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PRIMARY TREATMENT

- **NATURE**
  - **Physical and chemical processes.**
    - **Physical: sedimentation based in density differences**
    - **Chemical: coagulation and flocculation, pH adjustment, precipitation (formation of insoluble compounds by addition of chemicals)**
- **OBJECTIVES**
  - **Removal of suspended solids**
  - **Removal of heavy metals, phosforous and non-soluble pollutants**
  - **Partial removal of BOD**
- **FLOW SEPARATION**
  - **Treated liquid effluent**
  - **Sludge: 1-3% of dry waste (Generally classified as Hazardous Waste)**
  - **Heavy metal sludge**

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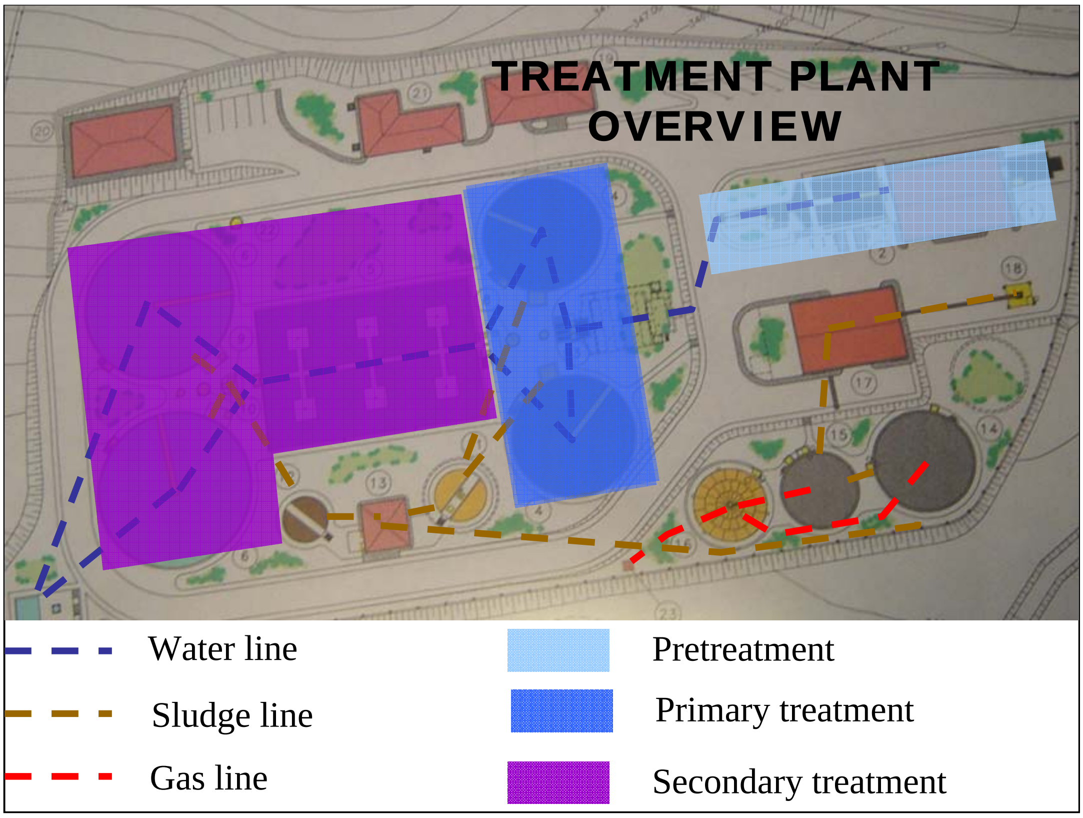
TREATMENT PLANT

The Linares wastewater treatment plant begun operating in 2001. It treats urban wastewater of an equivalent population of 60.000 people. The average design flow is 17.280 m^3/day (12 m^3/min), and treated water is discharged into the Baños stream, within the Guadalquivir area. There is no segregation in the sewerage system, which means that both white and black water must be treated in the treatment plant. Industrial wastewater content is minimum.



The treatment plant has two lines for water –blue lines- a sludge treatment line –brown line- and a biogas line –red line-.

Pretreatment (light blue colour) is composed of a storm tank (at the headwork) a sedimentation tank, a pumping system, a screening system, a degritter-degreasing unit and a flowmeter.

Primary treatment (in dark blue) has two decanters.

