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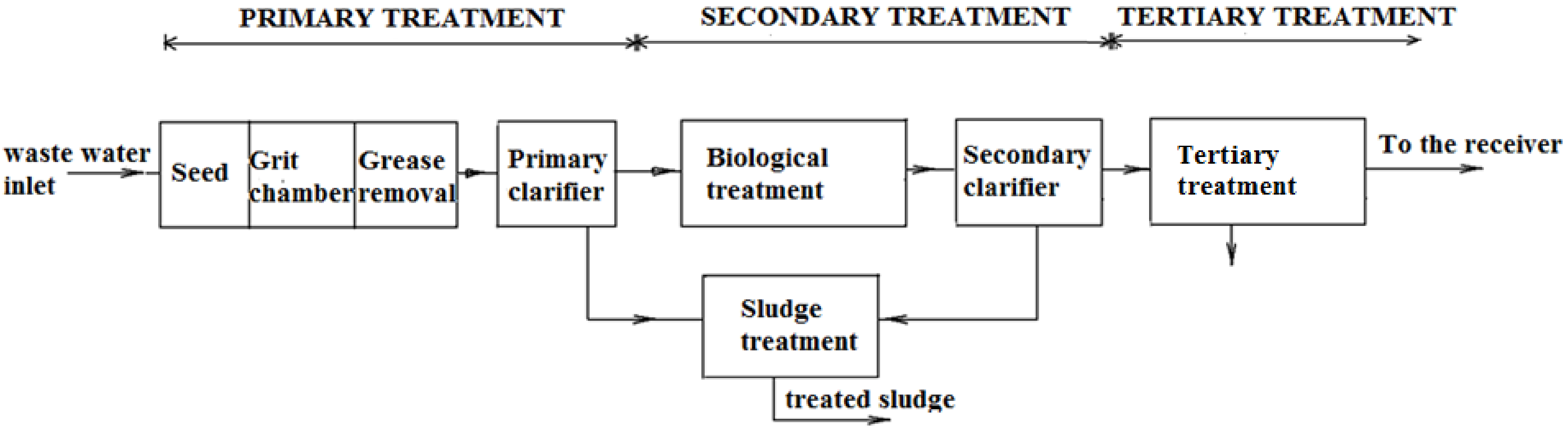
BUILDING SERVICES AND
PROCESS ENGINEERING

BME GÉPÉSZMÉRNÖKI KAR
1871

Wastewater Management III.

Generalized layout of a wastewater treatment plant



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Processes in tertiary treatment can be

- Disinfection
- Nitrification/Denitrification
- Chemical treatment (precipitation, neutralization etc.)
- Adsorption
- Membrane technology
- Evaporation
- Distillation etc.

What is the role of disinfection in tertiary wastewater treatment process?

- Protect human health
  - Stop pathogen pathway from one host to next
    - Water reuse
    - Discharge to surface waters
- Ecological Impact
  - Prevent spreading of diseases

Disinfection of Wastewater

- Disinfection procedures applied to wastewaters will result in a substantial **reduction** of all microbes so that bacterial numbers are reduced to a safe level.
- (Sterilization is the destruction of **all** microorganisms.)

Disinfection Techniques of Wastewater

- Chlorination;
- Ozone;
- Ultraviolet radiation (UV)
- Ultrasound (US)

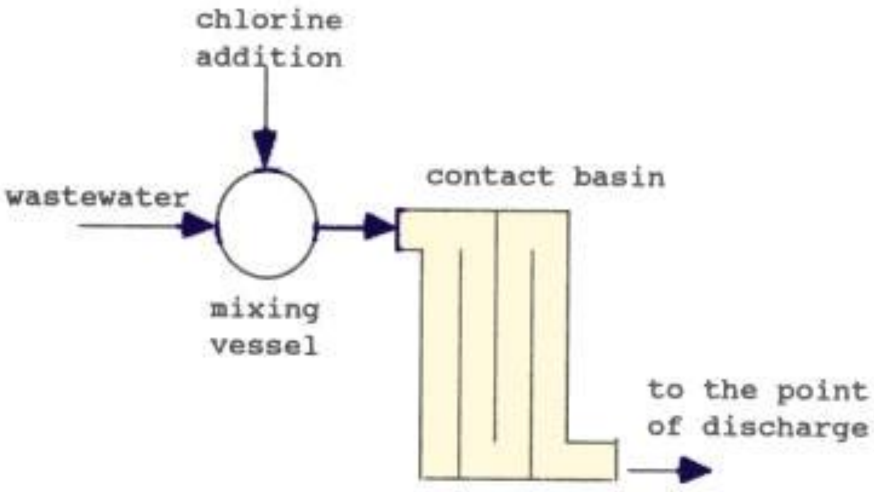
DISINFECTION
Advantages of Chlorination

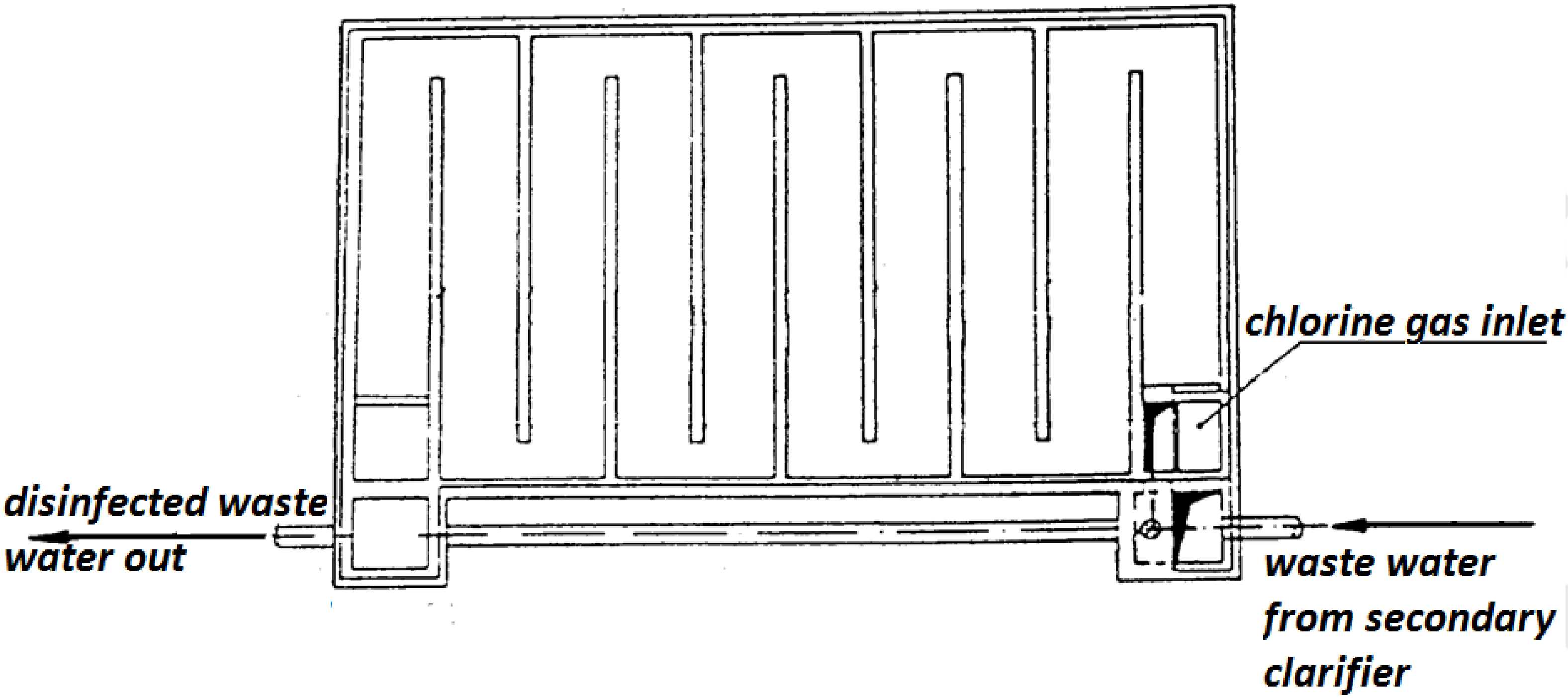
- Chlorination is a well-established technology
- More cost-effective than either UV or ozone disinfection
- The chlorine residual that remains in the wastewater effluent can prolong disinfection even after initial treatment and can be measured to evaluate the effectiveness
- Reliable and effective against pathogenic organisms
- Effective in oxidizing certain organic and inorganic compounds
- Flexible dosing control
- Can eliminate odors.

DISINFECTION
Disadvantages of Chlorination

- The chlorine residual is toxic to aquatic life and may require dechlorination
- Disinfection By-Products (DBPs)
- All forms are highly corrosive and toxic (storage, shipping, handling require safety regulations)
- Oxidizing certain types of organic matter can create more hazardous compounds

DISINFECTION
Chlorine contact basin





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DISINFECTION
Chlorine contact basin

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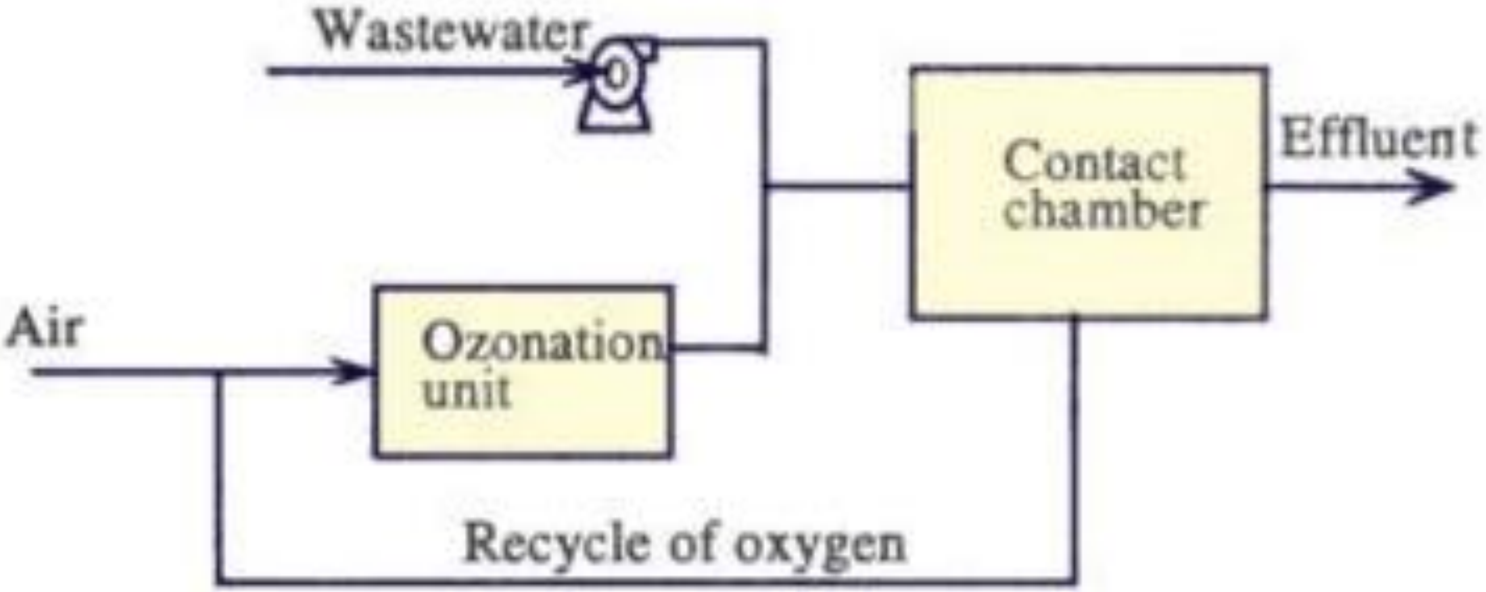
DISINFECTION
Ozone Disinfection



