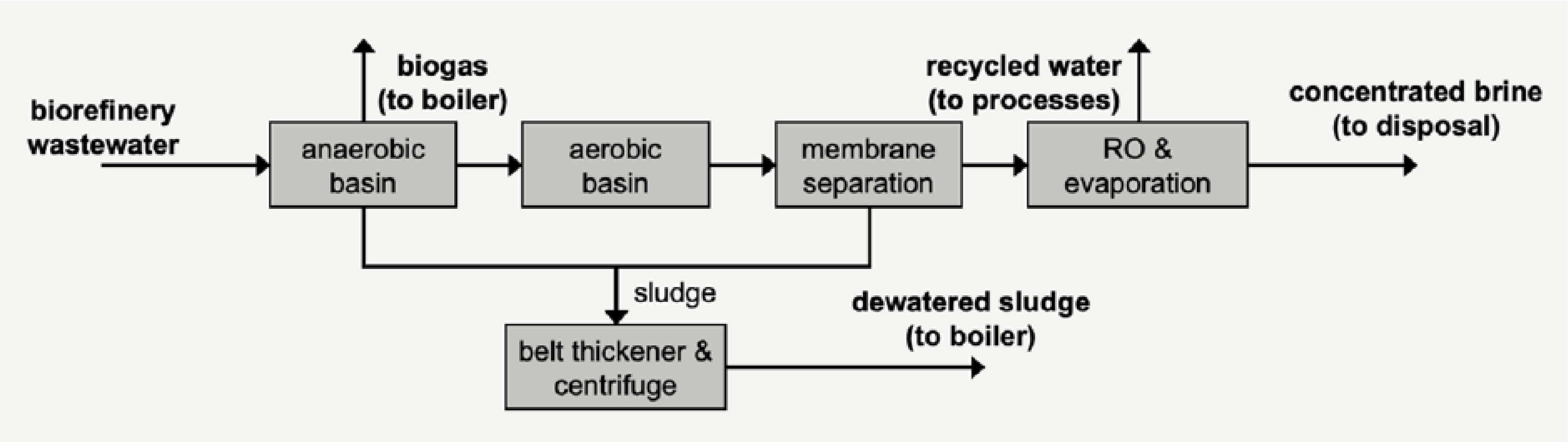
REFINERY WASTEWATER



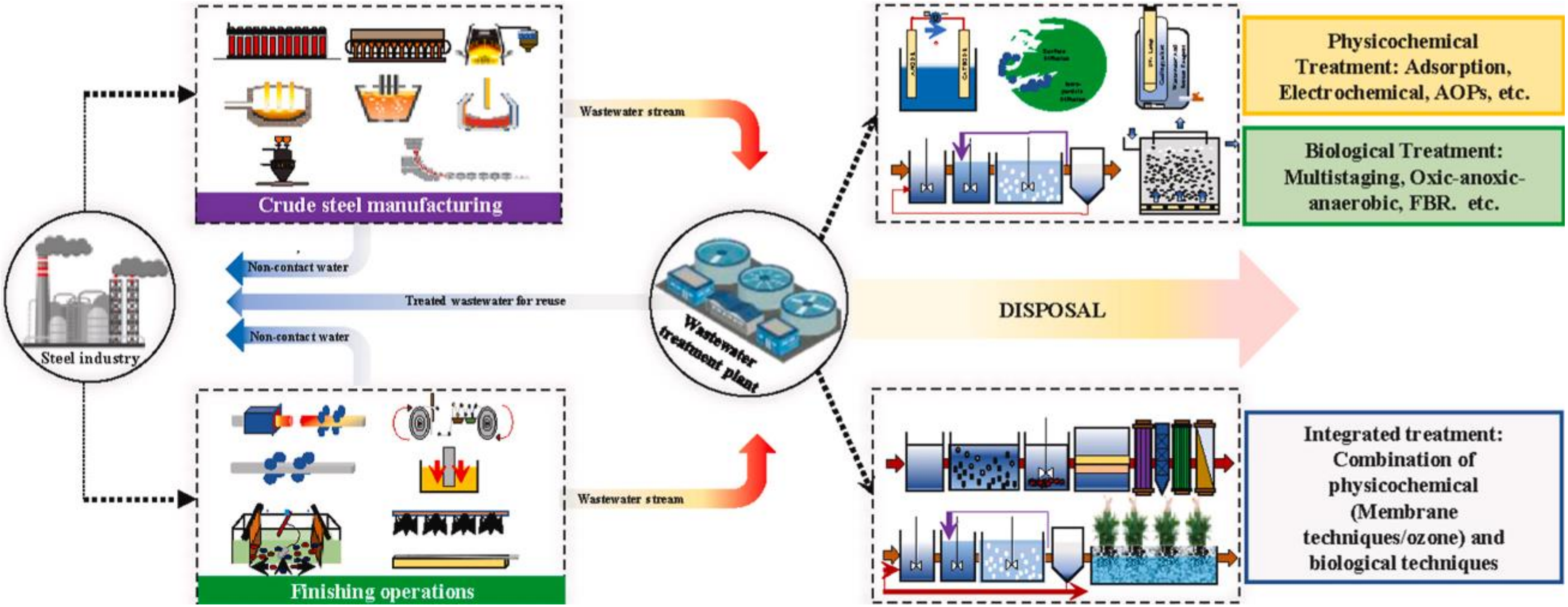
PETROCHEMICAL WASTEWATER



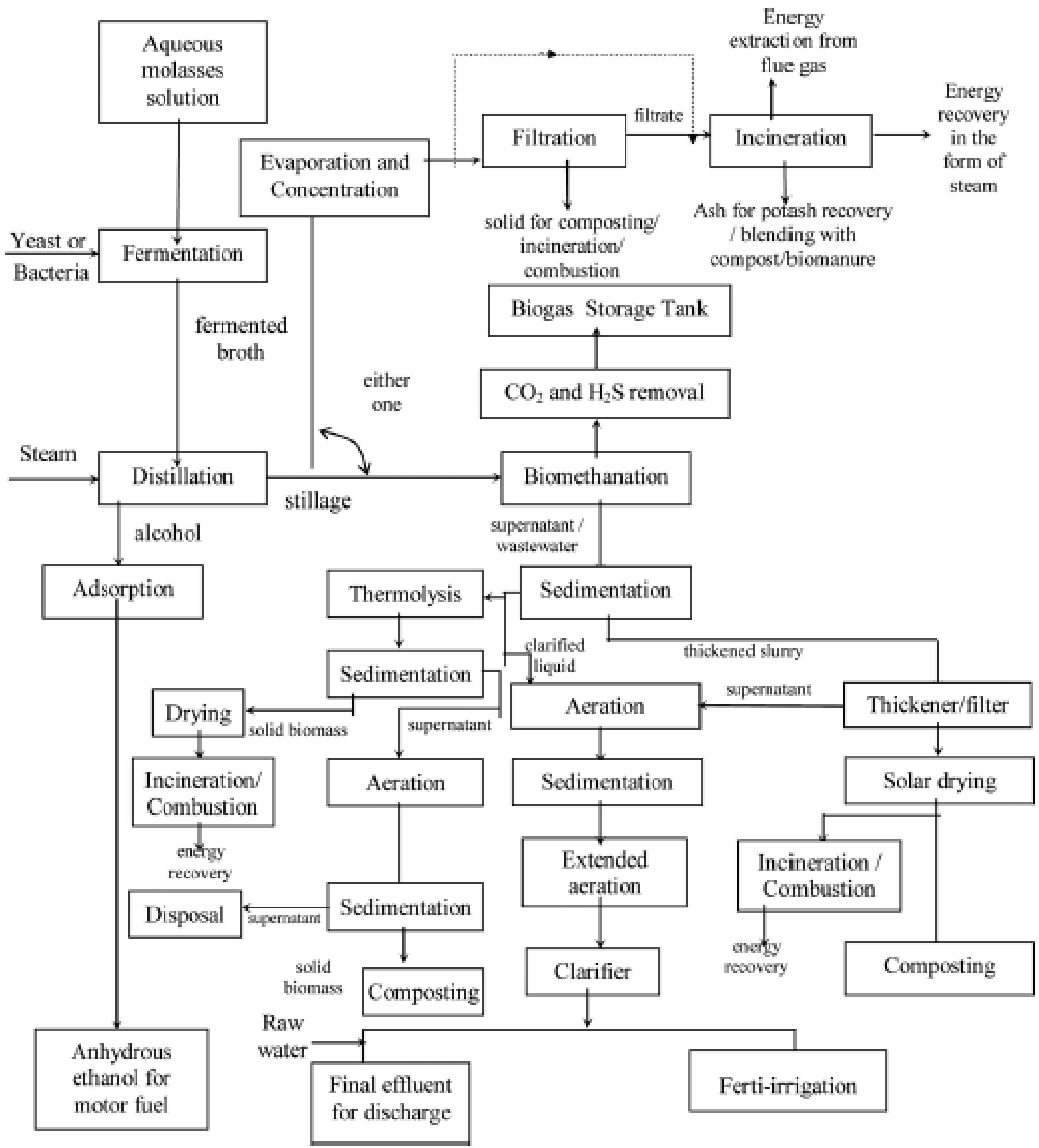
BIOREFINERY WASTEWATER



STEEL INDUSTRY WASTEWATER

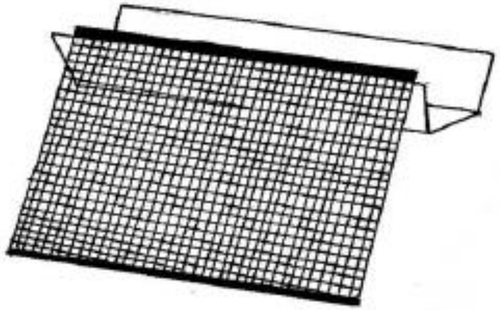