The secondary treatment (purple) is composed of an aerobic digester with sis mechanical stirrers and two clarifiers.

Sludge treatment consists in a thickener and a flotation tank, together with a high load anaerobic digester and a low load digester.

The biogas line has a gasholder, a torch and auxiliary systems for energy production.

Note that some additional auxiliary systems are not indicated in the scheme.

*Gasholder: *gasómetro de campana*

* Sludge*: fango or lodo*

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TWO WATER LINES

Two water lines (two decanters) exist in the primary treatment

The image shows the manhole where water flow coming from pretreatment is divided in two lines.

Only one line may be in operation due to maintenance works or a low flow

Manohole: *arqueta*.

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PRIMARY DECANTER

Primary decanter.

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SEDIMENTATION

Separation of a dispersed phase (solid or liquid) from a continuous phase (liquid or gas) based in the density differences.

$$v = \left(\frac{4 \cdot d \cdot g (\rho_d - \rho_c)}{3 C_D \cdot \rho_c} \right)^{1/2}$$

- **v = final speed downwards**
- **d = diameter**
- **g = gravity**
- **ρ_d = specific weight of the dispersed phase**
- **ρ_c = specific weight of the continuous phase**
- **C_D = carryover coefficient ($24/R_e + 3/R_e^{1/2} + 0{,}34$)**
- **R_e = Reynolds number**

Ø (mm)	Type	Sedimentation (for 1 m)
10	Gravel	1 s
1	Sand	10 s
0,1	Fine-size sand	2 min
0,01	Clay	2 hours
0,001	Bacteria	8 days
0,0001	Colloidal particle	2 years
0,00001	Colloidal particle	20 years

Sedimentation is the separation of a dispersed phase (solid or liquid) from a continuous phase (liquid or gas) based in the density difference between both phases.

In wastewater treatments, sedimentation is the separation process of solid particles of a density higher than 1 kg·L-1 (settleable solids, usually known as SS) that are in movement along with wastewater. Moving particles are subject to gravitational and frictional forces, all of them proportional to gravity and to particle size.

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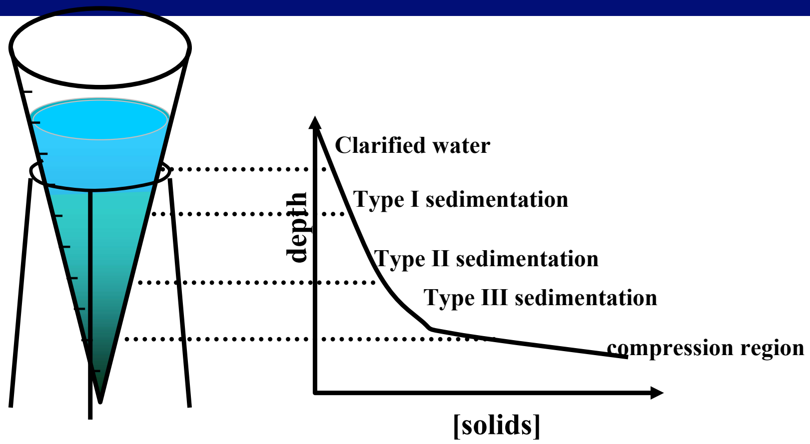
SEDIMENTATION: VELOCITY