DISINFECTION
Ozone Disinfection

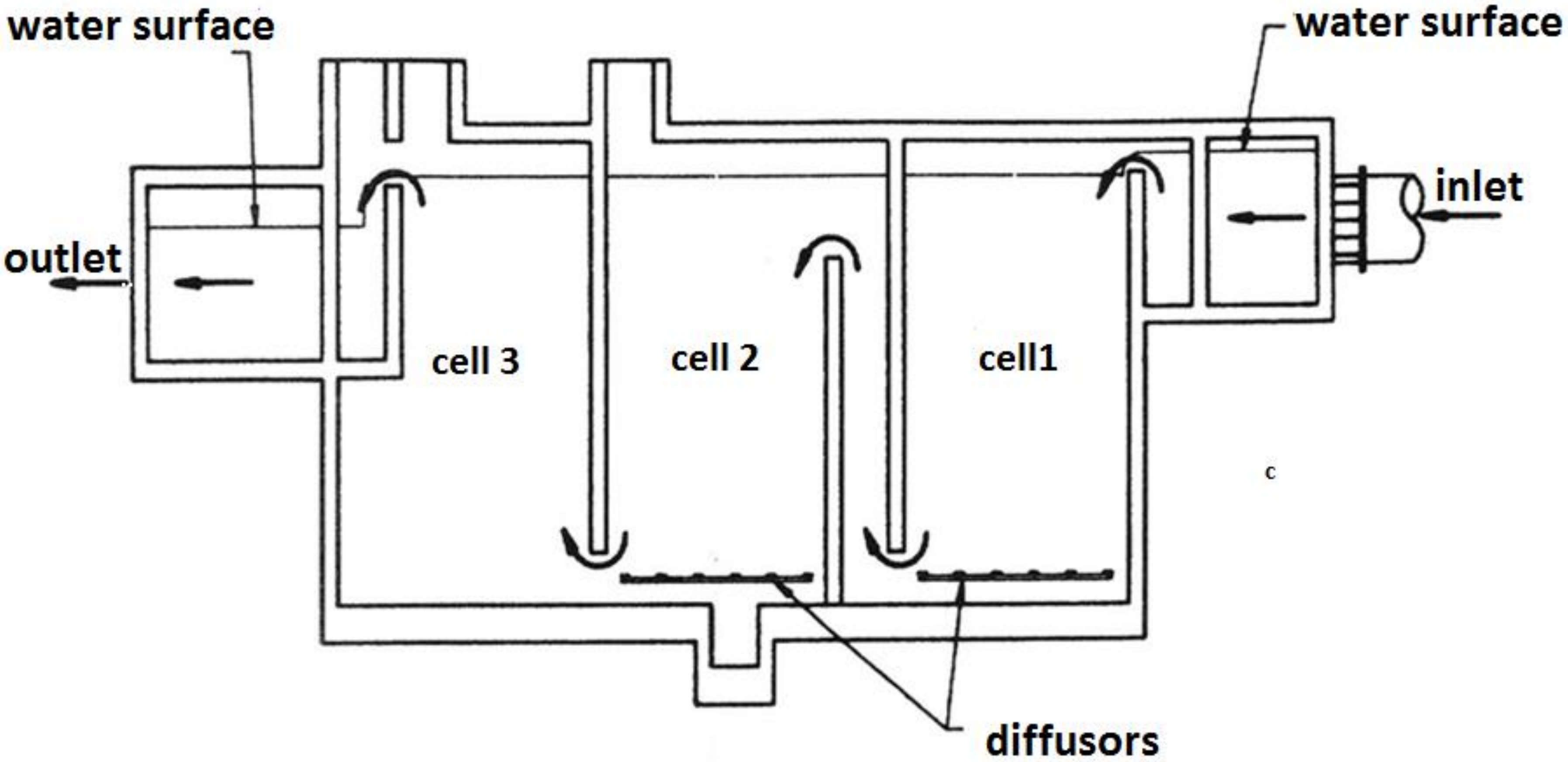
advantages:

- elimination of odors;
- oxygenation of residual organic compounds;
- ozone can be generated from air.

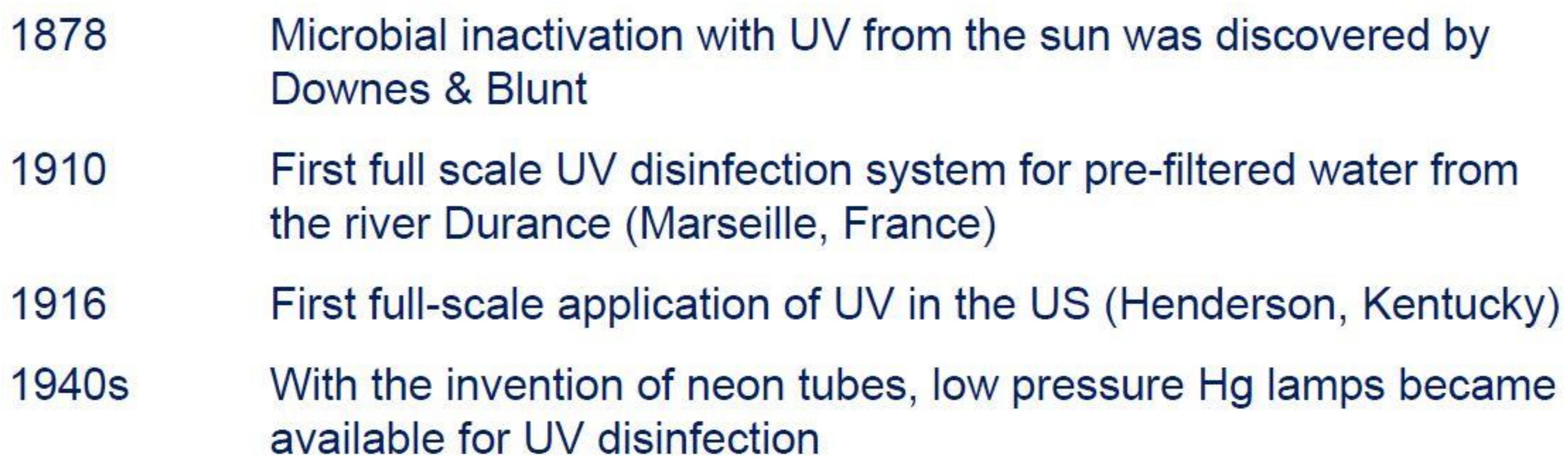
disadvantages:

- high cost of production;
- potential to cause localized air pollution.

DISINFECTION
Ozone Disinfection



DISINFECTION
UV (Ultra-Violet) Disinfection
History



1878	Microbial inactivation with UV from the sun was discovered by Downes & Blunt
1910	First full scale UV disinfection system for pre-filtered water from the river Durance (Marseille, France)
1916	First full-scale application of UV in the US (Henderson, Kentucky)
1940s	With the invention of neon tubes, low pressure Hg lamps became available for UV disinfection

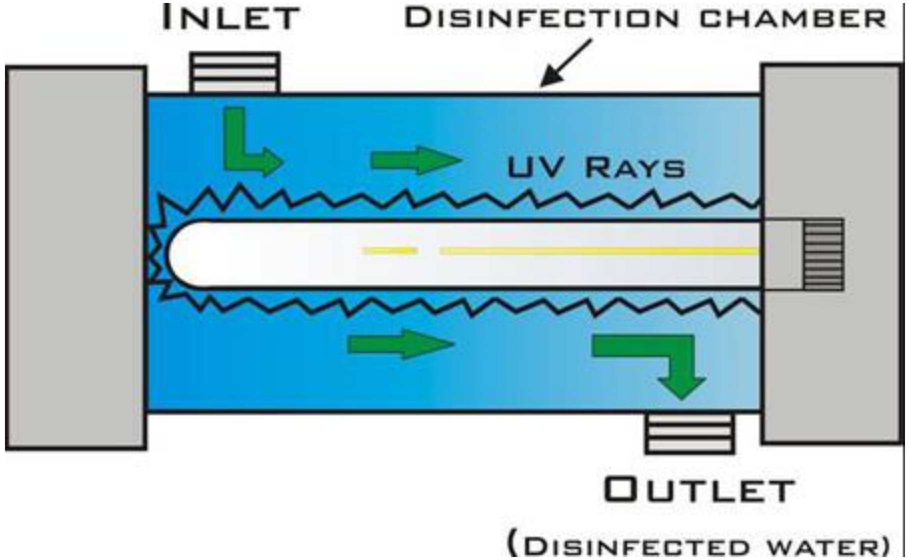
DISINFECTION
UV (Ultra-Violet) Disinfection

Ultra-violet light is produced by a special mercury discharge lamp. The effectiveness of UV radiation depends on the dose received by the micro-organisms, and this depends on:

- the intensity of the radiation (the most effective wavelength is 254 nm);
- the path length from the source to the microorganisms;
- the contact time at the required dose;
- the quality of the wastewater (particularly regarding turbidity).

Lamps are prone to interference from chemical constituents of the wastewater such as ferric and hardness salts.
Periodic cleaning of the lamps is therefore required.

