Environmental Technology in Mining

Chapter 3.1.1.3 Water and Wastewater Treatment

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Environmental Technology in Mining

Section 3 Environmental impact and restoration

Chapter 3.1. Environmental Technology

3.1.1 Water management

3.1.1.3 Water and wastewater treatment

Group of Environmental Engineering

Department of Water and Environmental Sciences and Technologies

Universidad de Cantabria

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Water classification according to the source

a) Groundwater:
   - Deep wells
   - Shallow wells

b) Surface water:
   - Rivers
   - Lakes or reservoirs
   - Sea

Generally groundwater ↑↑ quality than surface water

Water classification according to the source

General characteristics of groundwater and surface water

Ground	Surface
Constant composition	Varying composition
High mineralization	Low mineralization
Little turbidity	High turbidity
Low or no color	Color
Bacteriologically safe	Microorganisms present
No dissolved oxygen	Dissolved oxygen
High hardness	Low hardness
H_2S, Fe, Mn	Tastes and odors
	Possible chemical toxicity

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Water Quality Standards

- Standards depend on the use of water:

  (Drinking, bathing, cultivating shellfish, etc.)
- Consider all types of pollutants

  Physical, chemical, radiological and microbiological
- Drinking water standards:
  - Required parametric values (highest level allowed)
  - Indicator parameters: help to identify water treatment deficiencies (no direct public health impact)

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of 16 December 2020

on the quality of water intended for human consumption

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Water Treatment Plants

The treatment processes will depend on:

- The source of water (initial characteristics)
- The quality to be achieved → Water Quality Standards

Water Treatment Plants

POLLUTANT	PROCESS
Floating materials Big solids	Bar racks Screening Comminutors / Macerators
Sand, grit and similar particles	Sand, grit removal
Suspended solids Turbidity	Decantation Coagulation – Flocculation - Decantation Flotation Filtration

Water Treatment Plants

POLLUTANT	PROCESS
Recalcitrant organic matter	Activated carbon Oxidation
Dissolved solids (salts)	Chemical precipitation Adsorption Ion exchange Electrodialysis Reverse osmosis
Dissolved gases	Aeration Air stripping
Bacteria and other microorganisms	Chlorination Ozonation UV Radiation

Water Treatment Plants

WTP: water treatment plant (usually to produce drinking water)

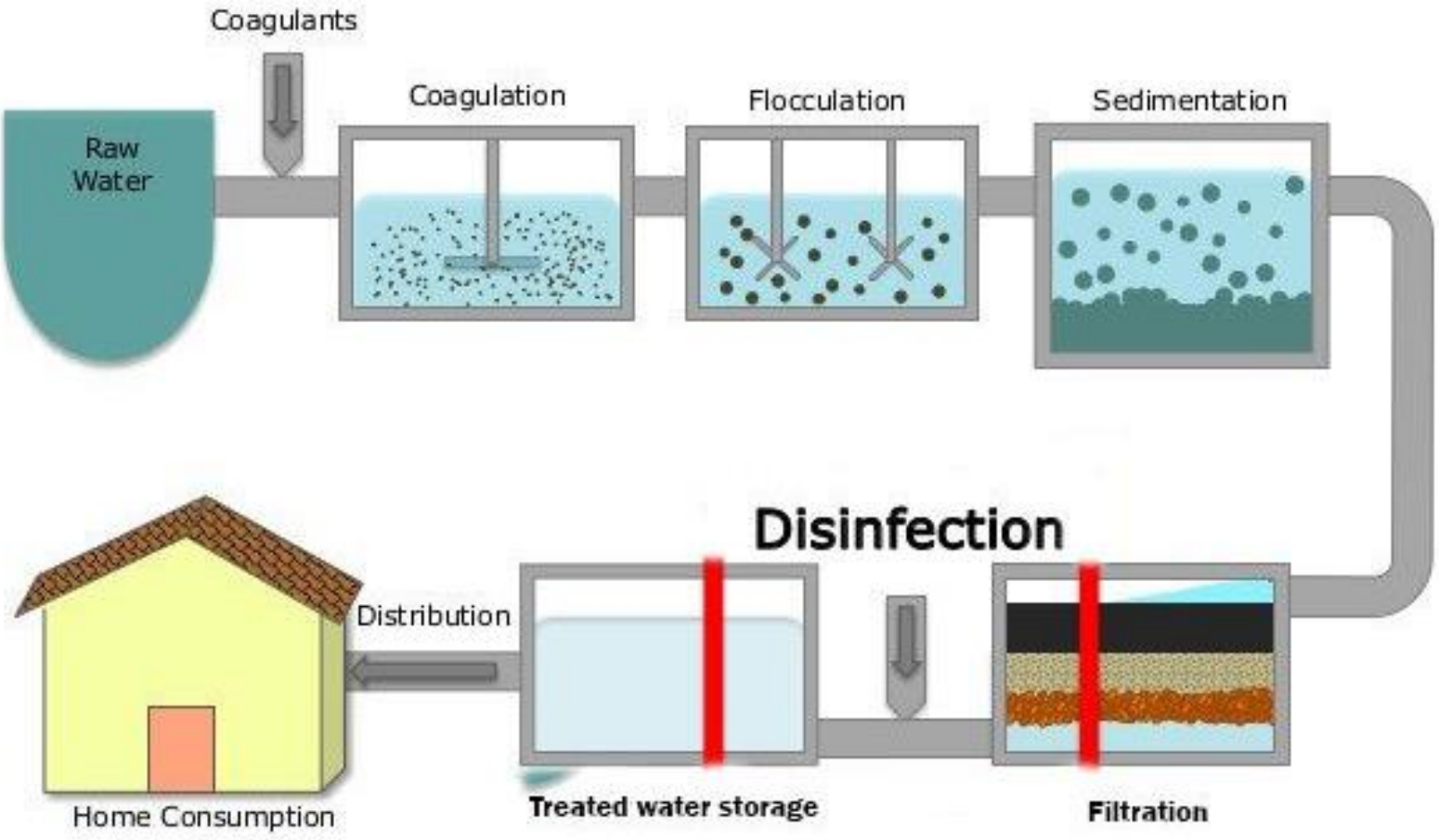
Basic WTP alternatives:

a. Simple chlorination

b. (C-F-D) + Filtration + a.

c. Softening (to remove hardness) + b. + a.