DISTILLERY WASTEWATER – STILLAGE, SPENT WASH AND BIODIGESTER EFFLUENT



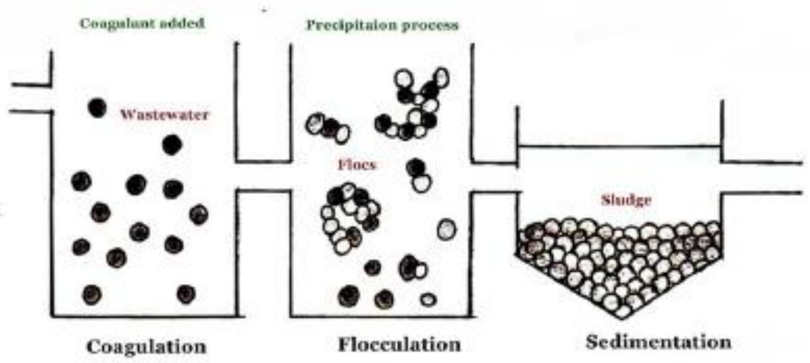
PULP AND PAPER MILL WASTEWATER

1. Primary treatment (for the removal of suspended solids)



Bar screener

coagulants: ferric chloride, aluminium sulphate, lime, poly aluminum chloride



coagulants, flocculation and sedimentation process

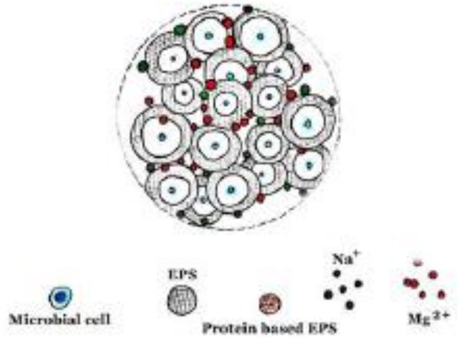
Advantages: remove suspended solids, and reduce COD, color etc..
Disadvantages: It attribute high BOD, long detention time, accumulate hydrogen sulfide due to anaerobic conditions and difficult to remove noxious volatiles.