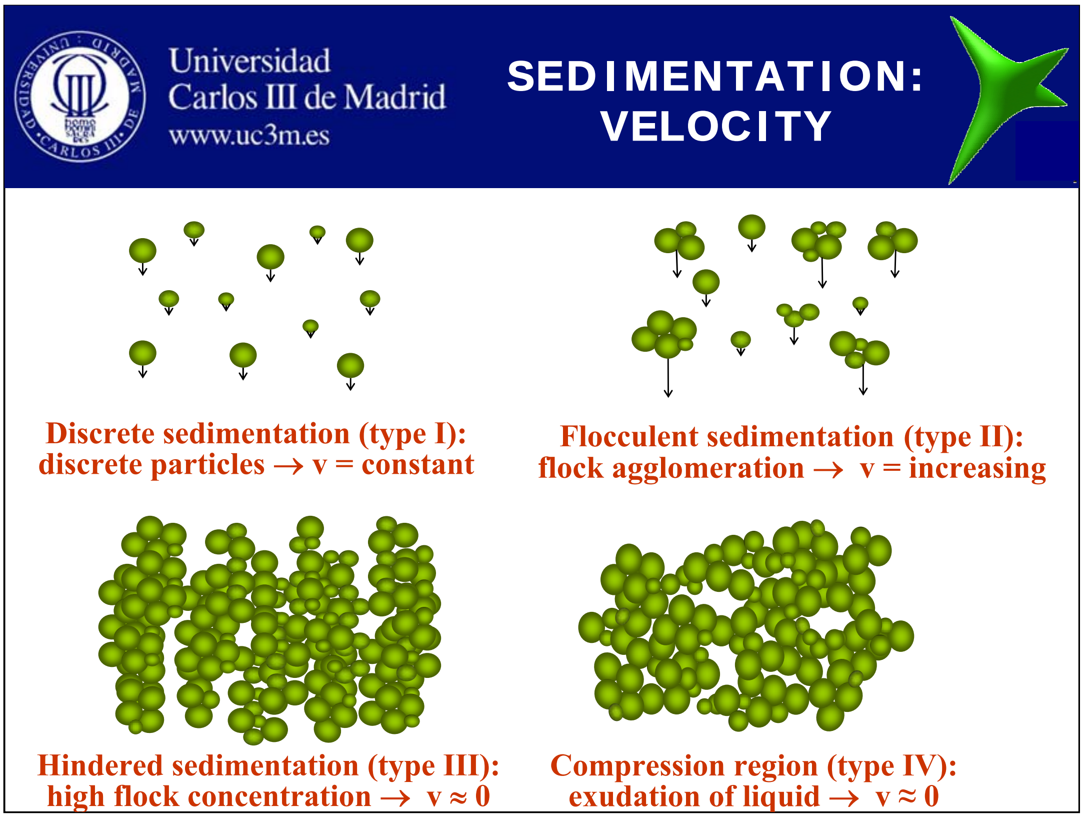
- **Discrete sedimentation (type I): discrete particles → v = constant**
- **Flocculent sedimentation (type II): floc agglomeration → v = increasing**
- **Hindered sedimentation (type III): high concentration of flocs → v ≈ 0**
- **Compression region: water is exuded out of the sludge → v ≈ 0**

Sedimentation is a complex process that can be viewed as composed of several stages. When a given volume of water with suspended solids is allowed to settle, a clear solid compositional gradient will be observed after a while in an initially homogeneous system, with solid concentration increasing when going deeper into the liquid column, which is observed as an increase of water turbidity with depth. If solid concentration is represented versus depth several regions can be observed:

* Clarified water: higher layer without solids causing turbidity.
* Type I sedimentation: discrete particles.
* Type II: flocculent sedimentation.
* Type III: hindered sedimentation.
* Type IV sedimentation or compression region.

v stands for vertical velocity

Hindered sedimentation: *sedimentación impedida*



Type I Sedimentation: region where solid concentration is very low and solids behave as discrete particles moving at a constant speed. Particle velocity follows Newton law and is a function of size and density.

Type II Sedimentation: distance between particles decreases as solid concentration increases, so that the attractive forces among them gain importance thus favouring particle agglomeration and formation of flocks of a larger size. Sedimentation velocity is a function of particle size and therefore increases with concentration.

Type III Sedimentation: solid concentration is so high that flocks are so close that do not allow a free movement. First the acceleration of the sedimentation process decreases until null due to the deaccelerating effect of repulsive forces. The movement is cooperative, so that relative particle positions are kept and they are forming a quasi-homogeneous mass that settles down, with a distinctive top solid-liquid between the floccules aggregate and the clarified effluent. The velocity decreases when approaching the compression area.

Type IV Sedimentation: the compression region where particles are concentrated so that movement leads to compression, due to the weight of new particles arriving from the upper liquid and to exudation of the liquid in that region.