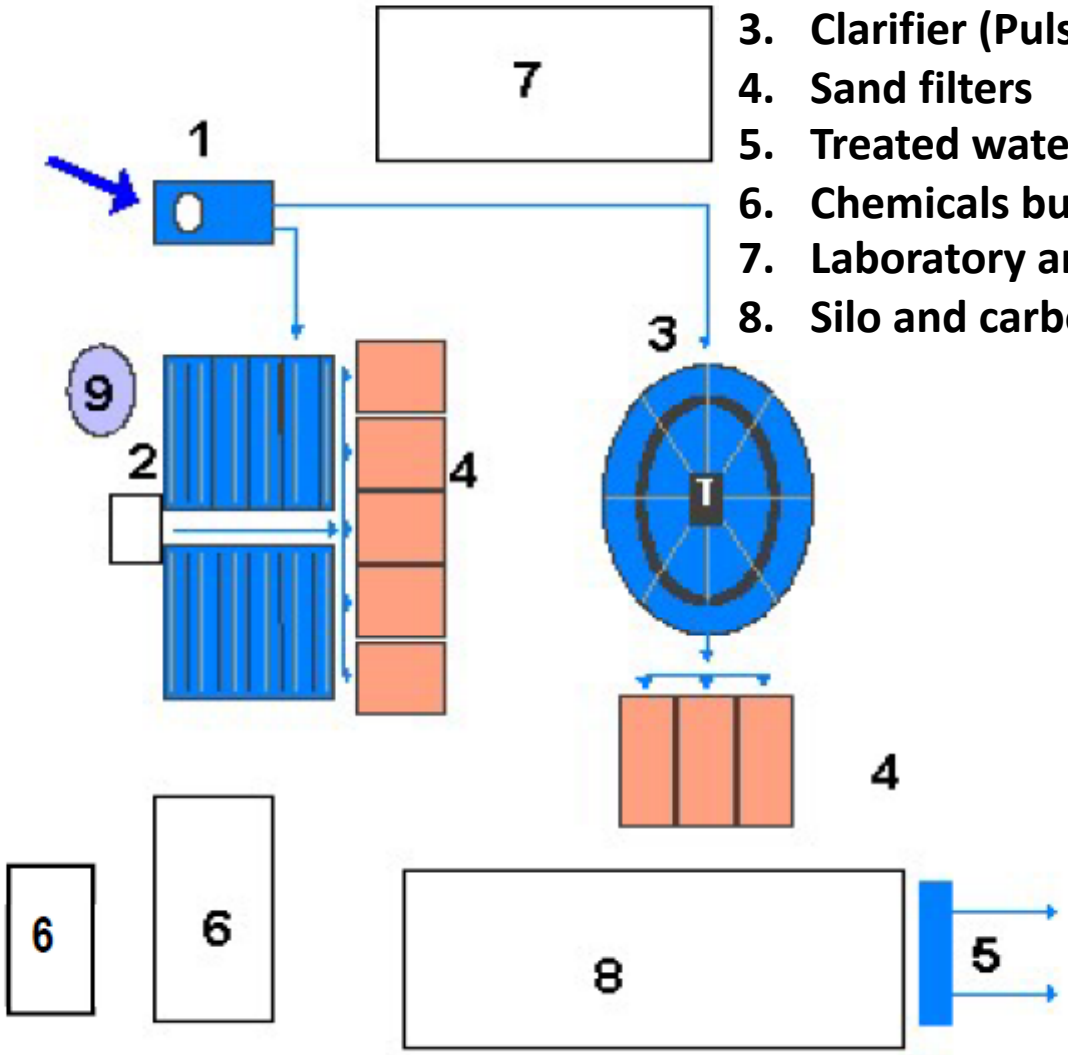
Flow diagram of a typical WTP



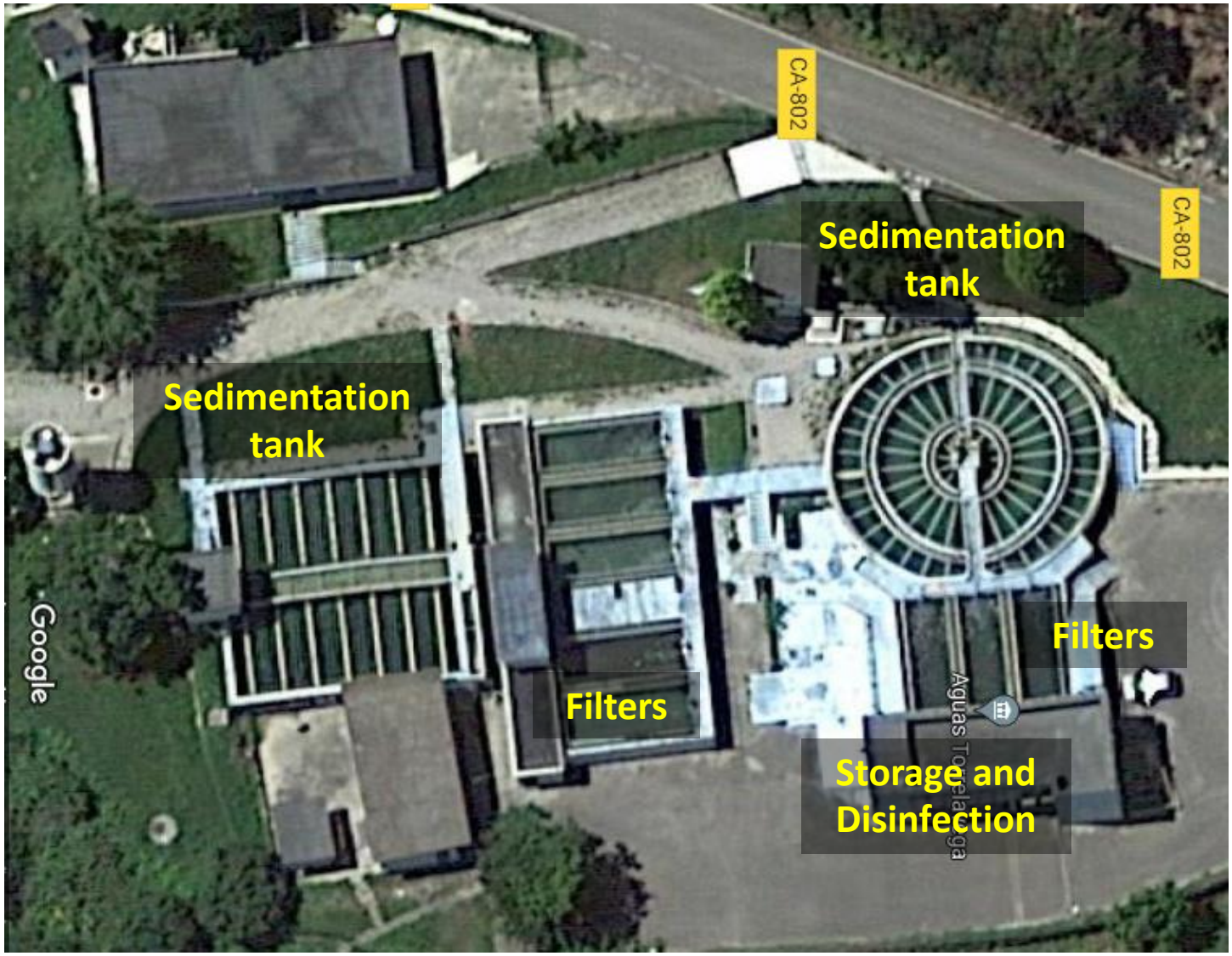
https://civiconcepts.com/blog/water-treatment-process

Water Treatment Plant of Torrelavega

1. Inlet
2. Clarifier (Superpulsator)
3. Clarifier (Pulsator)
4. Sand filters
5. Treated water outlet
6. Chemicals building
7. Laboratory and control room
8. Silo and carbon dosage



Water Treatment Plant of Torrelavega



Coagulation - flocculation

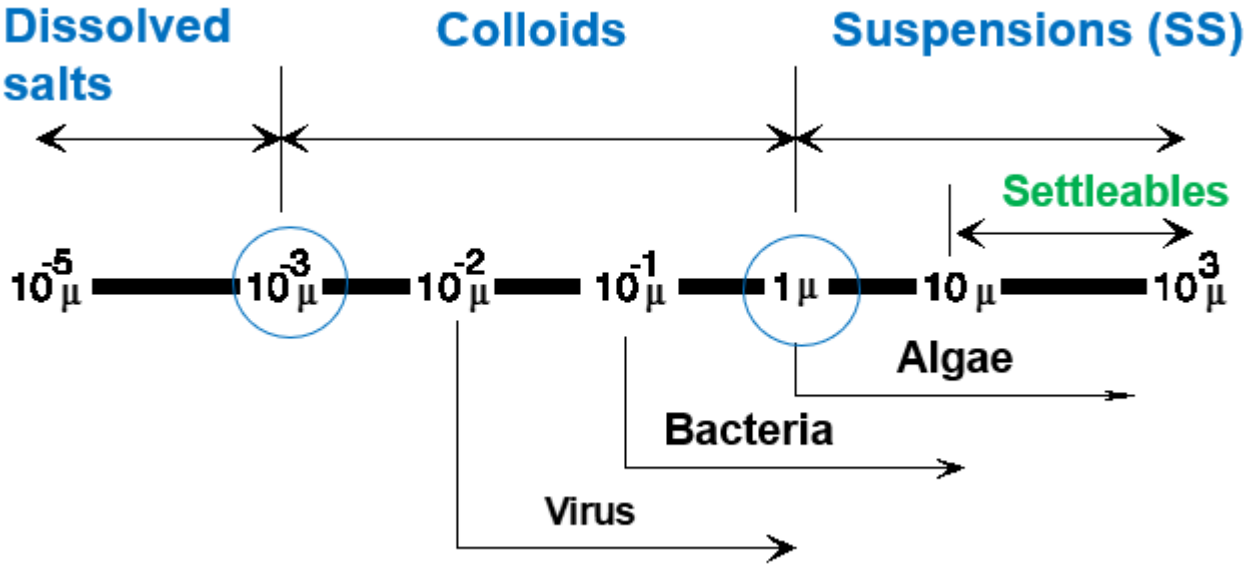
The problema of colloids

COLLOIDS are small particles with:

- little weight
- large surface area
- electric surface charge

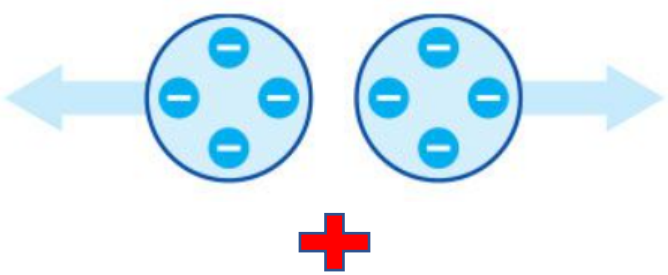
➡ Very "*stable*" in water

Give to water: Turbidity, color, bacteria, viruses



The problem of colloids

Negative charge
(repulsion)



Light weight and large volume

Stability
(do not settle)

SOLUTION

Destabilization
(adding opposite charges) => aggregation=> submicron flocs or coagulum

COAGULATION

Aggregate flocs and add extra weight => macroflocs

FLOCCULATION

(+ Settlement)

The problem of colloids

To remove colloids:

Reduce surface charge → COAGULATION

+

Aggregate solids → FLOCCULATION

+

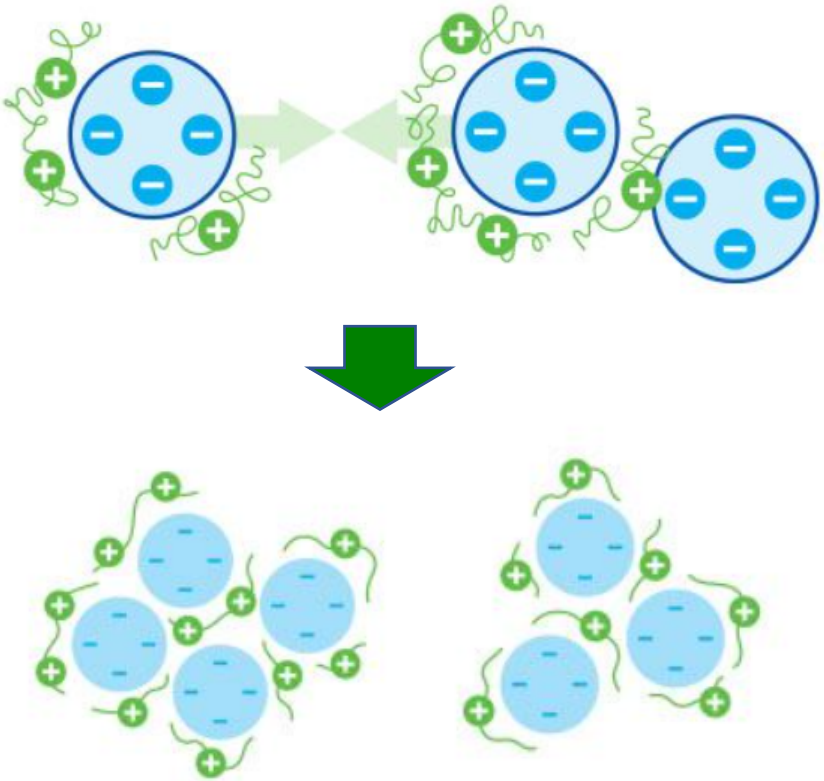
Separate solids from water → SETTLEMENT

+

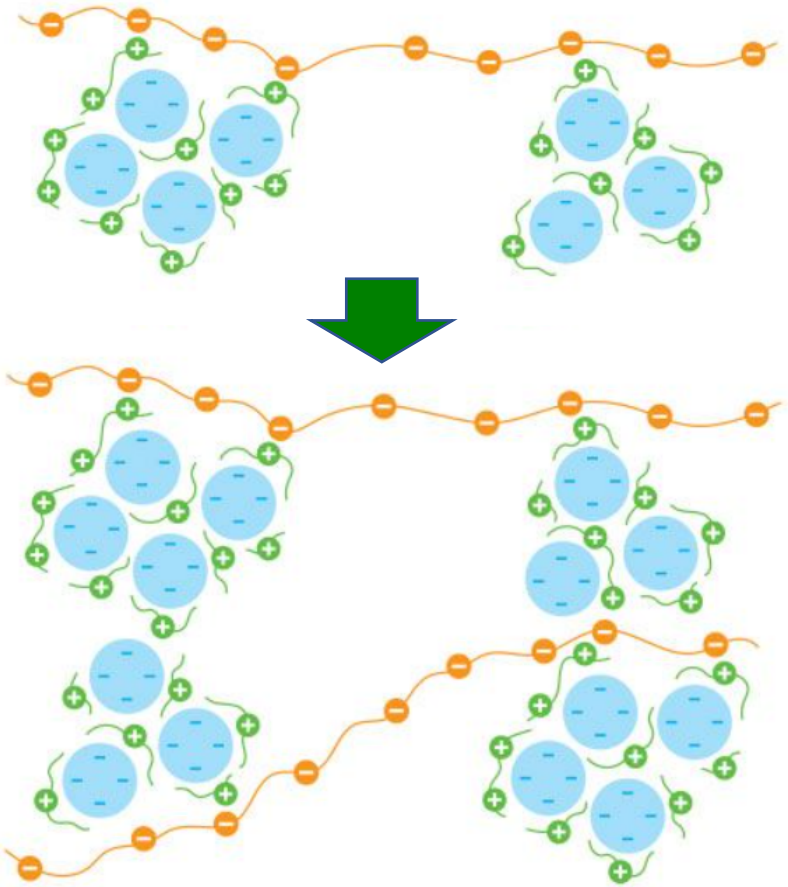
Final removal of solids → FILTRATION

Coagulation and flocculation

COAGULATION



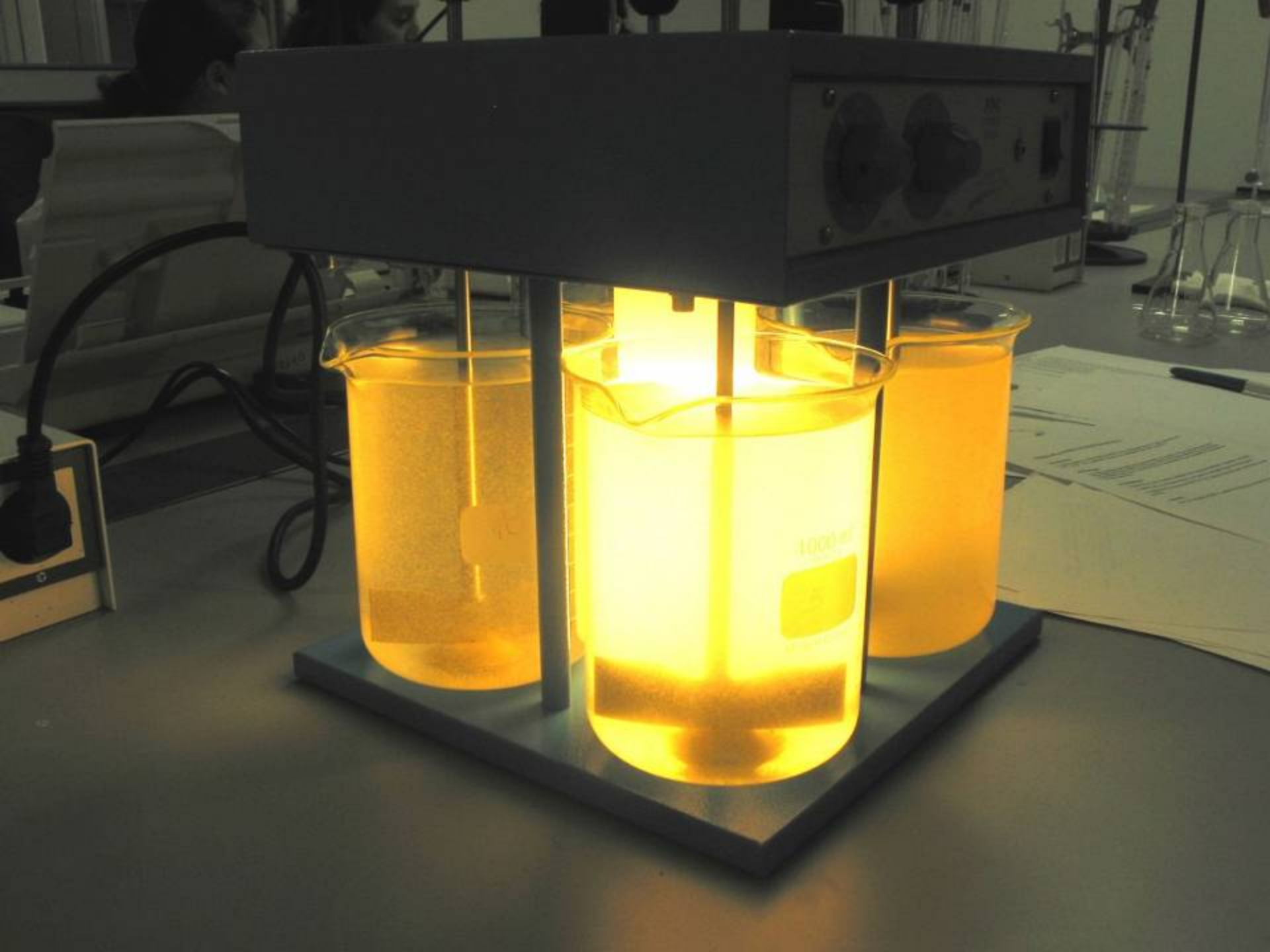
FLOCCULATION

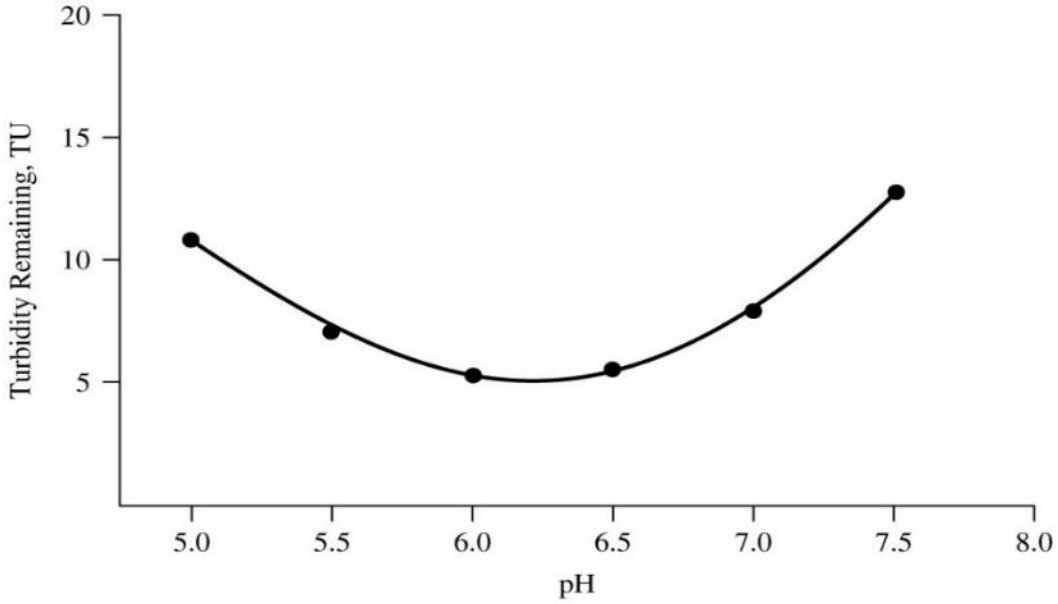


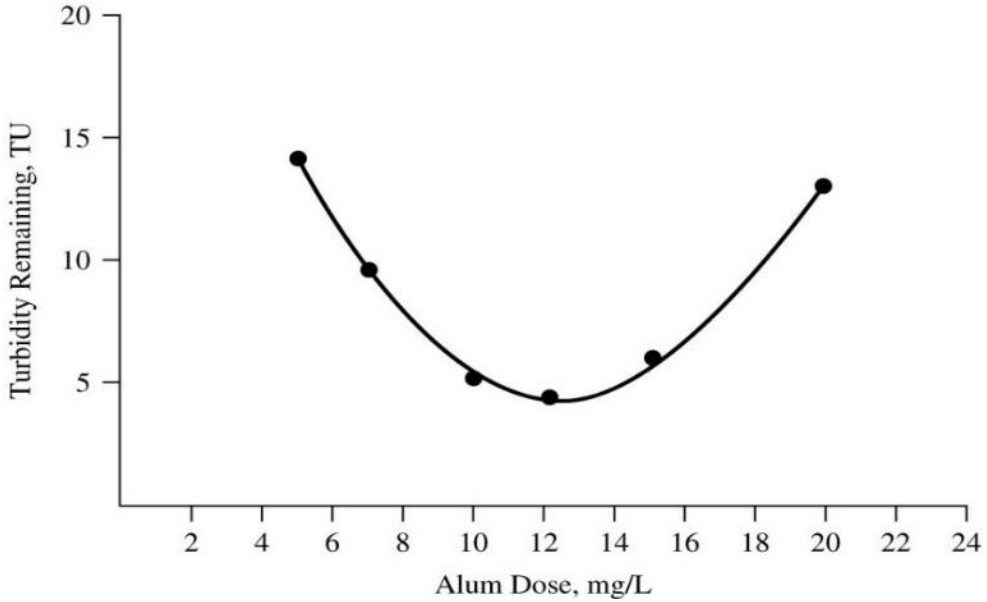
https://rosuaritma.com/urun/partikul-topaklayici/