2. Secondary treatment (for removal of organic matter)

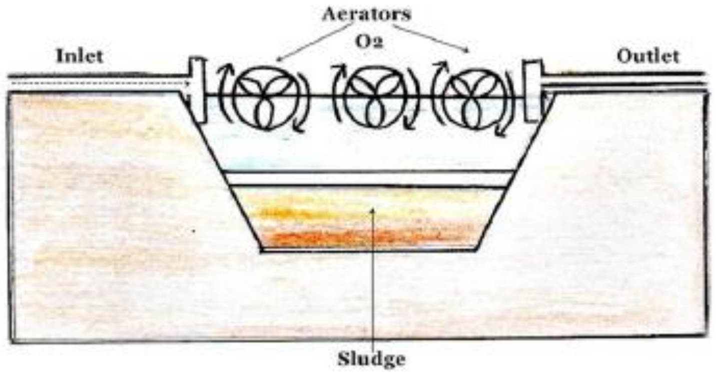
AS

Advantages: high pollutant removal efficiency, requires less surface area, easy microbial adaptation.

Disadvantages: high construction and operation cost, large



Activated sludge

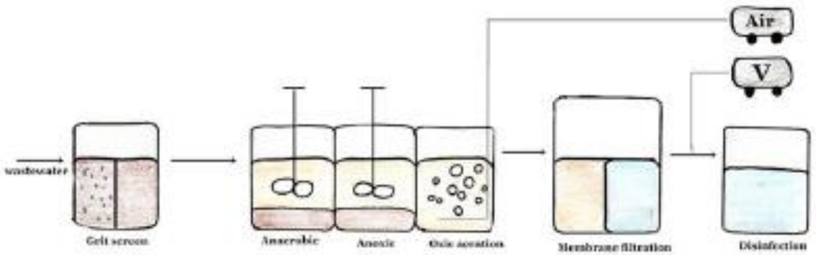


Aerated lagoons

AL

Advantages: lower operating cost, large settling zone, minimal operator attention.

Disadvantages: large residence time (3-20 days), need aeration devices, low efficiency, large area required.



Membrane bioreactor

MBR

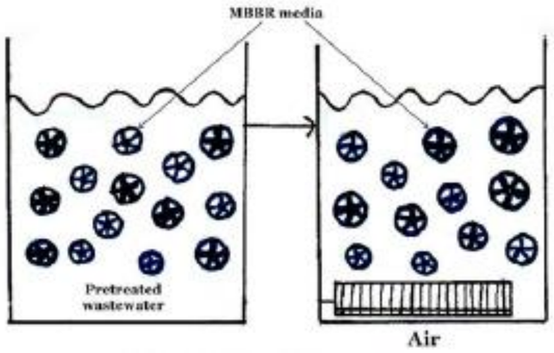
Advantages: space saving, higher removal of suspended matter, low sludge production, high quality effluent.

Disadvantages: high maintenance and operation cost, pretreatment required, fouling, clogging and cleaning problem.

MBBRR

Advantages: compact unit, low sludge production, low head loss, no need periodic backwashing, lower HRT.