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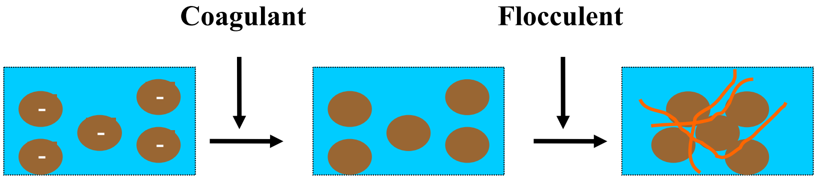
COAGULATION AND FLOCCULATION



COMPOUD	FORMULA	EFFECT	DOSE
Alum	$Al_2(SO_4)_3 \cdot nH_2O$	Coagulant	60 g Al_2O_3 /m^3
Sodium aluminate	AlO_2Na	Coagulant	25 g Al_2O_3 /m^3
Aluminum polychloride	$Al(OH)_{1,5}(SO_4)_{0,125}Cl_{1,25}$	Coagulant	5 g Al_2O_3 /m^3
Ferric sulfate	$Fe(SO_4)_3 \cdot nH_2O$	Coagulant	60 g Fe_2O_3 /m^3
Ferrous sulfate	$FeSO_4 \cdot nH_2O$	Coagulant	60 g Fe_2O_3 /m^3
Melanine –formaldehyde		Coagulant	< 3 g/m^3
Epichlorhydrine-dimethylamine		Coagulant	< 3 g/m^3
Active silica	SiO_2	Flocculent	
Starch		Flocculent	< 5 g/m^3
Guar gum		Flocculent	< 5 g/m^3
Jelly		Flocculent	< 5 g/m^3
Alginates		Flocculent	< 5 g/m^3
Polyvinylamines	$(R\text{-}NH_3\text{-})_n \cdot n\ Cl$	Cationic floccul.	< 5 g/m^3
Polyvinylsulfonate	$(R\text{-}SO_3\text{-})_n \cdot n\ Na$	Anionic floccul.	< 5 g/m^3
Polyacrylamides	$(R\text{-}CONH_2\text{-})_n$	Non ionic floccul.	< 5 g/m^3

In a colloidal system electrostatic interactions between particles and with water may be found in equilibrium. In order to enhance sedimentation the concentration of charges in solution has to be increased. This is achieved by the addition of polyvalent ions (coagulants).

To complete the coagulation process and achieve a good sedimentation, it is usually necessary to favour particle aggregation, flocculants are added.

Note: coagulants produce the destabilization of particles, minimizing particle-particle repulsions, thus allowing them to form larger particles. Flocculants, which are typically organic molecules, form bonds with particles.

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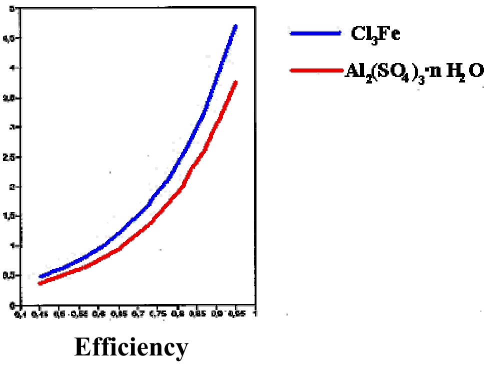
JAR TEST

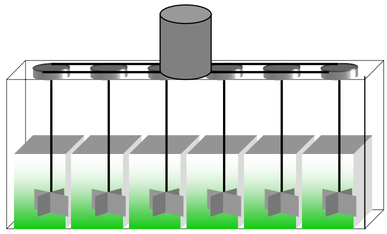
Llaboratory procedure to determine optimum operating conditions for wastewater treatment

Measures the performance of coagulation



Simulates the coagulation and flocculation processes

- pH adjustments
- Addition of coagulant:
  - Change of doses
  - Test different coagulants
- Alternate mixing speeds