DISINFECTION
UV (Ultra-Violet) Disinfection



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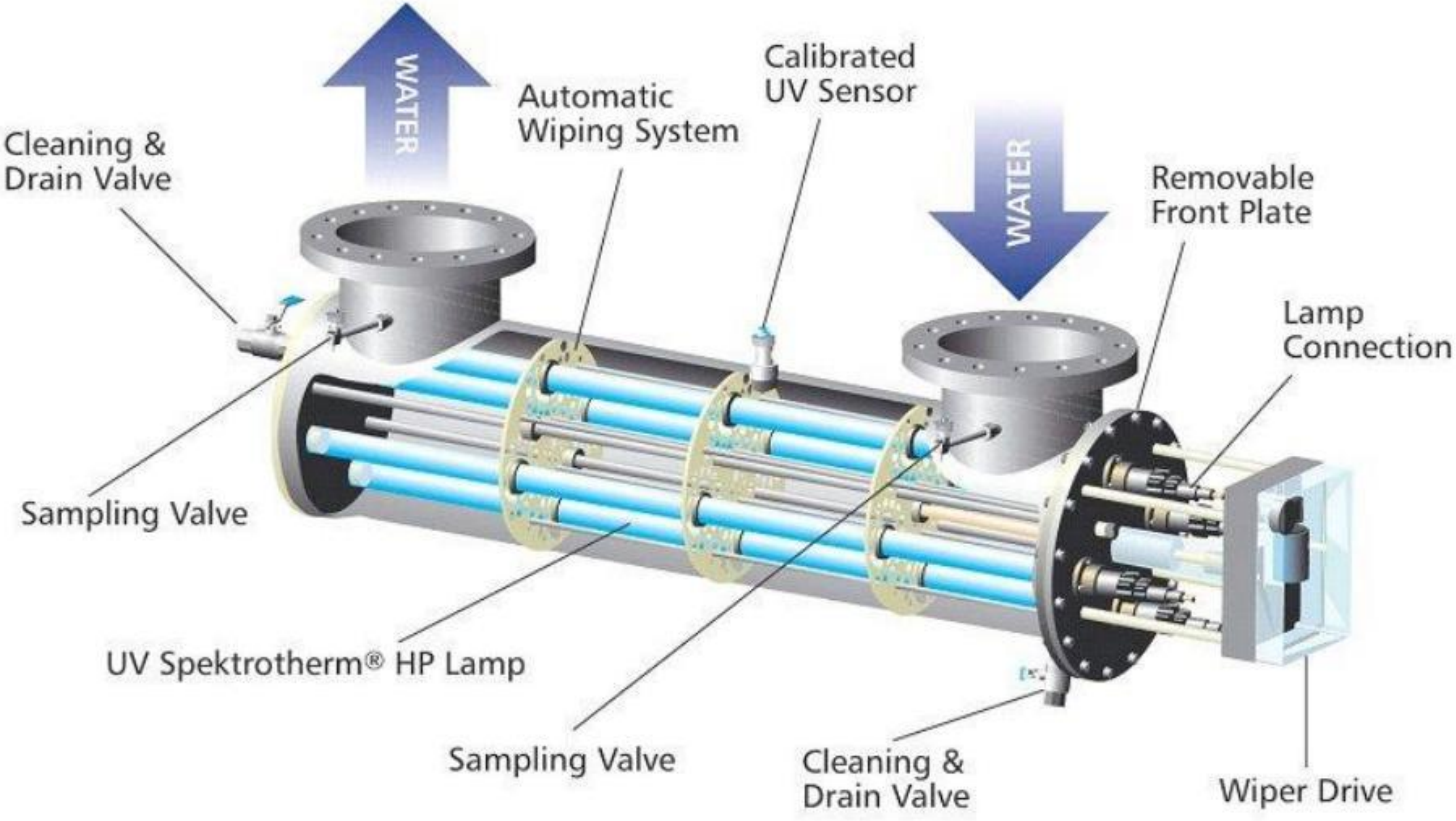
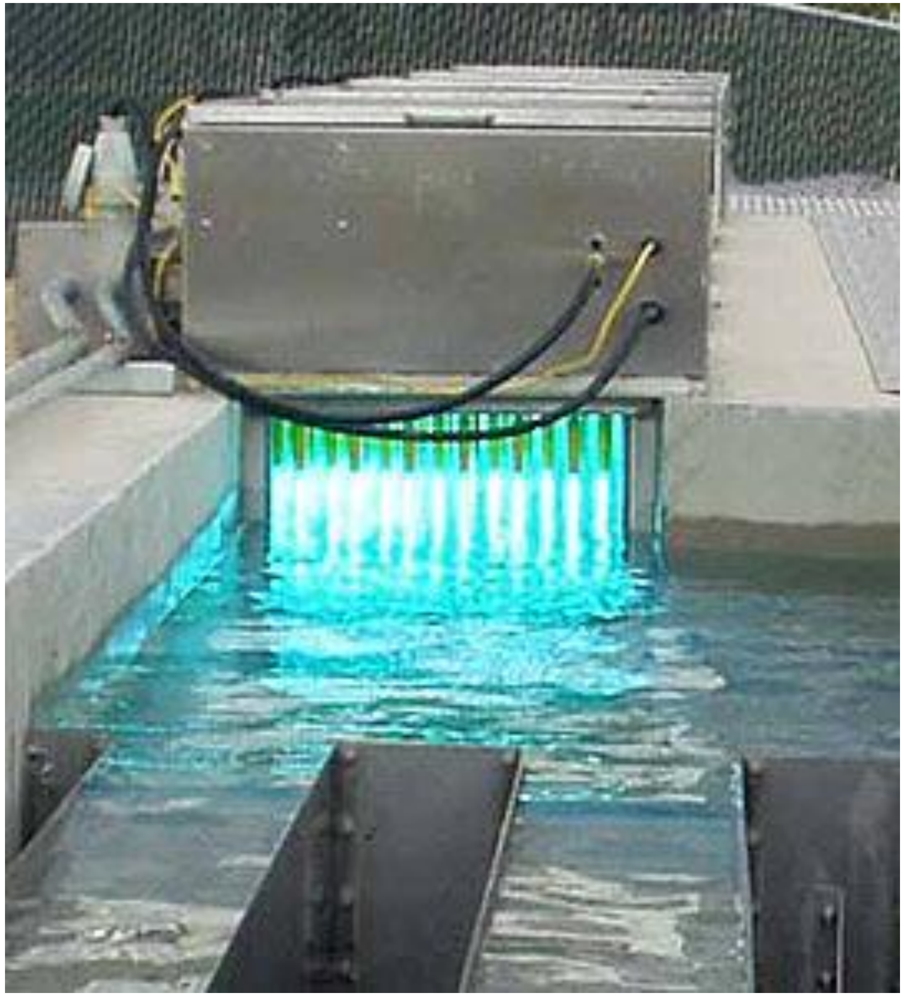
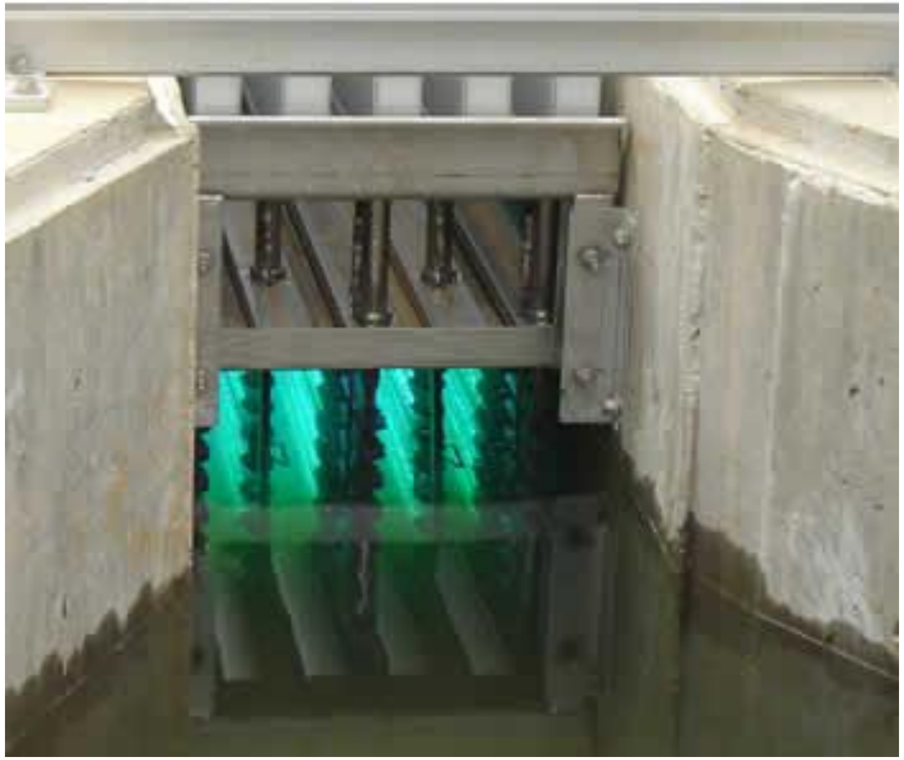
DISINFECTION
UV (Ultra-Violet) Disinfection



DISINFECTION
UV (Ultra-Violet) Disinfection

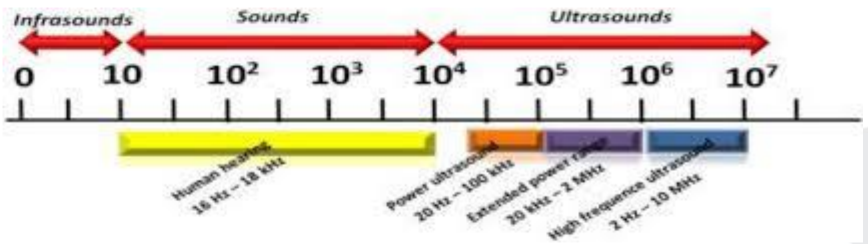


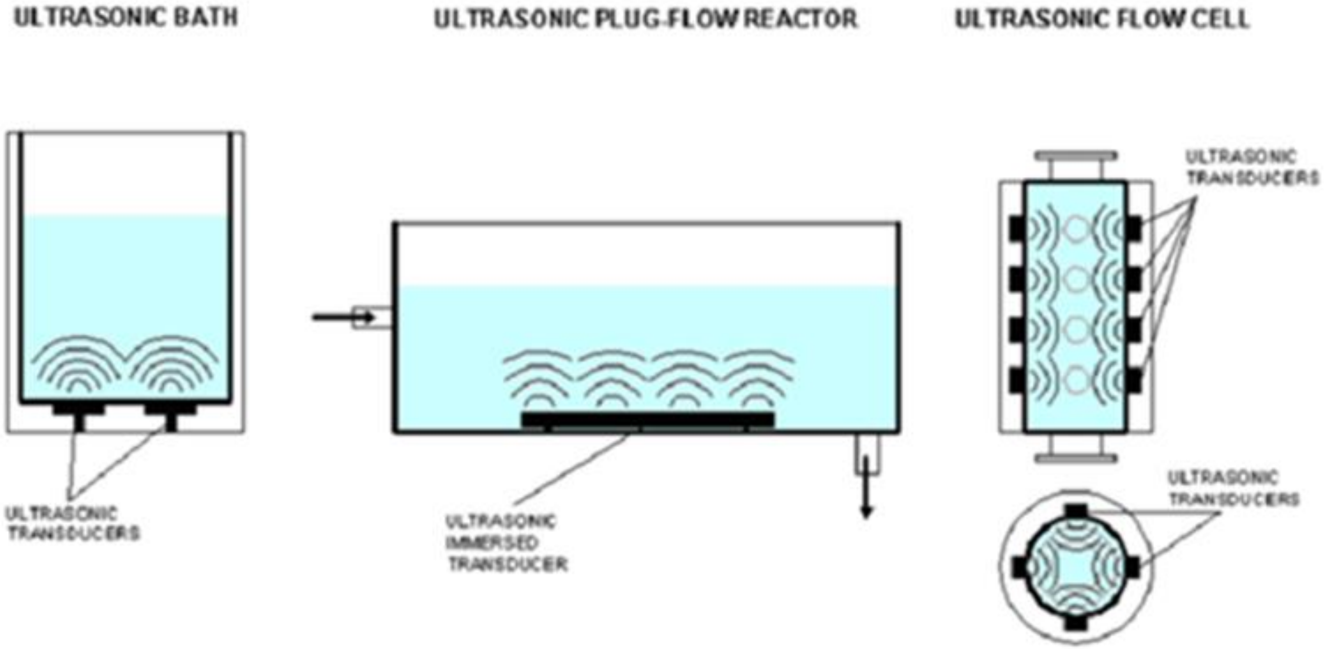


DISINFECTION
UltraSonic Disinfection

- Ultrasound can be used for the disinfection of turbid and highly concentrated wastewater, where the standard chlorine and UV methods fail.
- Voids in the water become bubbles filled with water or gas;
- They grow in extension phases of ultrasound and shrink in compression phases, until they implode (cavitation)
- Pressures of 5000 bar and a temperature of 5000 °C are produced locally.
- Frequency range: 20 to 100 kHz;
- When these bubbles collapse, they cause extreme mechanical shear forces.

DISINFECTION
UltraSonic Disinfection





NITRIFICATION/DENITRIFICATION

Nitrification is the biological oxidation of ammonia to nitrite followed by the oxidation of the nitrite to nitrate. Aerobic process.

$$NH_3 \rightarrow NO_2^- \rightarrow NO_3^-$$

Denitrification: reduction of nitrate and production of molecular nitrogen (N_2). Anaerobic process.

$$NO_3^- \rightarrow N_2$$

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CHEMICAL TREATMENT:

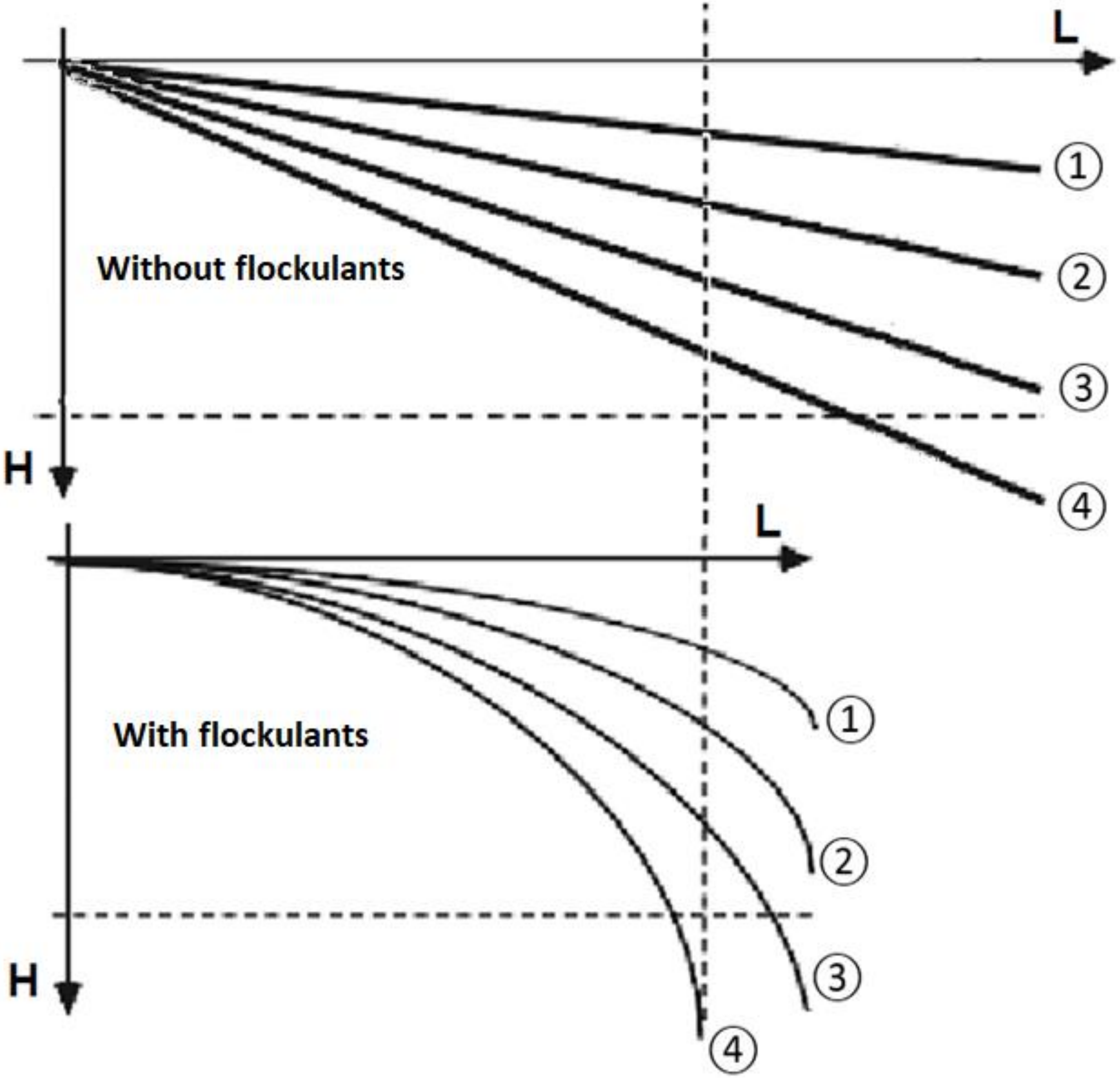
Chemical treatment must be used:

- for industrial wastewater treatment;
- For neutralization of acidic and basic wastewater (if pH≠7 a measure of acidity or basicity);
- if contaminants can be well precipitated;
- to improve settling properties,
- to remove heavy metals
- for phosphorus removal.