Coagulation and flocculation: design

- Key design factors ⟶ Jar Test
  - Optimum coagulant
  - Need for coagulant aids
  - Optimum Dose
  - Optimum pH







Results from Jar test

Coagulation → **process**

- Objective:

  Alter the stability of colloids so that they can approach and adhere to each other to form *flocs*

↓

To reduce the surface charge

↓

Introducing ions or polymers in water ("coagulants")

+ coagulant aids

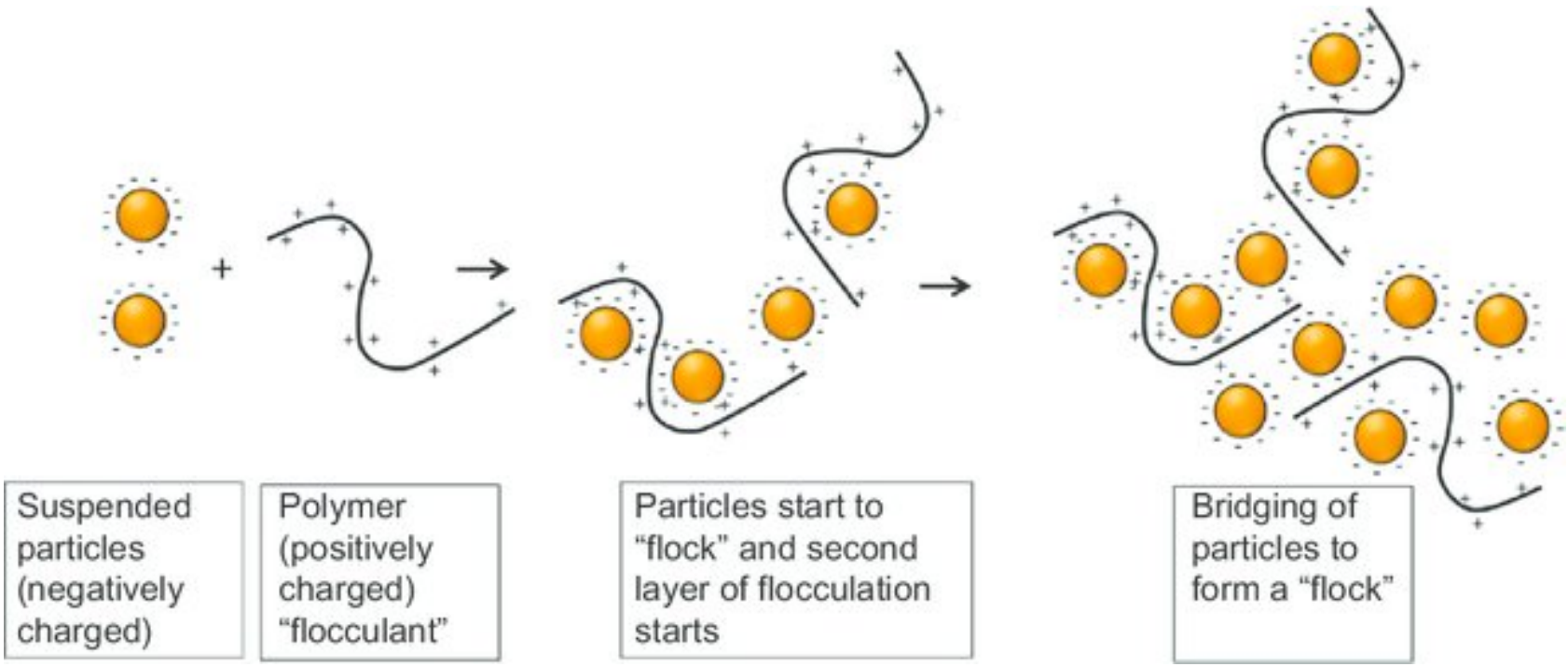
+ rapid mixing

Flocculation → **process**

- Objective:

  Bring the particles into contact so that they collide, stick together and grow to a size that readily settles

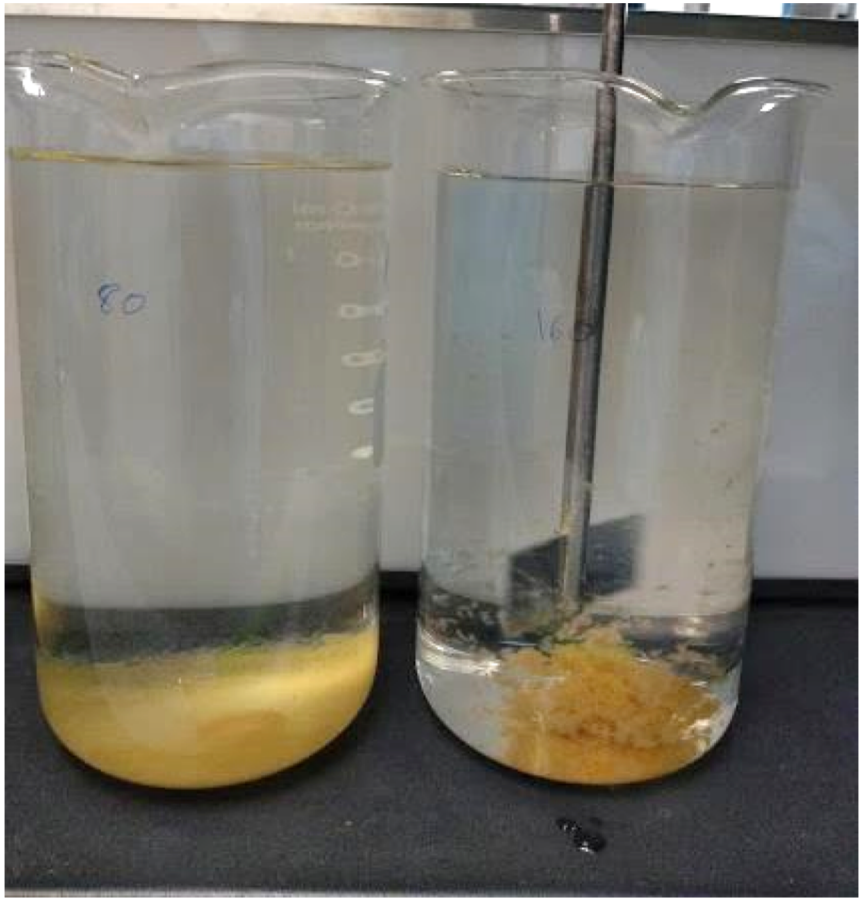
  Slow mixing is required (avoid floc breakage)



Flocculation → **process**

- Coagulation vs. flocculation

Coagulation



Flocculation

Sedimentation

Objective of sedimentation = clarification

Removing particles that settle within a reasonable period of time

Diámetro de partícula (mm)	Tipo de sólido	Tiempo de sedimentación para 1 metro (orden de magnitud)
10	Grava	1 segundo
1	Arena	10 segundos
0.1	Arena fina	2 minutos
0.01	Arcilla	2 horas
0.001	Bacteria	8 días
0.0001	Partícula coloidal	2 años
0.00001	Partícula coloidal	20 años

In WTP to reduce turbidity before the filters.