Six 1 litre containers with paddles

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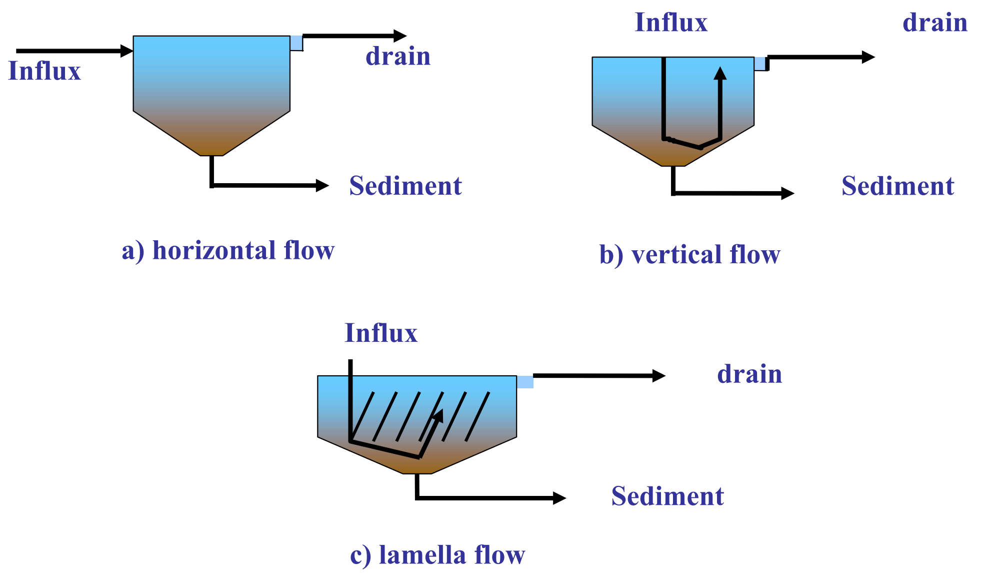
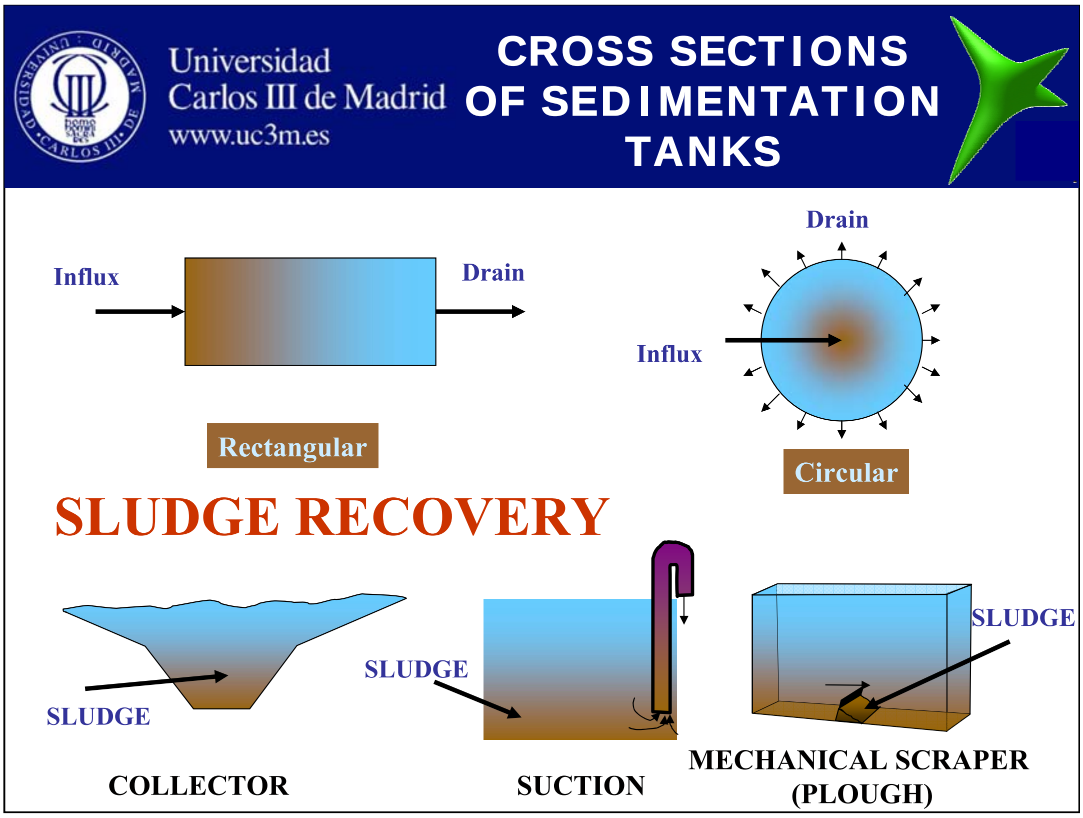
FLOW IN SEDIMENTATION



Solid removal by sedimentation is performed in sedimentation tanks (also called basins). Their large volume allows a hydraulic detention time long enough for the particles to settle down and reach the bottom of the tank.

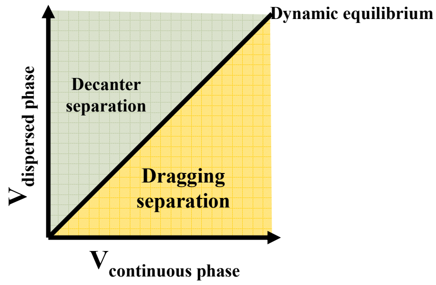
Sedimentation tanks can be classified according to the relative direction of the water and the particle movements as horizontal, vertical and lamellar flow. In lamellar tanks, water is parallel to water flow, and the existence of lamellas increases the surface, thus increasing hydraulic load.