Disadvantages: required manual bacterial monitoring, skilled operator needed



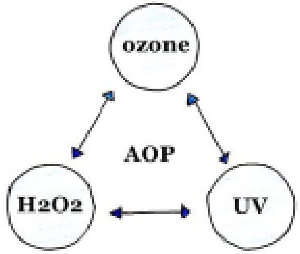
Mobil bed bioreactor

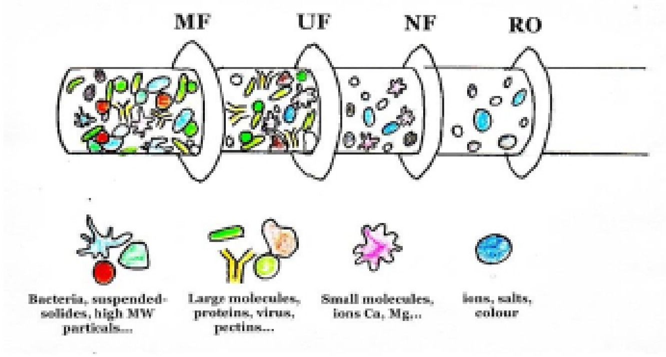
3. Tertiary treatment (for the reduction of toxicity, suspended solids, color, etc.)

AOP

Advantages: removing recalcitrant and anthropogenic substances, decolorization.

Disadvantages: ozone diffusers is easily clogged with suspended solids and precipitates



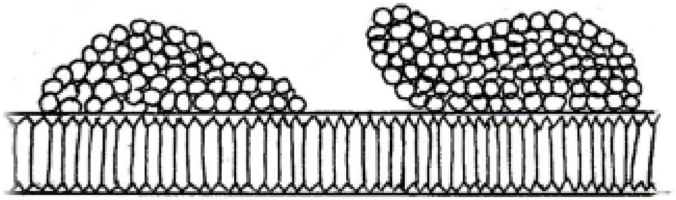


Membrane filtration

MF, UF, NF, RO

Advantages: small space require, efficient removal of particles, suspended solids and microbes, volatile compounds, phenols, cyanide, etc.

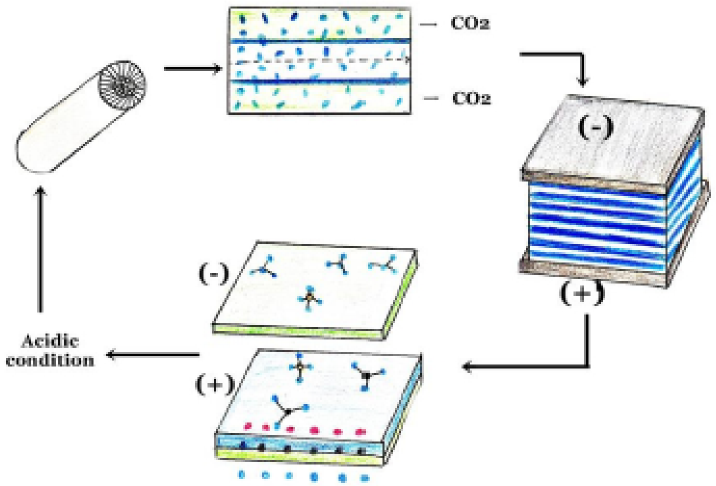
Disadvantages: membrane fouling and frequent backwashing, high maintenance and operation cost.



Adsorbents (activated carbon, silica, coal ash, etc.)

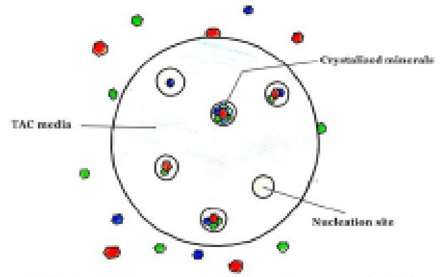
Advantages: efficient to remove certain organics, chlorine, fluorine, micro-pollutants etc.
Disadvantages: not effective for microbial contaminants, metals, nitrates and other inorganic contaminants.

4. Advance treatment (to remove specific waste constituents that can't be removed by secondary/ tertiary treatment)



Electrodialysis

Electrochemical membrane separation technique for ionic solutions that has been used in several industries. It can be used in the separation of salts, acids, and bases from aqueous solution. Also separate monovalent ions from multivalent



Filtration assisted crystallization technology (FACT) : It is hybrid process, patented by TNO, combining heterogeneous crystallization and a simple filtration.

THANK YOU