Settling properties can be improved by flockulants

Settling velocity due to gravity:

$$v_{sg} = \frac{d_S^2(\rho_S - \rho_F)g}{18\mu_F}$$



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CHEMICAL PRECIPITATION

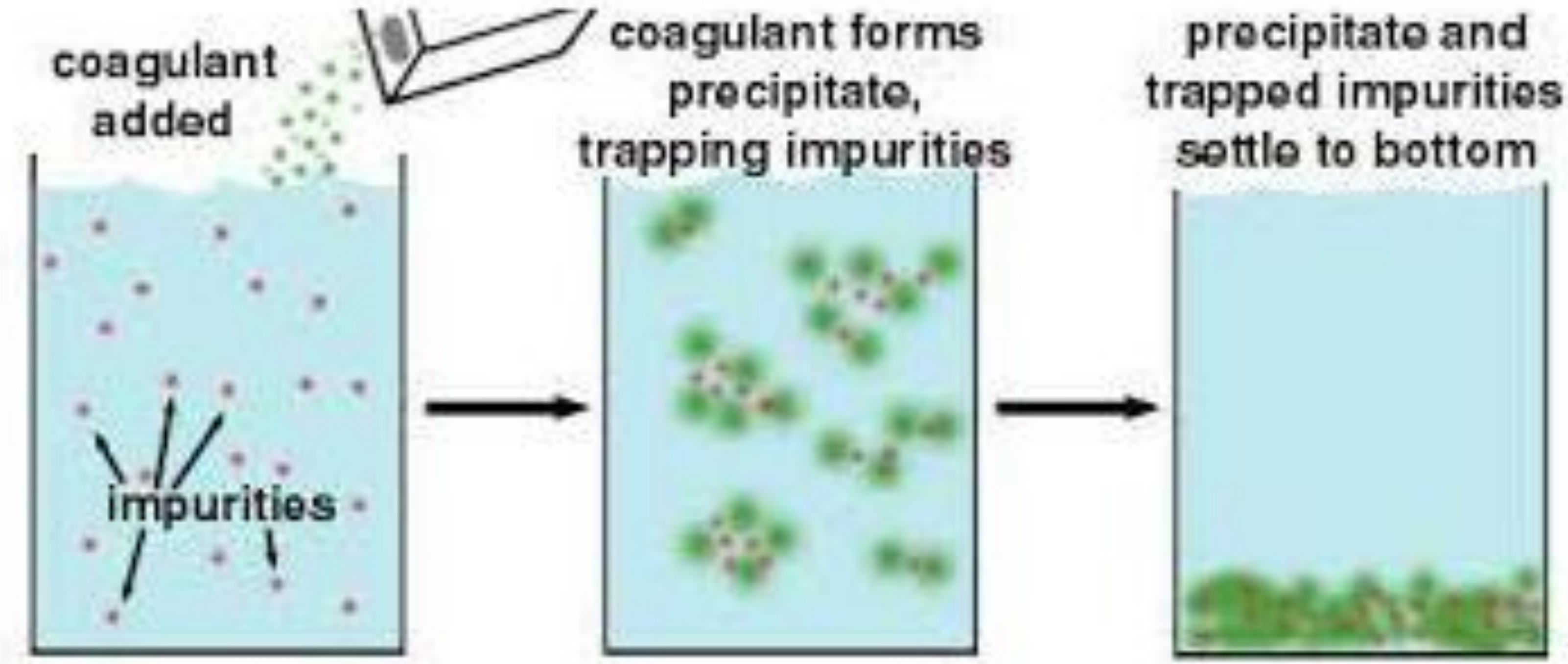
Chemical precipitation is a method of wastewater tertiary treatment.

Chemical precipitation in water and wastewater treatment is the change in form of materials dissolved in water into solid particles or liquid of high density (chemicals are added to form particles which settle and remove contaminants)

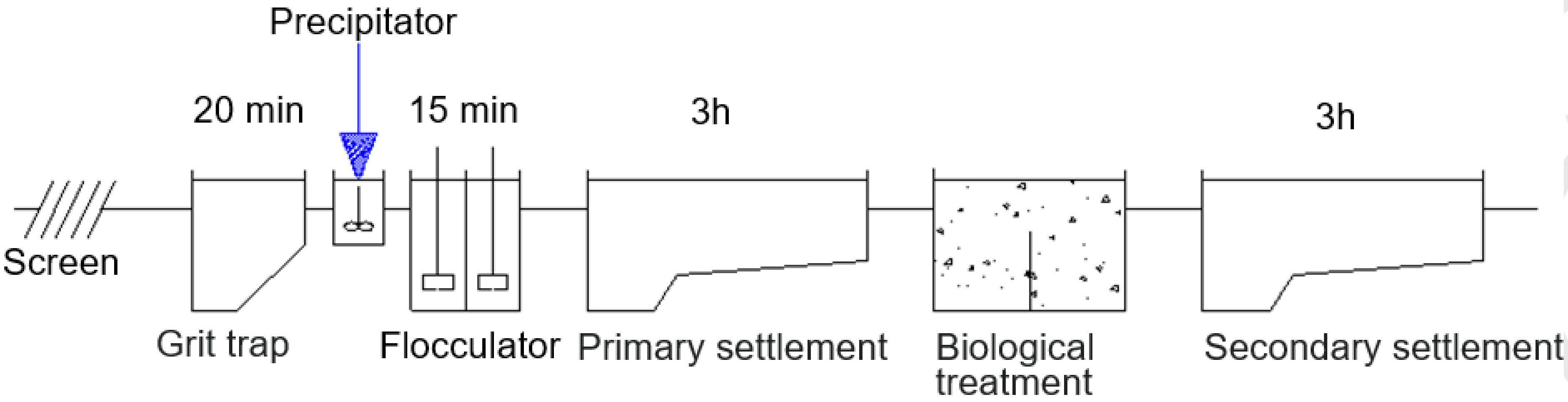
It is used for removal of

- Ionic constituent to reduce the solubility
- Metallic cations
- Anions (fluoride, cyanide, phosphate)
- Organic molecules
- Oily emulsions.

CHEMICAL PRECIPITATION

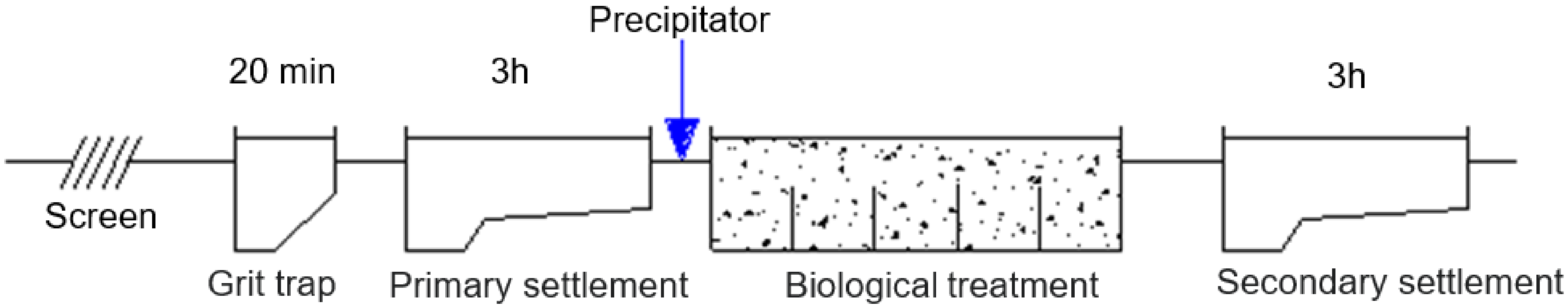


Pre-precipitation



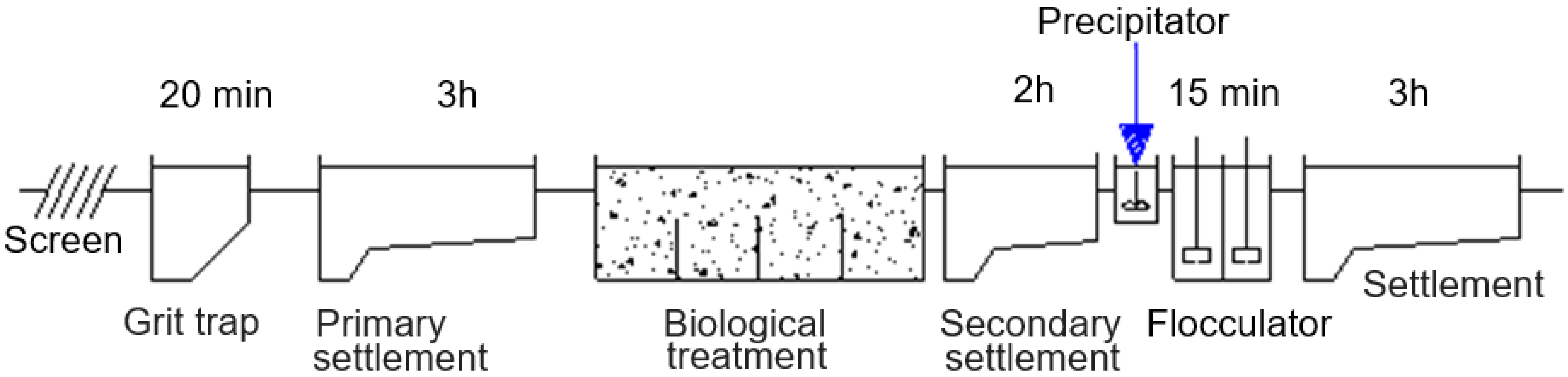
- In case of neutralization or improvement of settling properties,
- Physical and biological treatments can be interfered,
- Plus feed tank and flocculator.

Simultaneous precipitation



- No mixing basin,
- Less contamination removal efficiency than in pre-precipitation,
- Biological treatment can be interfered.