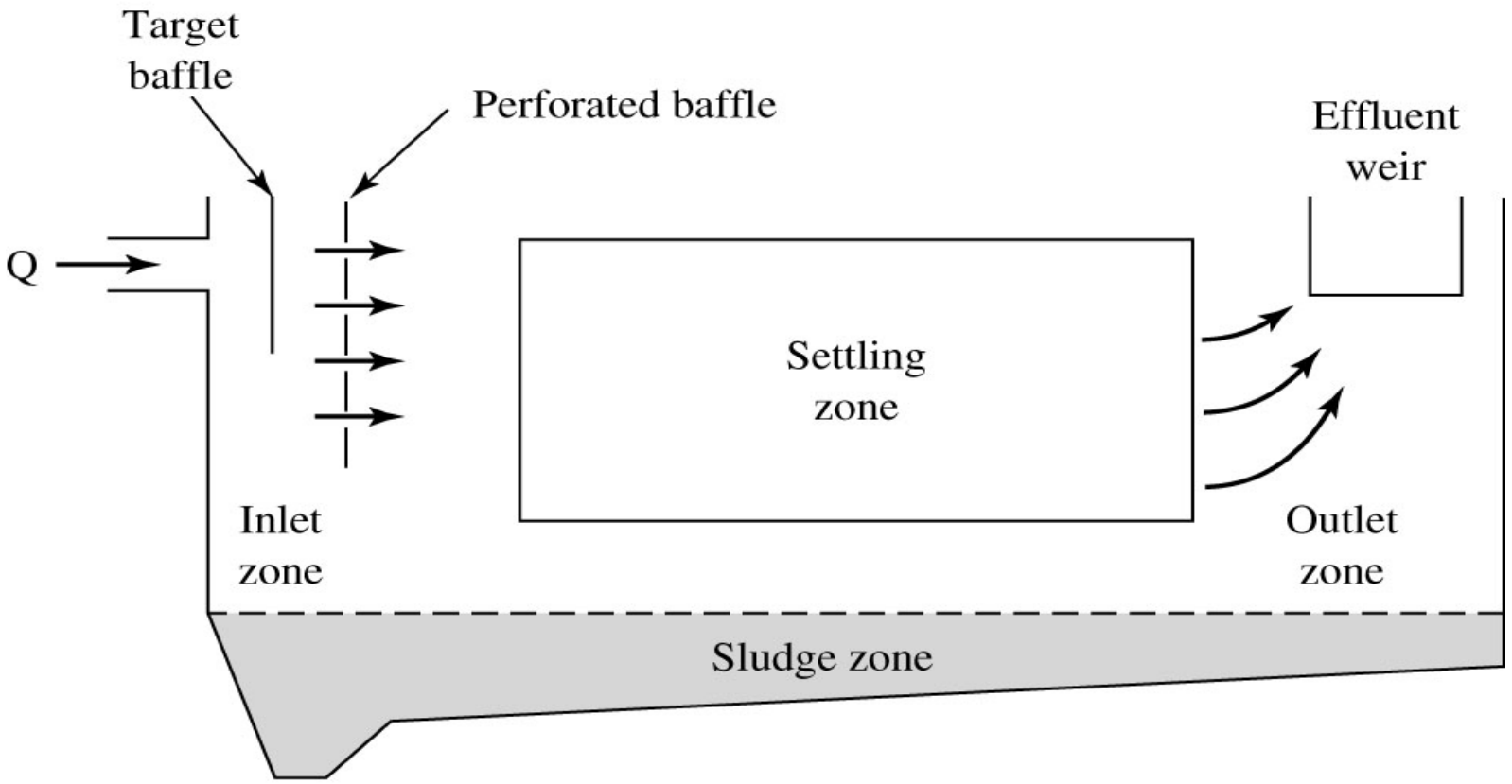
It is used with or without a previous coagulation-flocculation stage

Elements of Sedimentation basins

= clarifier, settling tank, decanter

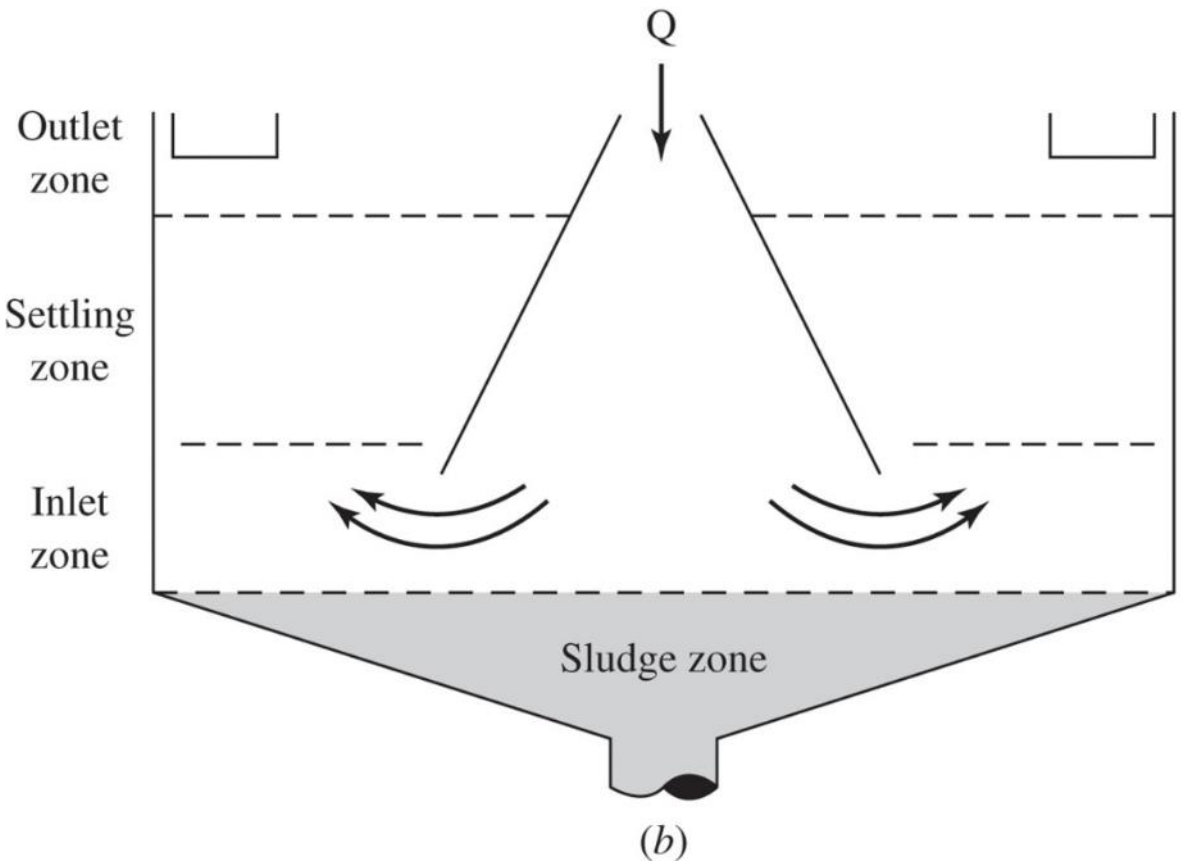
- Type of basins:
  - Rectangular → Horizontal flow
  - Circular → Upflow
- Basin zones:
  - Inlet → Baffles, to evenly distribute the flow
  - Outlet → Weirs, to avoid “scouring” (washing out)
  - Settling zone
  - Sludge storage → particules storage and removal

Zones in a horizontal flow clarifier



(*a*)

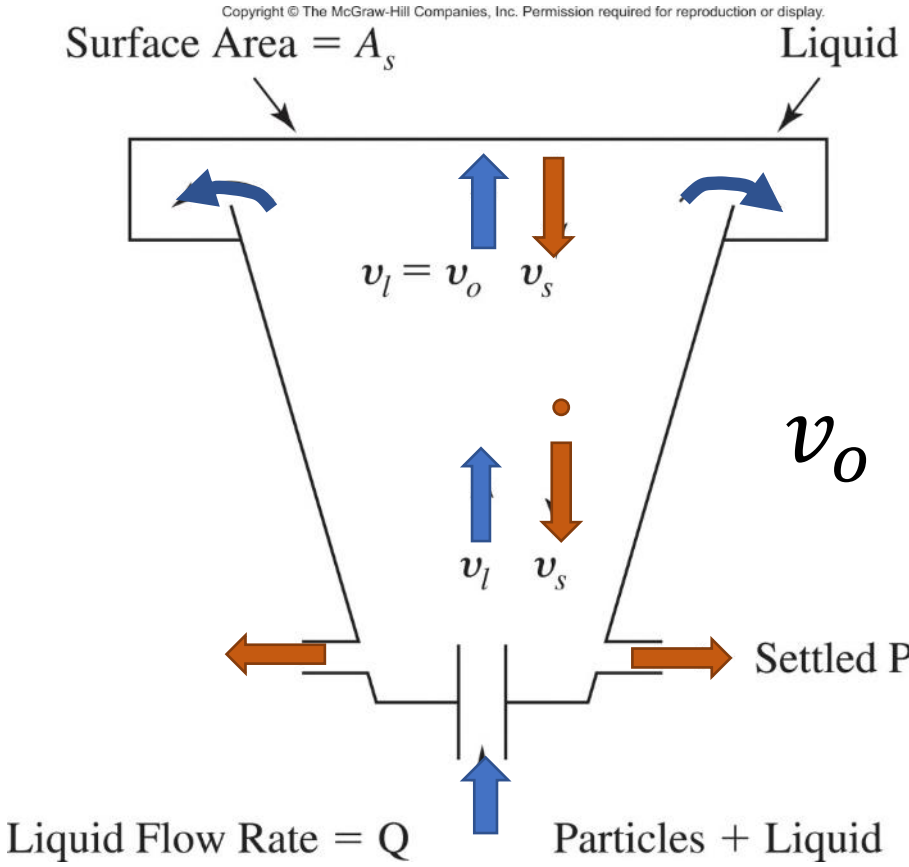
Zones in a circular clarifier



Analyzing the process: upflow settling tank

v_o: "overflow rate" or "surface loading rate" ($m^3/d \cdot m^2$)

v_s: settling velocity (m/d)



l = liquid

s = solids

$$v_o = \frac{Q}{A_s} < V_s$$

The velocity of a liquid equals the flow rate divided by the cross section (v = Q/A)

Filtration

Introduction

- Purpose of filtration:

  Usually required to reduce turbidity to less than the regulatory value

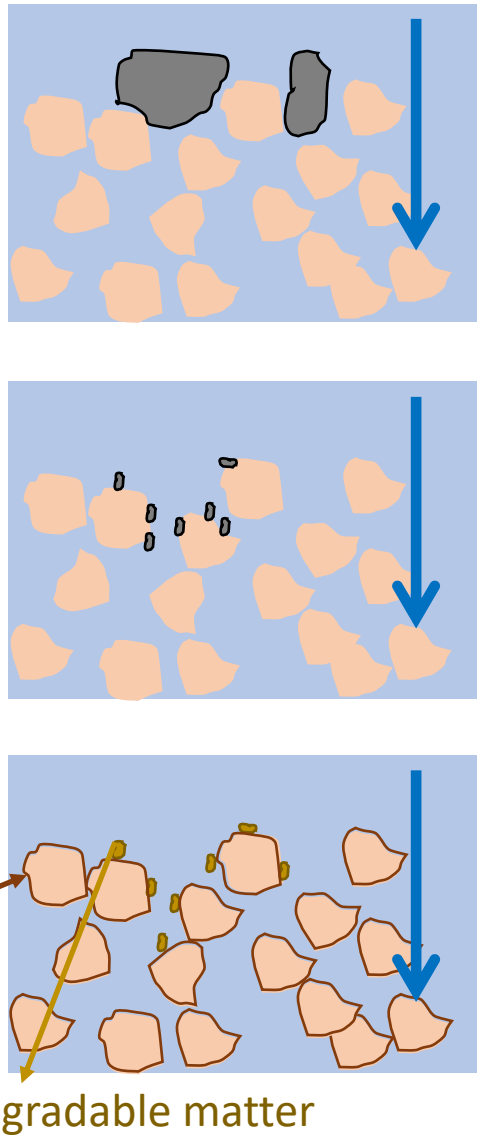
  i.e. Spanish regulation:

  Turbidity after WTP < 0,8 NTU

- Why such low turbidity is needed?
  - Turbid water is difficult to disinfect
  - Turbidity can cause deposits in the distribution system (=> tastes, odors and bacterial growths)

Filtration concept and mechanisms

- Process for separating suspended or colloidal impurities from water by passage through a porous medium
- Mechanisms of filtration:
  - *Straining:* particles bigger than the pores of the filter
  - *Adsorption:* solids become attracted to and "sticking" to the filter grains
  - *Biological action*



Loading rate

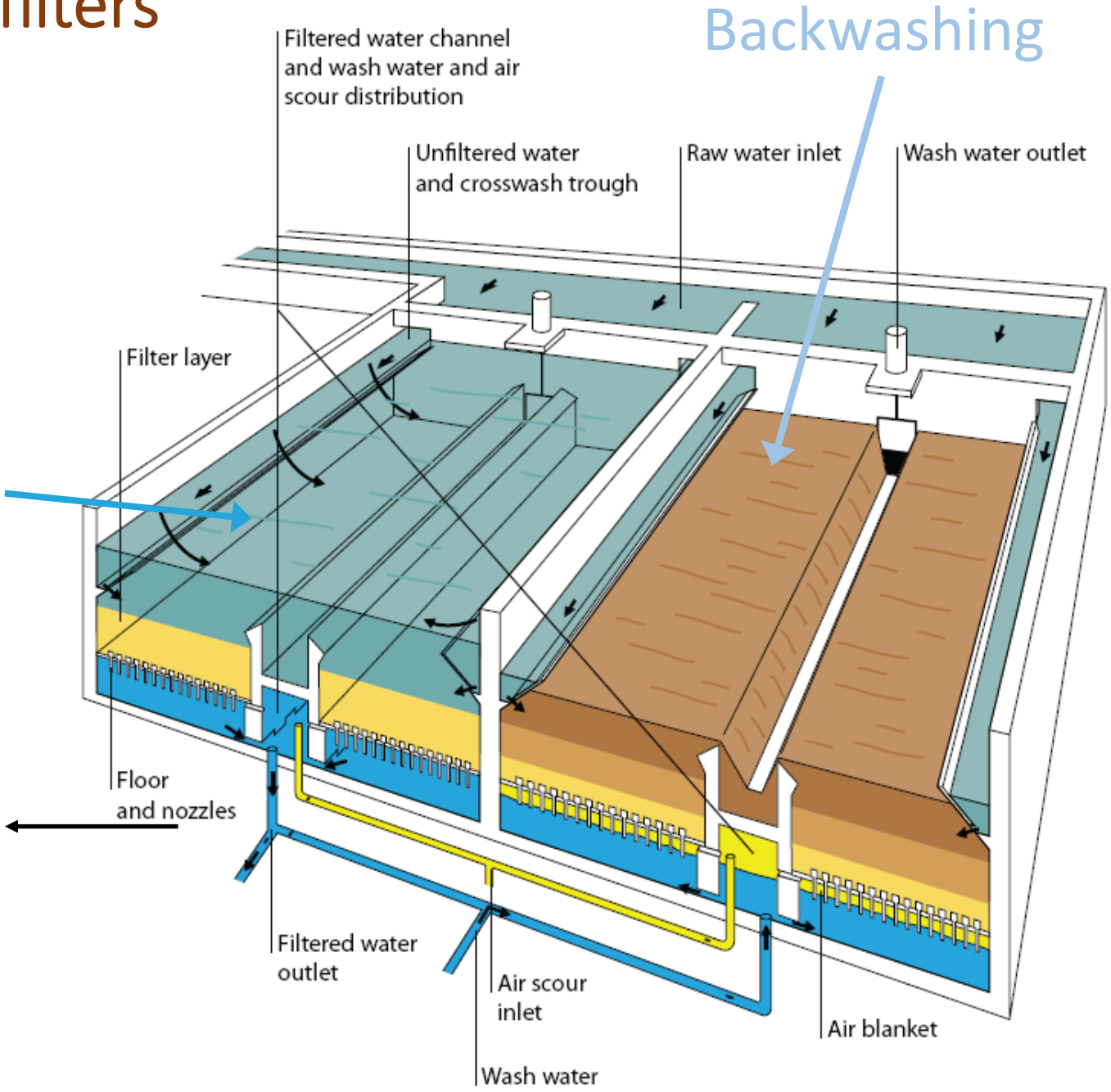
- Flow rate of water applied per unit area of the filter (or face velocity of the water)

$$v_a = \frac{Q}{A_s}$$

where v_a = face velocity, m/d
= loading rate, $m^3/d \cdot m^2$
Q = flow rate onto filter surface, m^3/d
A_s = surface area of filter, m^2

Rapid sand filters

- E.g. Aquazur (Degremont)



Rapid sand filters

- E.g: WTP of Santander. Sand filter battery

Rapid sand filters

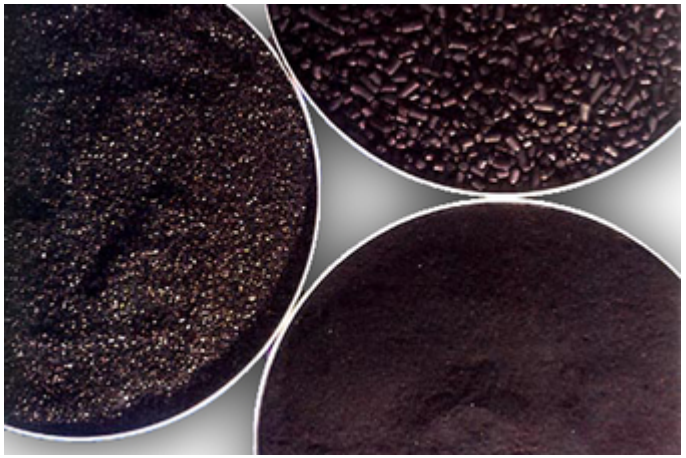
- E.g: WTP of Santander. Filtering.

Rapid sand filters

- E.g: WTP of Santander. Backwashing.

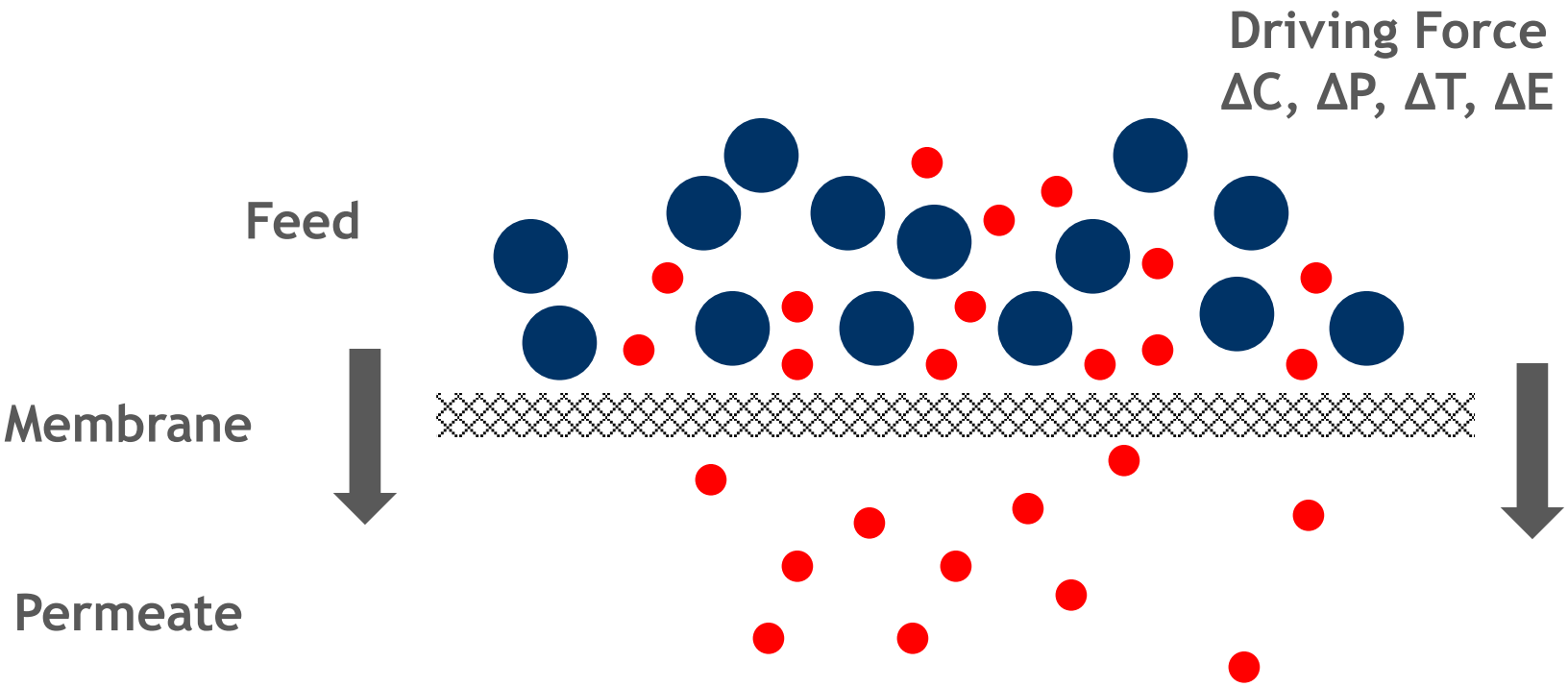
Adsorption

- A substance is transferred from the liquid phase to the surface of a solid
- In water treatment: activated carbon
  - GAC: granular activated carbon
  - PAC: powdered activated carbon
- Main usages:
  - Taste and odor control
  - Removal of:
    - SOC (synthetic organic contaminants): PCB, pesticides, dioxins…
    - VOCs (volatile organic compounds)
    - OM (organic matter)