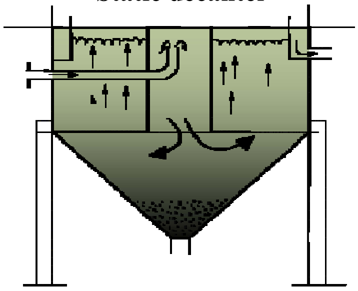
Rectangular sedimentation tanks are recommended when there is little space, and are easier to cover if a odour removal system is required. Another advantage is the possibility of building additional facilities wall-to-wall, for instance aeration tanks or clarifiers, thus reducing building costs. An important disadvantage is, however, that removal of settled sludge is more difficult.

CONTINUOUS VS DISPERSED PHASE VELOCITIES

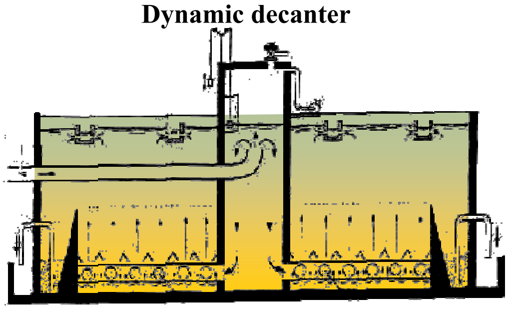
- Static separation:
  - High detention times
  - Separation by settling
- Dynamic separation:
  - Lighter particles dragged by water
  - Example: grit washers



Static decanter



Dynamic decanter



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SEDIMENTATION PROCESSES

Treatment	Name	Sedimentation regime	Sediment type	Sediment name
Pre-treatment	Degritter	Type I	Inorganic solids	Grit and grave
Primary	Decanter	Type II	Settleable solids	Sludge
Secondary	Clarifier	Type III	Biomass	Sludge
Sludge line	Thickener	Type IV	Sludge	Thickened sludge

Sedimentation takes place at several points along wastewater treatment. Depending on the treatment stage the type of solids that can be settled changes, and sedimentation tanks are designed to enhance the sedimentation regime required. Due to this differences they are referred to with a specific name (as show n in the table).

SEDIMENTATION DIMENSIONS

TABLE 2.4

Decanter type	Depth (m)	Length (m)	Width (m)	C_H ($m^3/m^2 \cdot h$)	t_r (h)
Rectangular primary decanter	3,0/5,0	15/90	3/25	1,00/2,00	1,5/3,0
Circular primary decanter	3,0/5,0	4/60		0,80/1,80	1,0/2,0
Clarifier for activated sludge	3,6/5,0	10/50		0,68/1,36	2,5/5,0
Clarifier for extended aeration	3,6/5,0	10/50		0,34/0,68	5,0/10,0

CH stands for hydraulic load.

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ADVANTAGES

Advantages and disadvantages of designing a treatment system wit/without a primary decanter (in the primary treatment).

ADVANTAGES	DISADVANTAGES
Less energy consumption (less biodegradable matter left for aerobic digester)	More complex
	Sludge homogeneity
More gas production	Vacuum removal of sludge
More capacity to thicken sludge	Odors caused by septic sludge
Deposit of grit and scum	Worse settlement
More hydraulic regulation	Less capacity for peak loads

If no primary decanter is installed, the digester has to be redimensioned.