Post precipitation

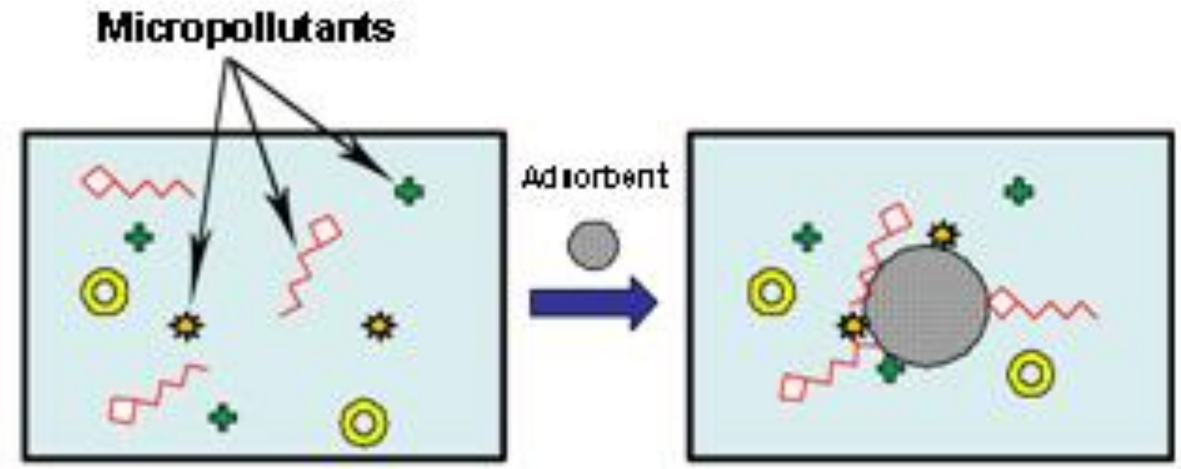


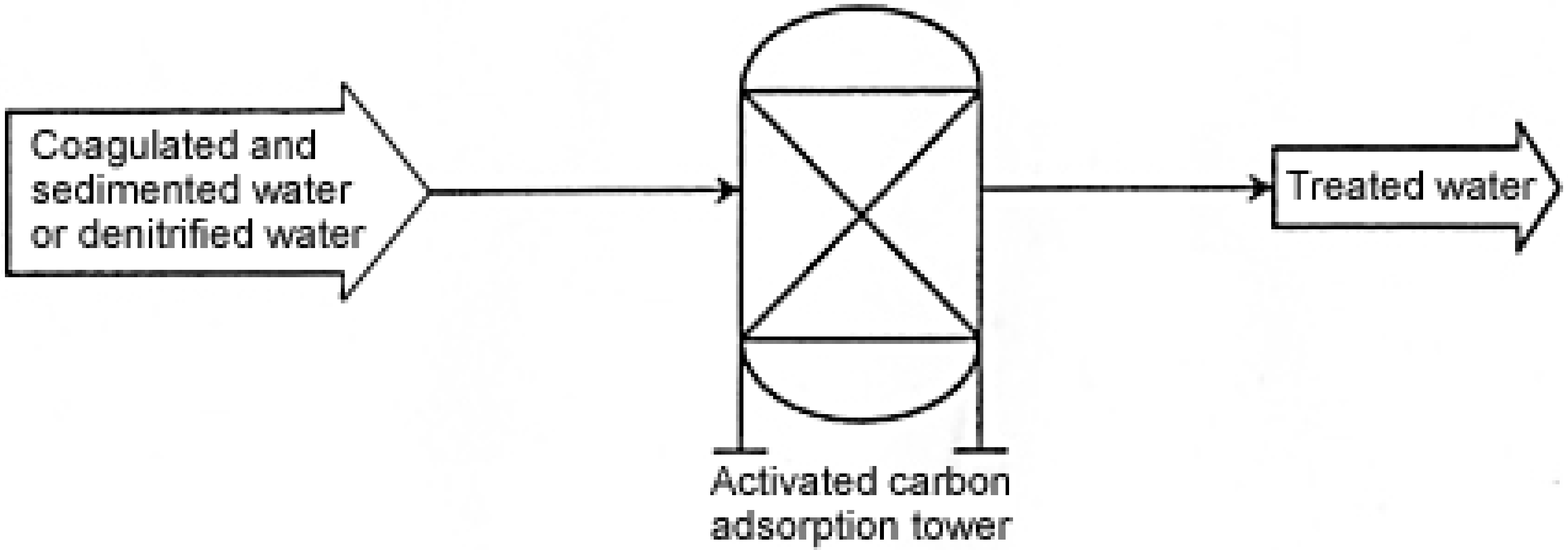
- Best contamination removal efficiency,
- Highest investment costs
- Physical and biological treatments are not interfered.

ADSORPTION

is the adhesion of atoms, ions, molecules of gas, liquid, or dissolved solids to a solid surface. This process creates a film of the adsorbate (the molecules or atoms being accumulated) on the surface of the adsorbent.

ADSORPTION


Micropollutants
Adsorbent


Coagulated and sedimented water or denitrified water
Treated water
Activated carbon adsorption tower

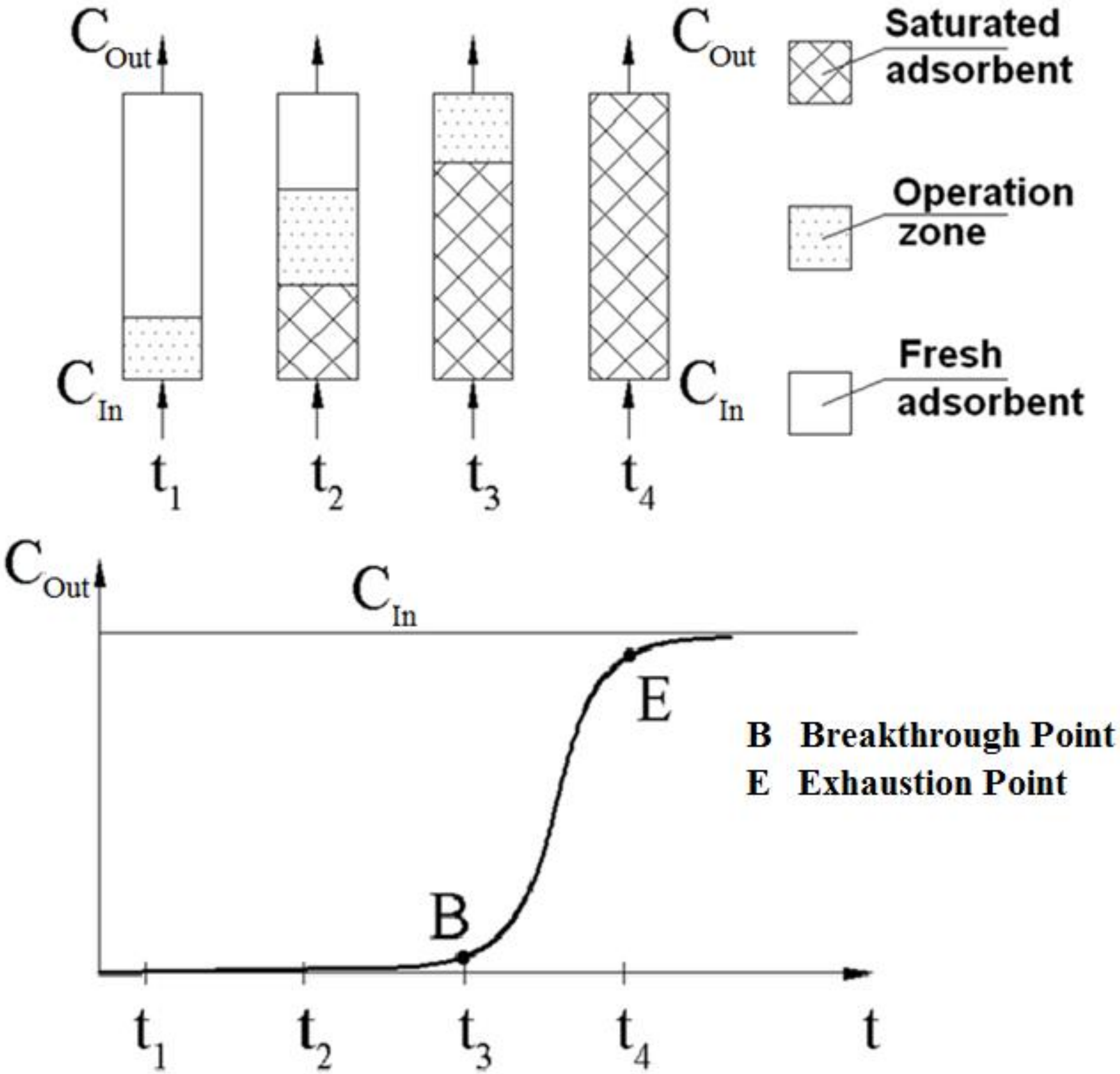
Fixed Bed Adsorbers

A part of the bed is saturated at inlet point of water and reaches adsorption equilibrium.
This part of the bed is not able to further adhesion so moves towards the outlet zone of the water. Zones in the bed are:

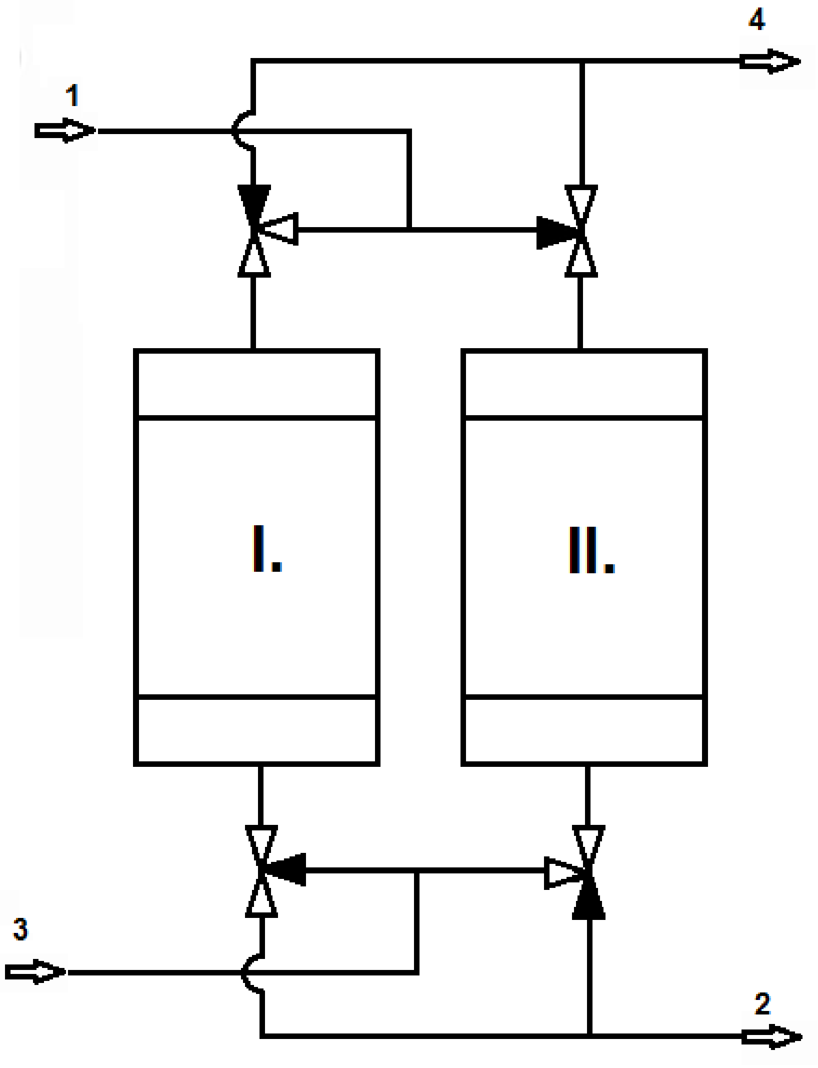
- saturated zone
- adsorption or operation zone
- free zone

Water flow to be cleared must be turned off at breakthrough point or exhaustion point and let into another adsorber column.
Saturated adsorber must be regenerated (desorbed.)

Fixed Bed Adsorbers



Fixed Bed Adsorber Station
Two parallel unit



I. Adsorption
II. Regeneration

1 wastewater in
2 cleaned wastewater out
3 regenerating steam in
4 regenerating steam out

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EVAPORATION

Evaporation is a thermal process, widely used for concentrating solutions, suspensions, and emulsions.

Concentration is accomplished by boiling out one part of the solvent, normally water, from the liquid phase.

At two-component systems mass of the total solution (m_L) is equal with sum of solvent mass (m_A) and solute mass (m_S):

$$\mathrm{m_L = m_A + m_S}$$

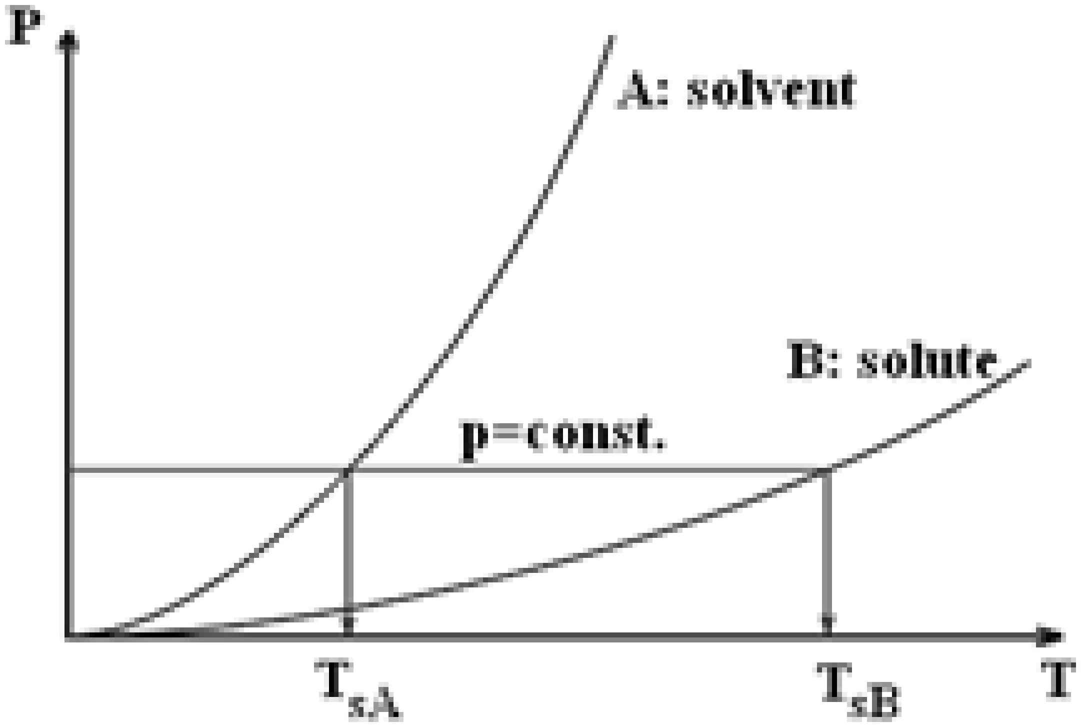
In wastewater treatment ‚A’ is the water, ‚S’ is the contaminant.