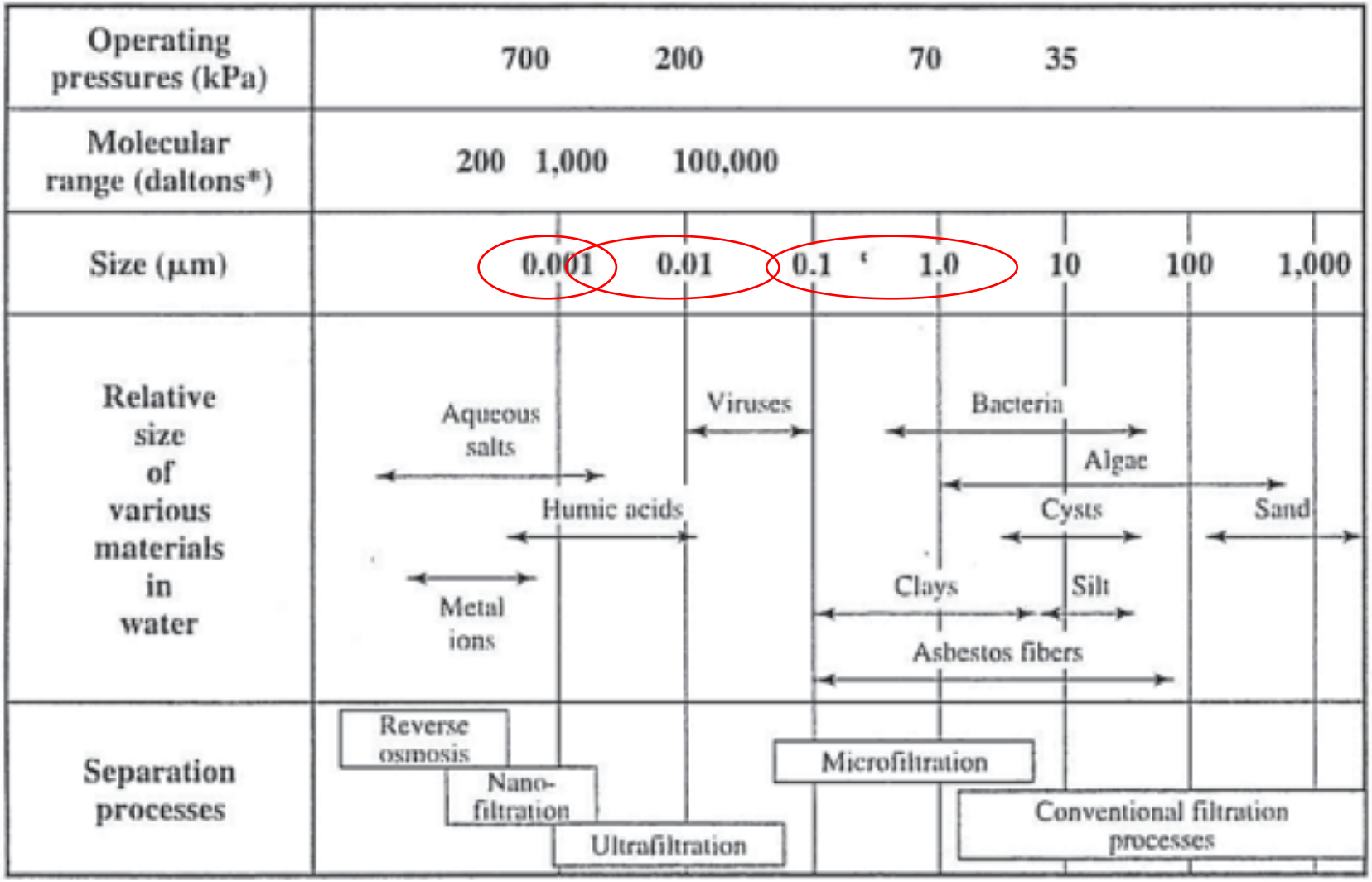


Membranes

- Ability to separate materials
- Increasingly popular in water treatment



Membranes


Operating pressures (kPa)
700
200
70
35
Molecular range (daltons*)
200
1,000
100,000
Size (μm)
0.001
0.01
0.1
1.0
10
100
1,000
Relative size of various materials in water
Aqueous salts
Viruses
Bacteria
Algae
Humic acids
Cysts
Sand
Metal ions
Clays
Silt
Asbestos fibers
Separation processes
Reverse osmosis
Nano-filtration
Ultrafiltration
Microfiltration
Conventional filtration processes

Disinfection

Disinfection methods

- Physical treatment
  - Solids removal (shelter for microorganisms)
    - Coagulation, flocculation, sedimentation, filtration.
  - Heat
- Radiation
  - Ultraviolet (UV)
- Chemical treatment (oxidation)
  - Chlorination
  - Ozonation
  - Others (Cu, Ag, permanganate, …)

Chlorine reactions in water

- When chlorine is added to water:

$$Cl_2\ (g) + H_2O \Leftrightarrow HOCl + H^+ + Cl^-$$

Chlorine gas + water ⇔ hypochlorous acid + hydrochloric acid

$$HOCl \Leftrightarrow H^+ + OCl^-$$

hypochlorous acid ⇔ hydrogen ion + hypochlorite ion

- Disinfectants are:
  - HOCl (more powerful) and OCl^- (less powerful)
  - HOCl / ClO^- is pH dependent