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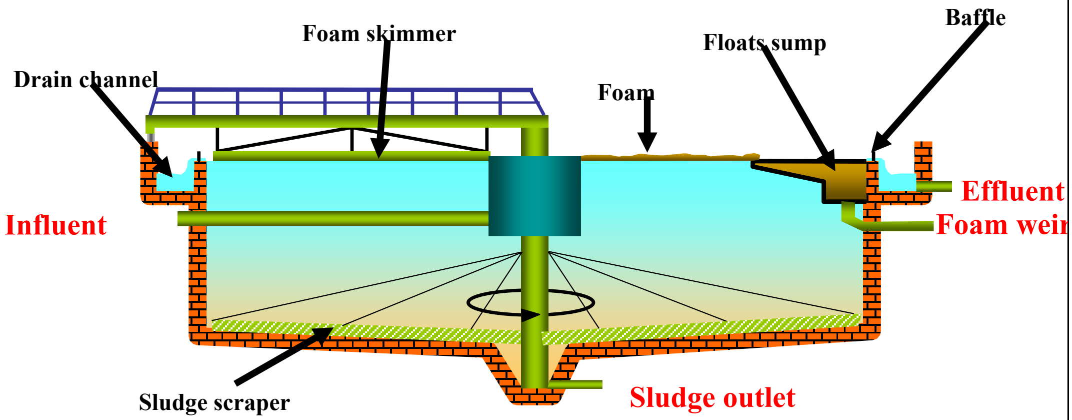
CIRCULAR DECANTER



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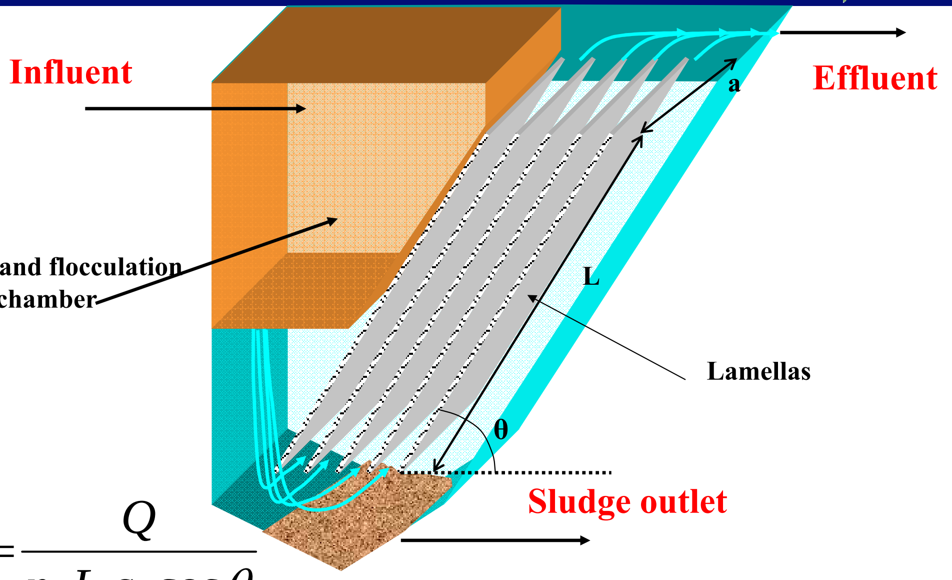
LAMELLA DECANTER



$$C_H = \frac{Q}{n \cdot L \cdot a \cdot \cos\theta}$$

n = number of lamellas

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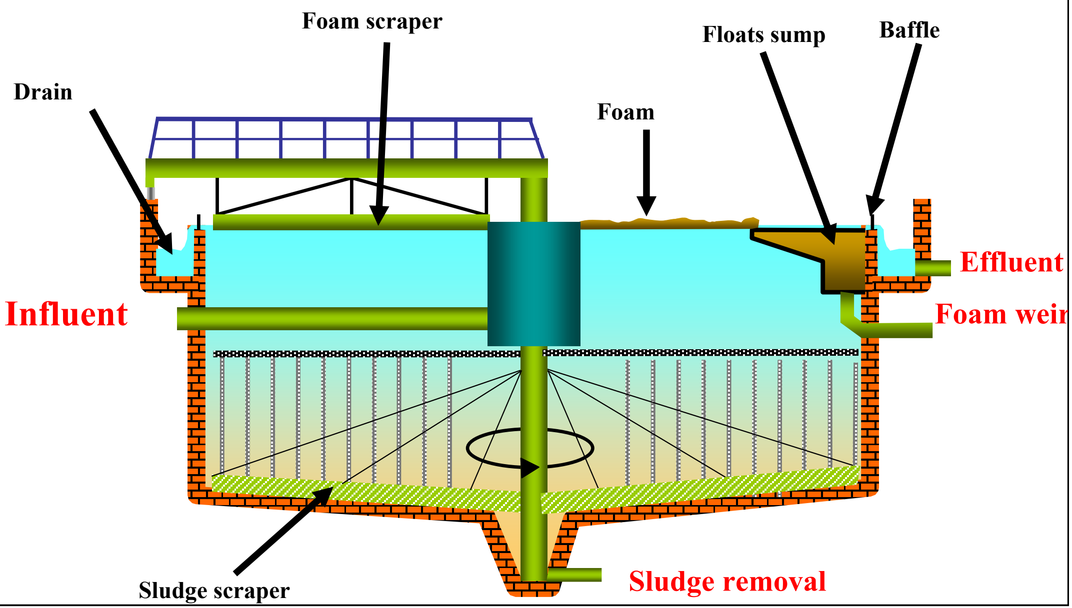
THICKENER