Concentration of solution:

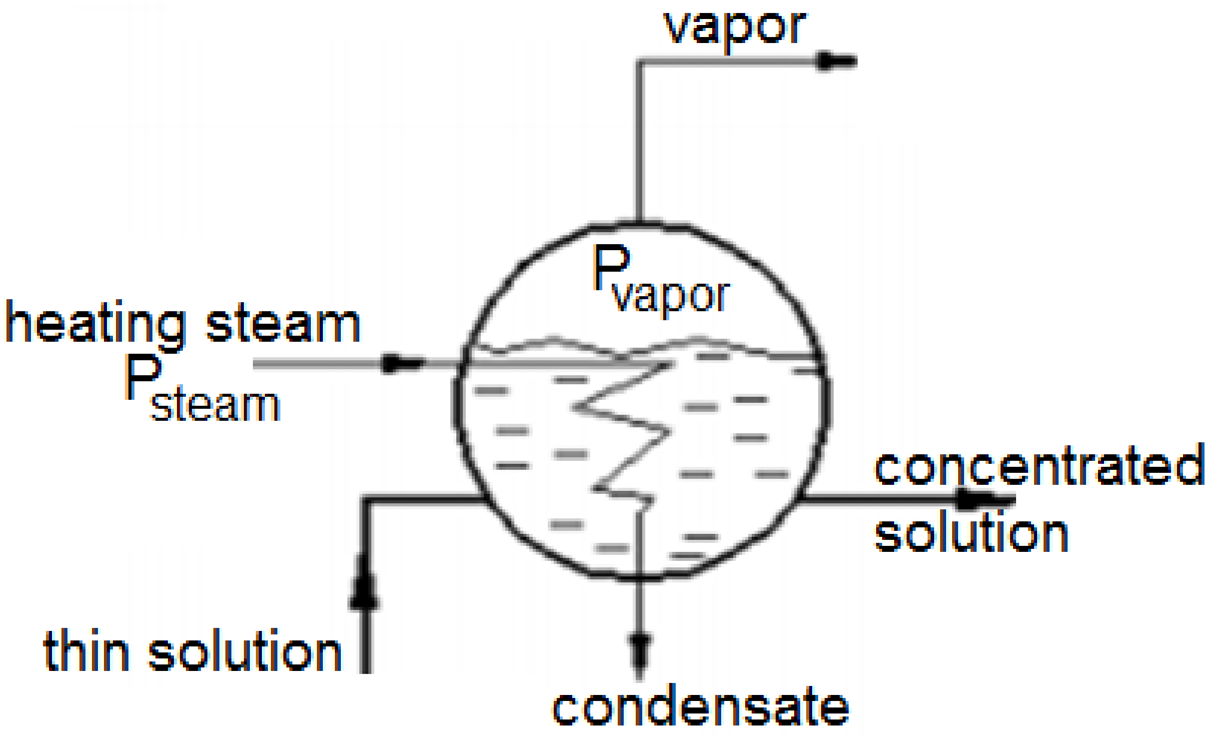
$$\mathrm{x = \frac{m_S}{m_L} = \frac{kg\ solute}{kg\ solution}}$$

EVAPORATION

Applicability of evaporation process:
Difference between boiling (saturation) points of solvent and solute.



EVAPORATION



EVAPORATION

Mass balance for a single effect evaporator :

$$\dot{m}_{steam} + \dot{m}_{Lo} = \dot{m}_{L1} + \dot{m}_{vapor} + \dot{m}_{condensate}$$

Heating chamber is separated from solution space so:

$$\dot{m}_{steam} = \dot{m}_{condensate}$$

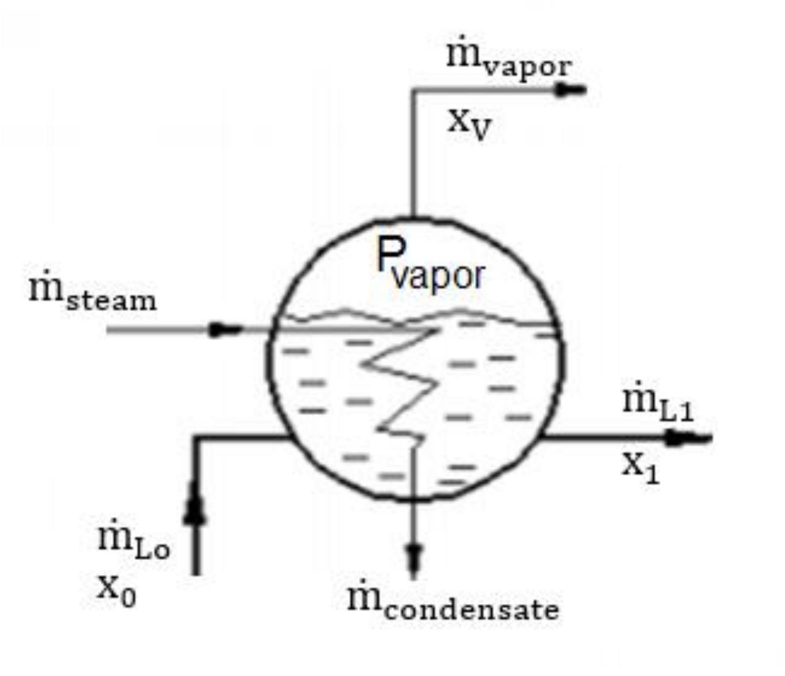
$$\dot{m}_{Lo} = \dot{m}_{L1} + \dot{m}_{vapor}$$

Mass balance of the solute:

$$\dot{m}_{Lo} \cdot x_0 = \dot{m}_{L1} \cdot x_1 + \dot{m}_{vapor} \cdot x_V$$

Vapor is pure solvent (water): $x_V = 0$

$$\dot{m}_{Lo} \cdot x_0 = \dot{m}_{L1} \cdot x_1$$



Concentration of the solution after evaporation:

$$x_1 = x_0 \cdot \frac{\dot{m}_{Lo}}{\dot{m}_{L1}}$$

EVAPORATION
Multi-stage evaporator station

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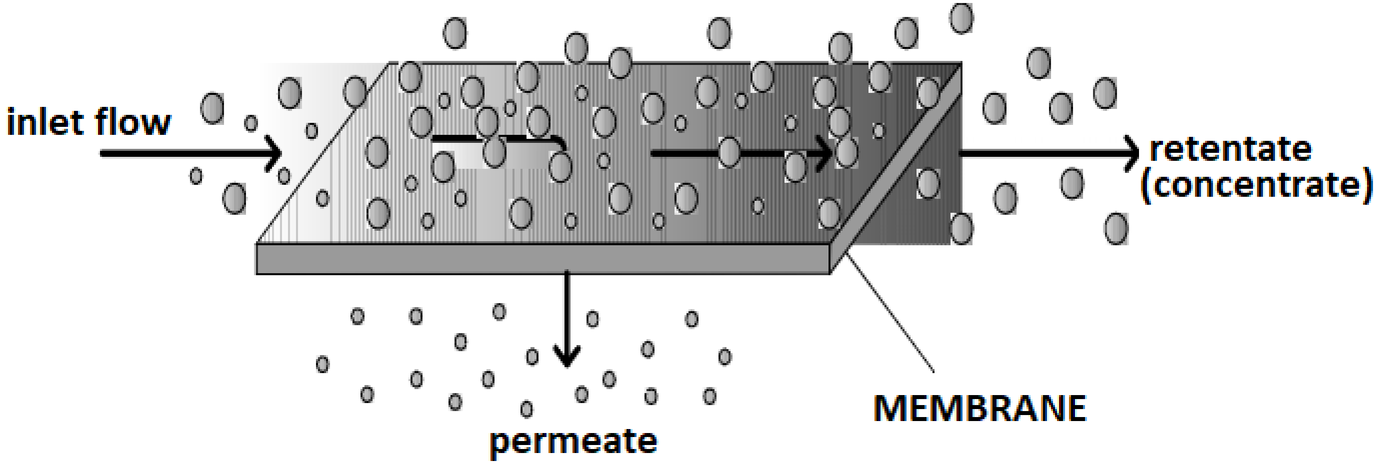
MEMBRANE TECHNOLOGY

Semi-permeable layer with two main features:

- selectivity
- permeability

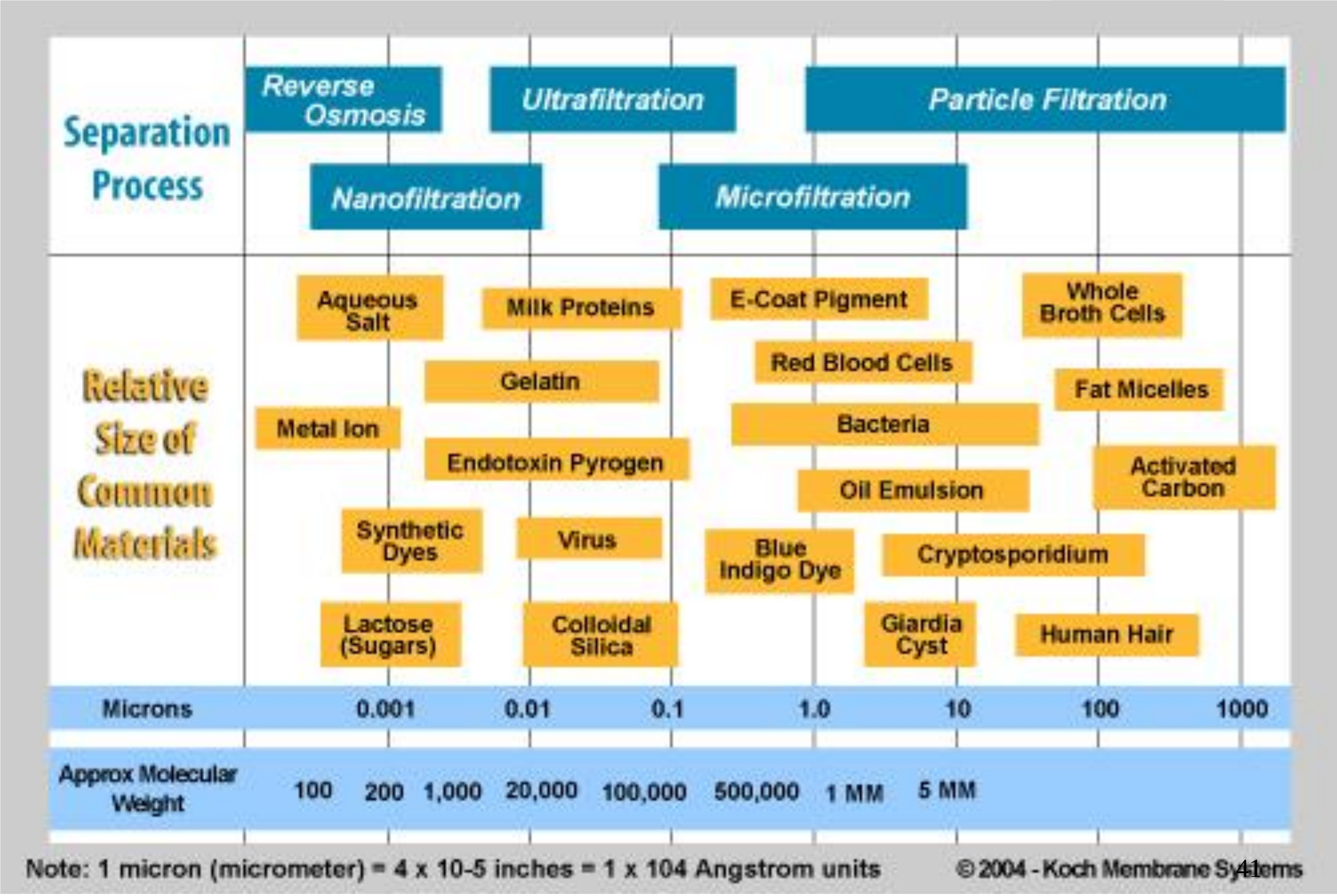


Inlet flow is separated:

- permeate (cleared water)
- retentate (concentrated contamination)

MEMBRANE TECHNOLOGY

- Ultrafiltration (UF) 5.10^{-9}-3.10^{-7} m
- Nanofiltration (NF) 2.10^{-9}-10^{-7} m
- Microfiltration (MF) 10^{-7}-5.10^{-6} m
- Reverse osmosis (RO) 5.10^{-10}-5.10^{-9} m
- Dialyzis 5.10^{-10}-5.10^{-8} m



Note: 1 micron (micrometer) = 4 x 10-5 inches = 1 x 104 Angstrom units

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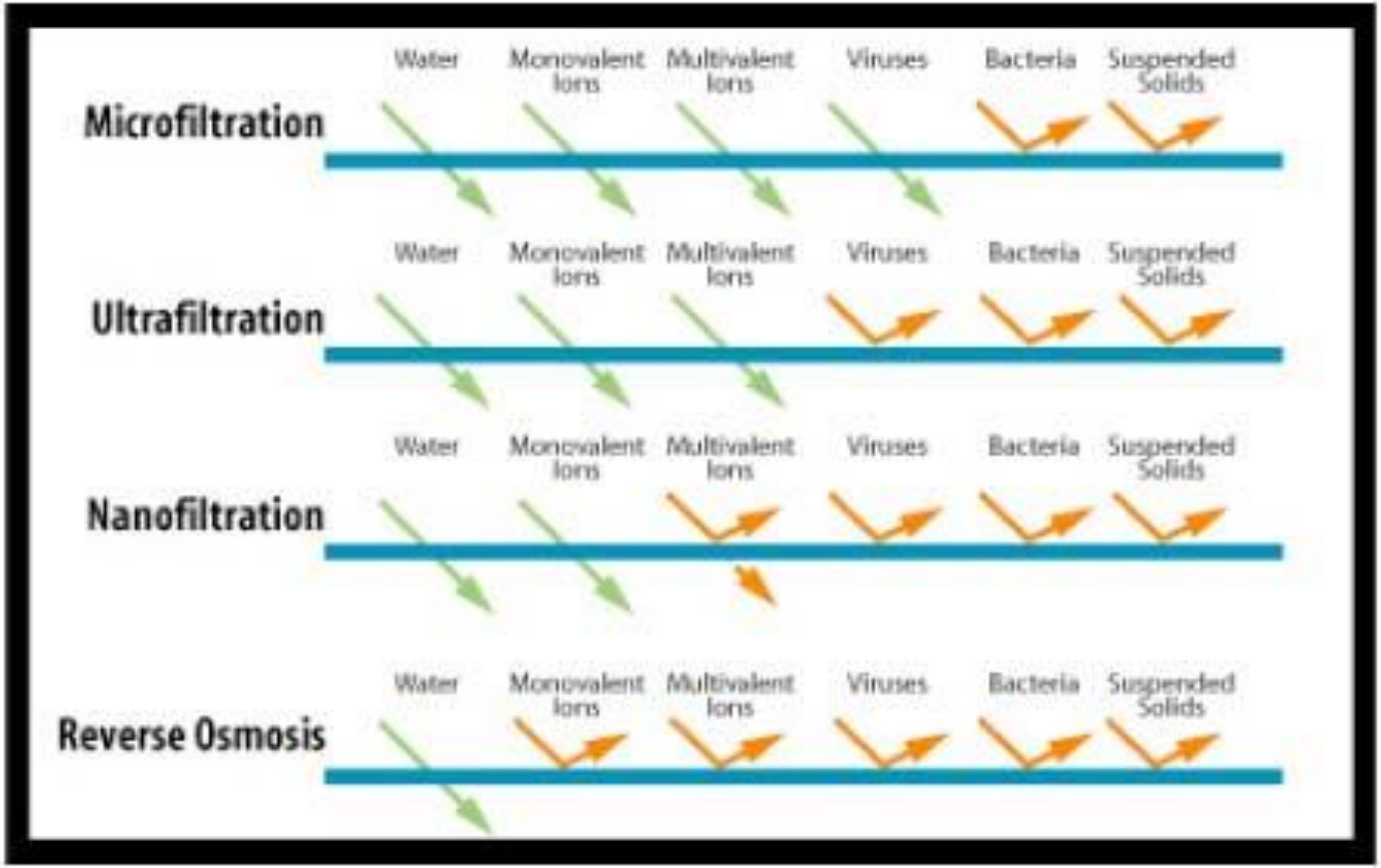
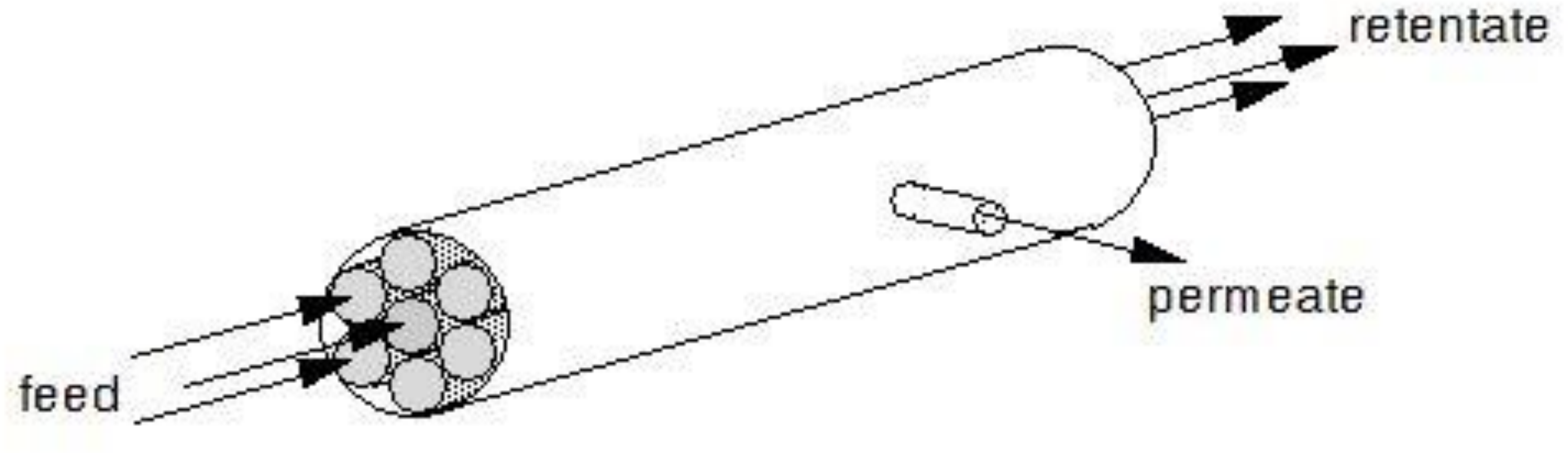