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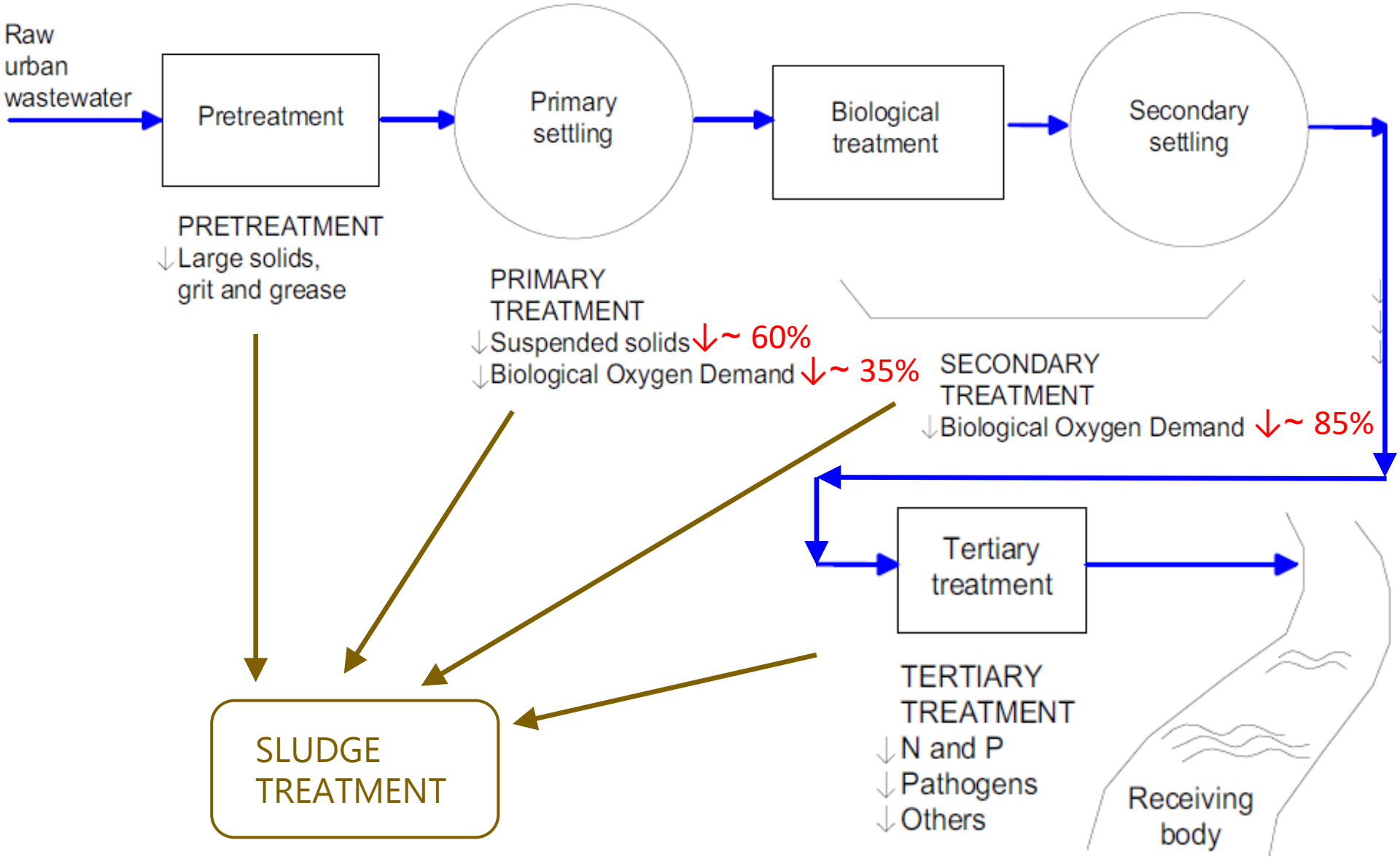
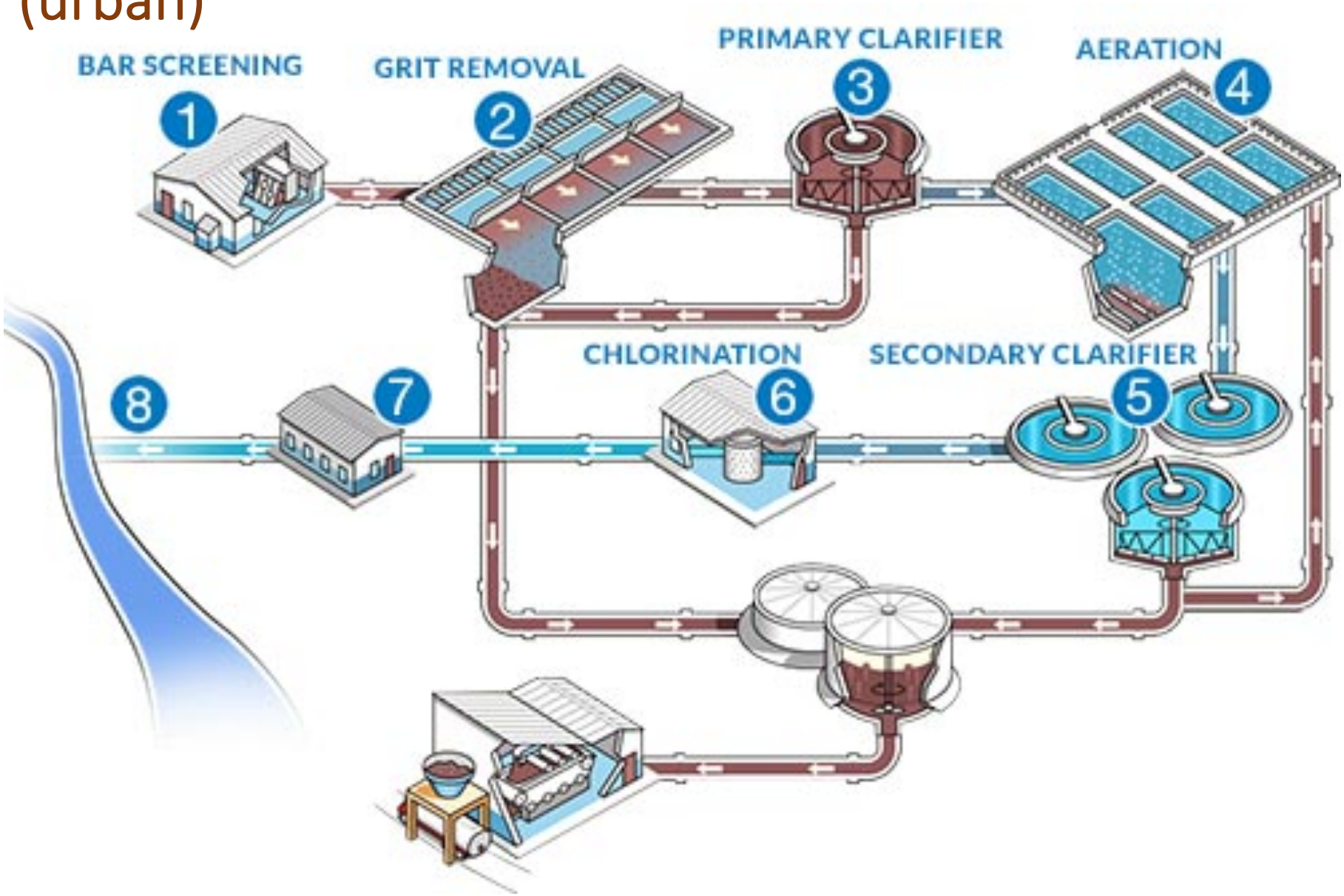
Wastewater pollutants

- Chemical characteristics (pollutants)
  - Biochemical oxygen demand, BOD_5
  - Chemical oxygen demand, COD
  - Total Nitrogen, N
  - Total Phosphorus, P
  - Toxic compounds (industrial WW)
  - pH (industrial WW)
- Biological characteristics
  - E. coli
  - Fecal coliform bacteria

Wastewater treatment plant typical scheme (urban)

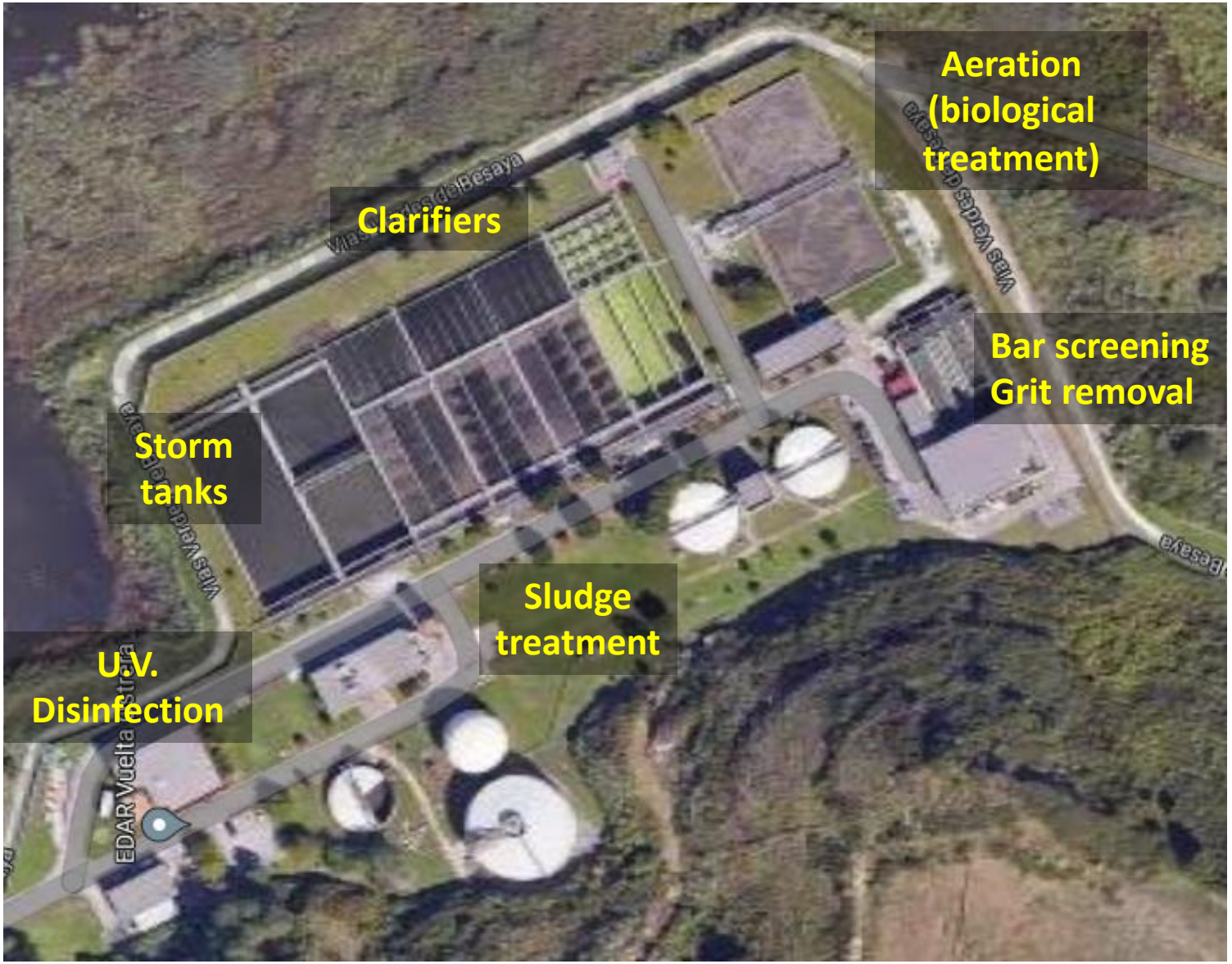


Wastewater treatment plant typical scheme (urban)



https://www.coleparmer.com/tech-article/eight-stages-of-wastewater-treatment-process

WWTP of Vuelta Ostrera (Suances)



Biological reactor (aeration tank) (WWTP of Santander)

Secondary clarifier (WWTP of Santander)

Chapter review (1/3)

- Water treatment will depend on water source and water quality standards.
- Typical water treatment plants (WTP) will have the following processes:
  - Removal of floating materials, big solids, sand and grit
  - Removal of colloids (difficult due to their stability): Coagulation-Flocculation-Sedimentation-Filtration
  - Disinfection
- Other processes: adsorption, membranes, …

Chapter review (2/3)

- Coagulation-Flocculation:
  - Jar test to obtain key design factors (optimum coagulant, dose and pH, need for coagulant aids)
- Sedimentation:
  - Design parameter: surface loading rate or overflow rate
  - Horizontal flow (rectangular) and vertical-upflow (circular)
- Filtration:
  - Straining, adsorption and biodegradation
  - Design parameter: loading rate or face velocity
- Disinfection: most common => chlorination (depends on pH)

Chapter review (3/3)

- Typical Wastewater Treatment Plant (WWTP) (urban)
  - Pretreatment (↓large solids, grit and grease)
  - Primary settling (↓↓ SS, ↓ BOD)
  - Biological treatment + Secondary settling (↓ ↓ BOD)
  - Tertiary treatment (↓ N, P, Pathogens, Others)
  - Sludge treatment (from all the processes)