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CIRCULAR DECANTER: OVERVIEW

Vertical flow circular decanter. The Linares plant has two primary decanters with a 20 m diameter, 3 m high, and a total unit volume of 1.026 m^3.

Circular decanters can have a diameter of up to 50 m.

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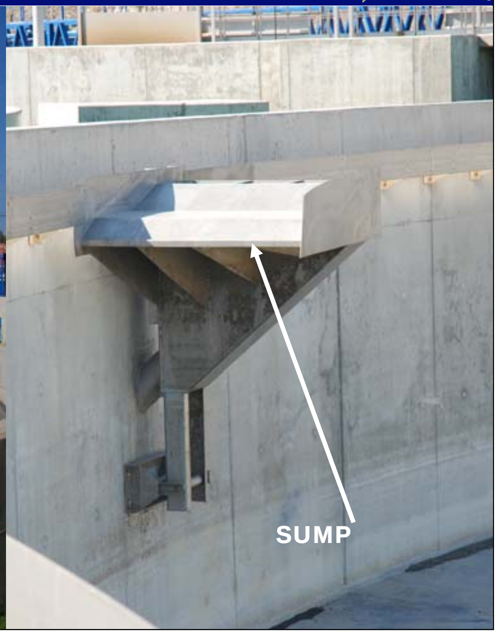
CIRCULAR DECANTER



Water is fed at the centre of the decanter, and wastewater flows towards the outer area of the decanter where a baffle minimizes turbulence (which would cause sediments being dragged along with treated water).

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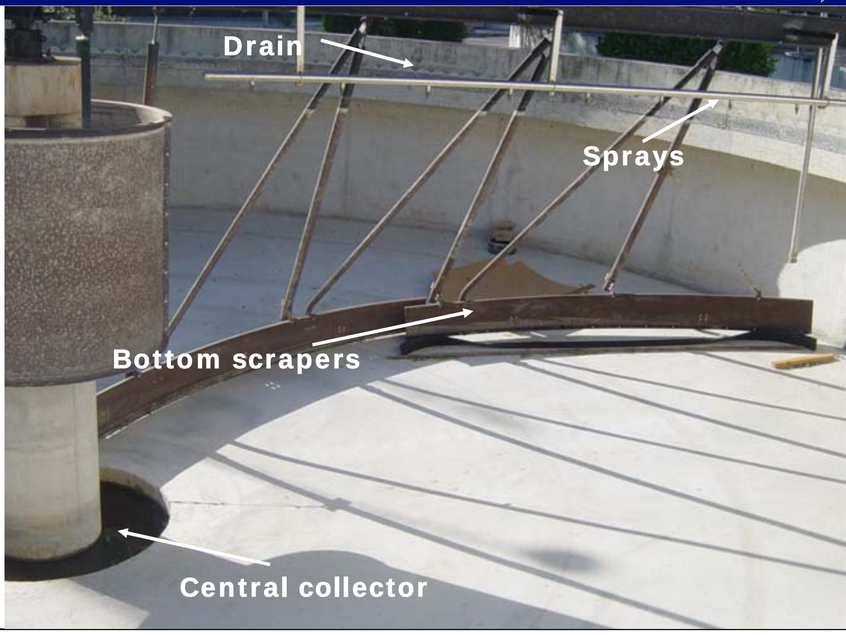
CIRCULAR DECANTER



Industrial wastewater treatment plant (*EDARI*).

Bottom scrapers push sediments towards the central collector where a pumping system extracts them.

The sprays inject water (generally with a disinfectant) over the decanter surface to break floating foams, (more typically produced in the secondary clarifiers).

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SLUDGE PUMP

Sludge is pumped from the primary decanter to the thickener.

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SLUDGE THICKENER

Sludge from the primary treatment is thickened after removal from the decanter. Thickening is achieved by sedimentation in a thickening tank.