Membrane Process Characteristics

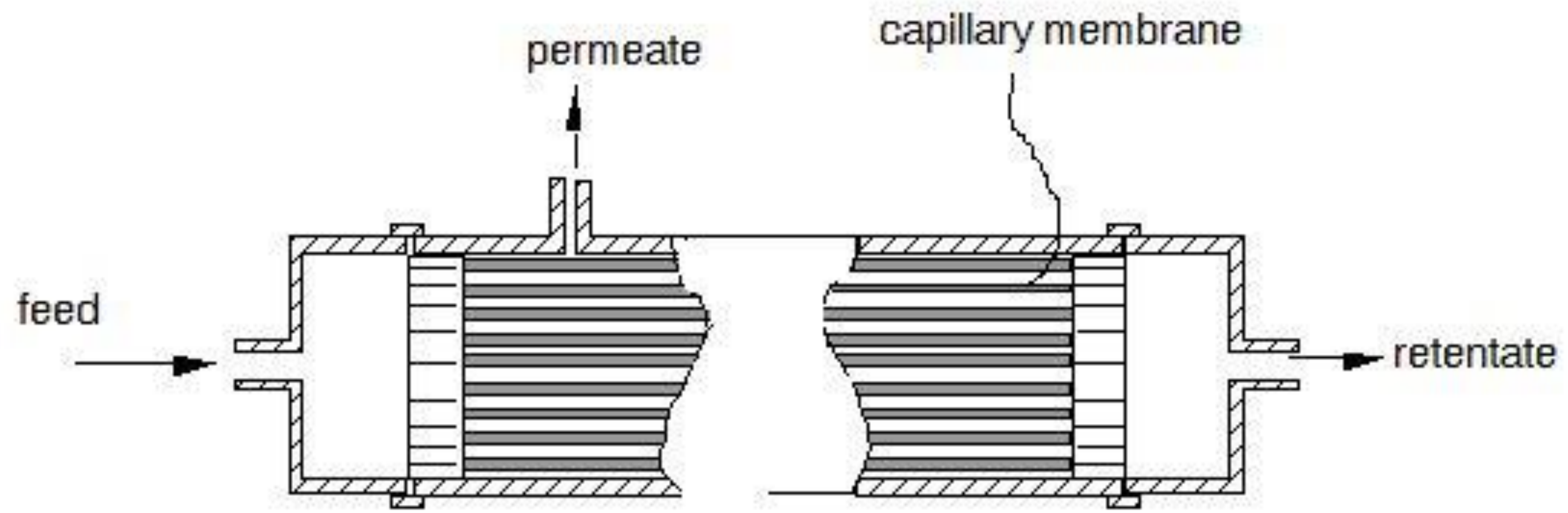
Tubular modules

Tubular module

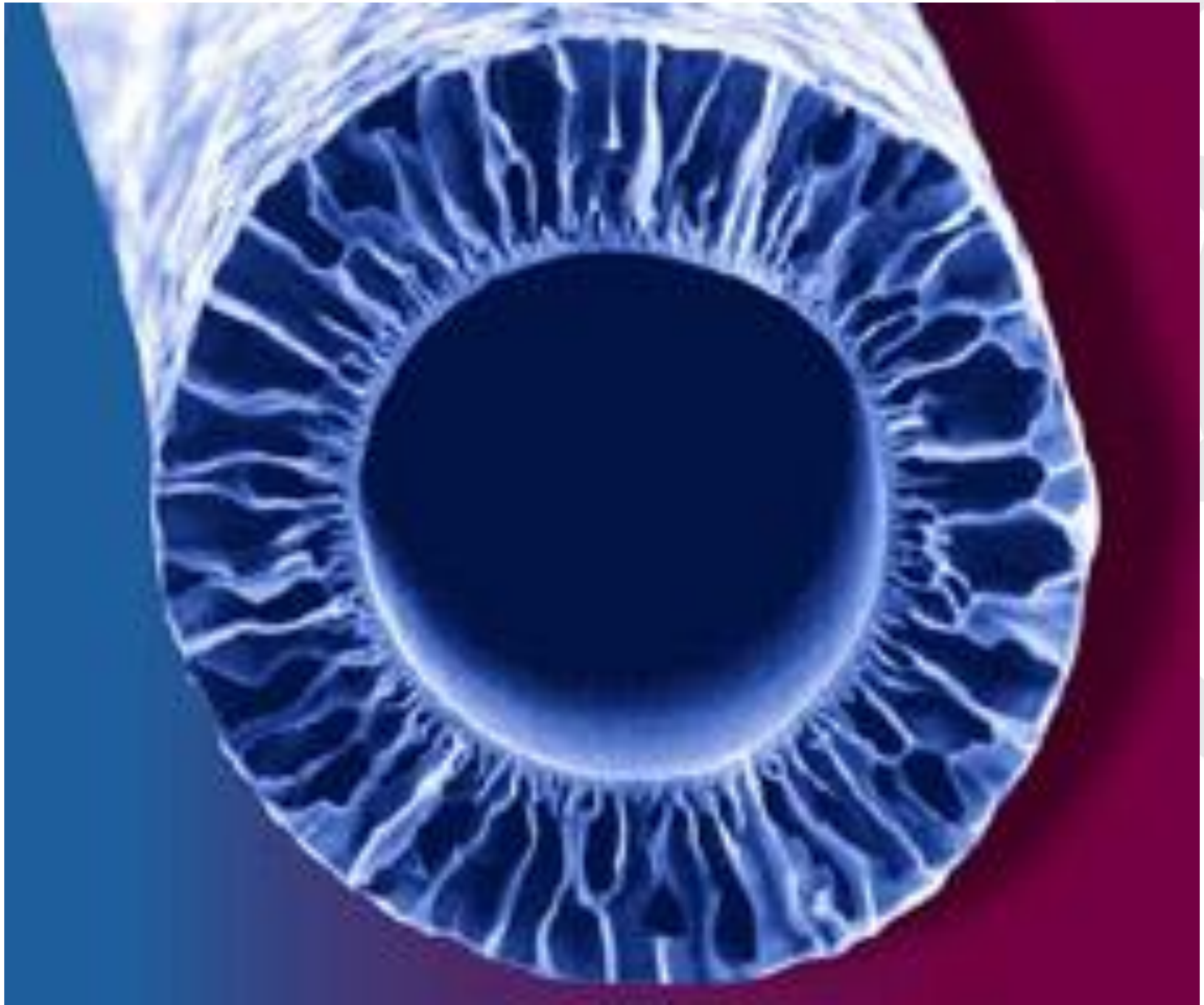


Membrane station

Capillary membrane module



Capillary membrane module



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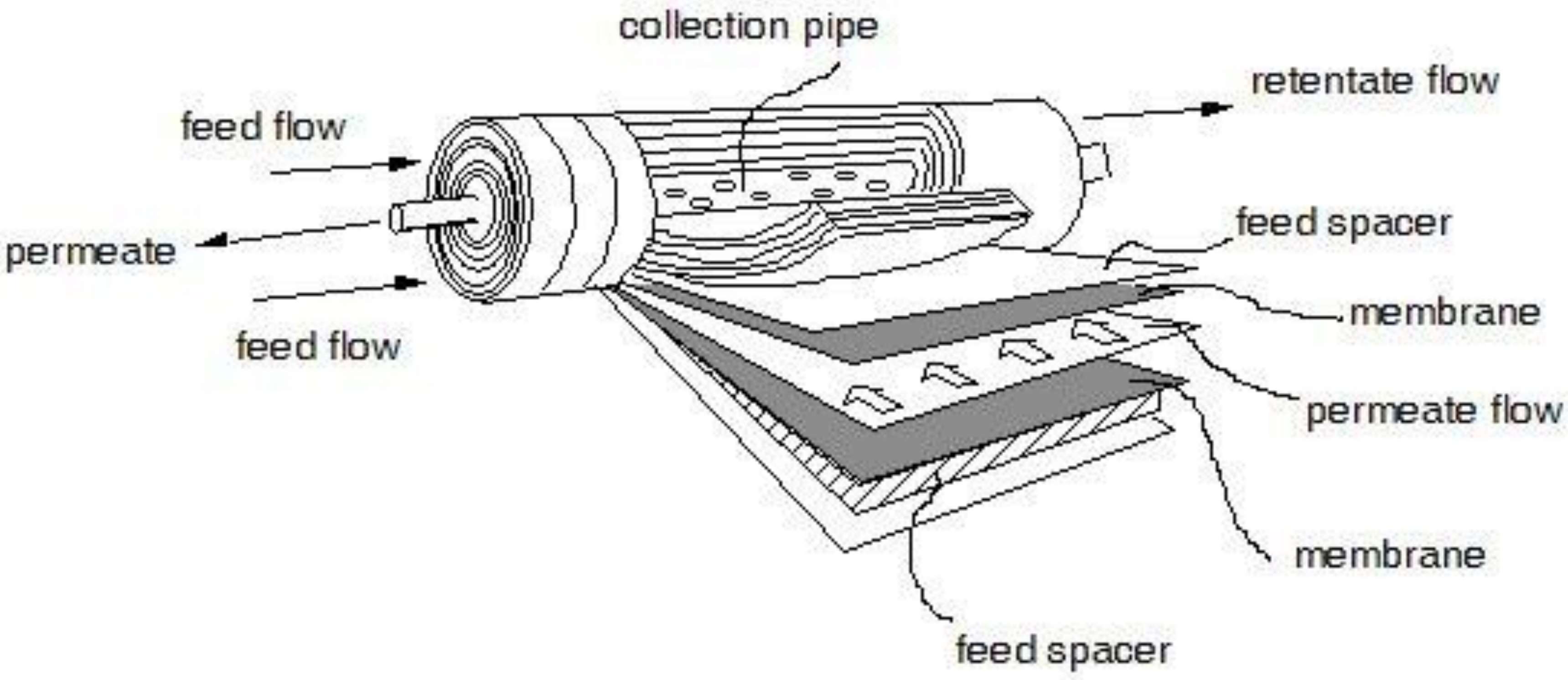
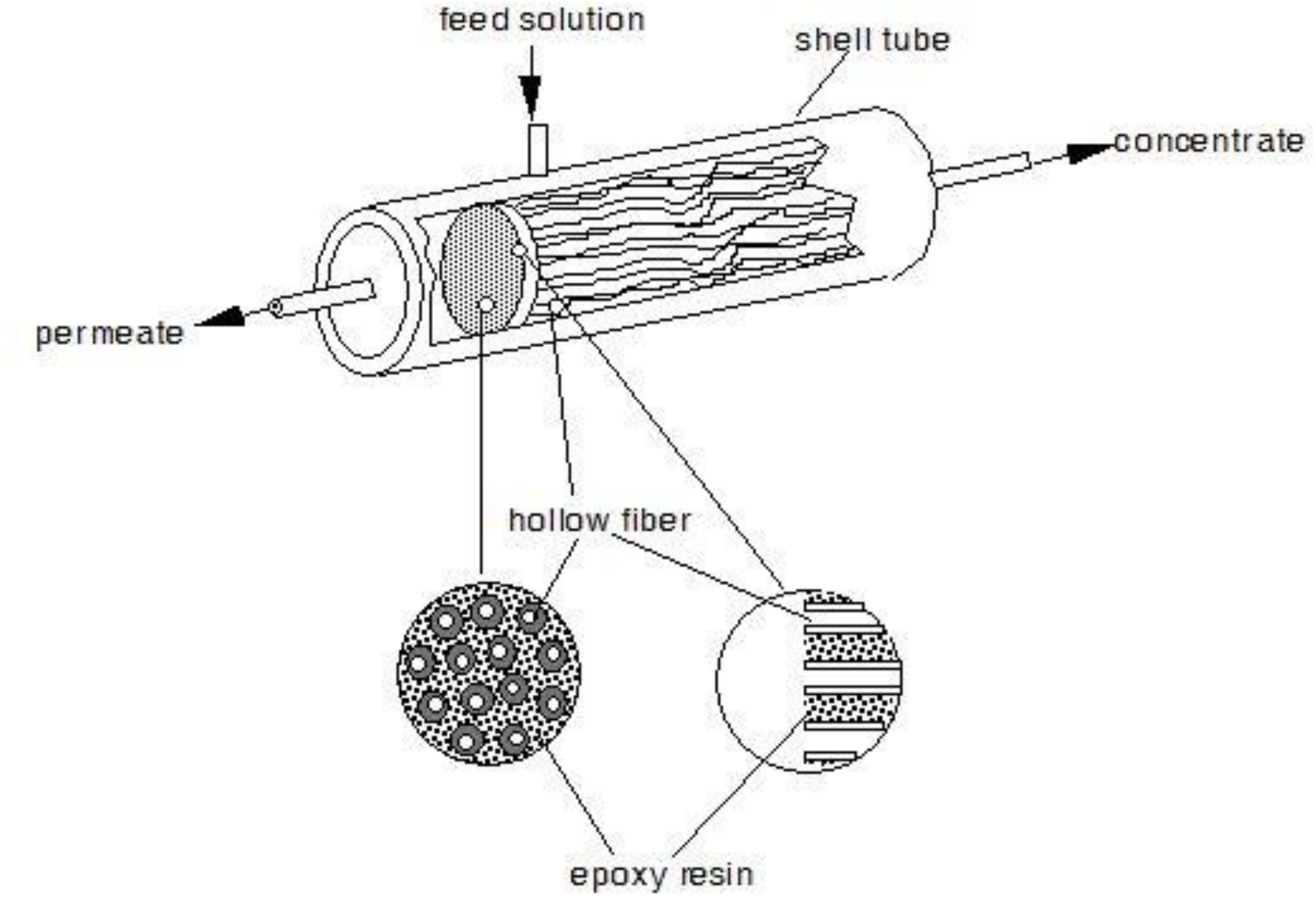
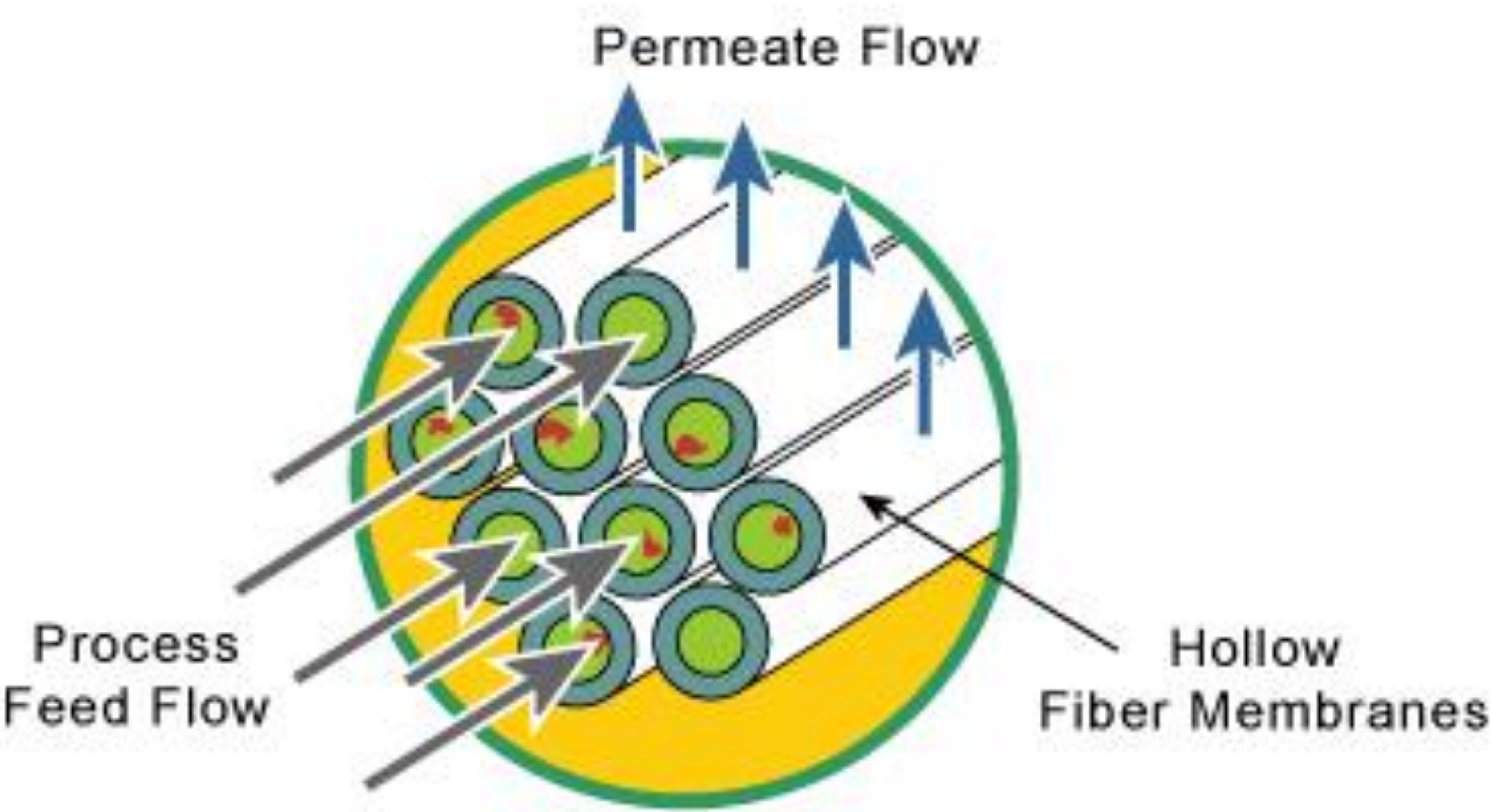
Spiral wounded module



Hollow fiber module



Hollow fiber module



Hollow fiber modules

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Spiral wounded module

Thank you for your attention!