TWO DAYS TRAINING ON THE OPERATION AND MANAGEMENT OF WWTPS

9-10 September, Murcia

Conventional Wastewater Treatment Design

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Contents

- Basic principles of WWTP design.
- General issues in WWTP design.
- Conventional WWTP design.
  - ✓ Pretreatment.
  - ✓ Primary treatment.
  - ✓ Secondary treatment.
  - ✓ Tertiary treatment.
- References

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Basic principles of WWTP design

- Wastewater characteristics.
- Treated water quality requirements.
- Geographical constraints.
- Social and environmental constraints.
- Economic constraints.
- Available technologies.

Wastewater characteristics

- Quantitative characteristics.
  - ✓ Design flowrates. Average, peak and maximum flowrate in rain periods.
  - ✓ Seasonal variation of flowrates.
  - ✓ Estimated future flows.
- Qualitative characteristics.
  - ✓ BOD_5, COD, TSS.
  - ✓ Ph, alkalinity.
  - ✓ N, P.

Treated water quality requirements

- Final use of treated water.
- Characteristics of environment.
- Legal constraints.

Geographical constraints

- Land availability.
- Relative location of wastewater sources.
- Climatic constraints.

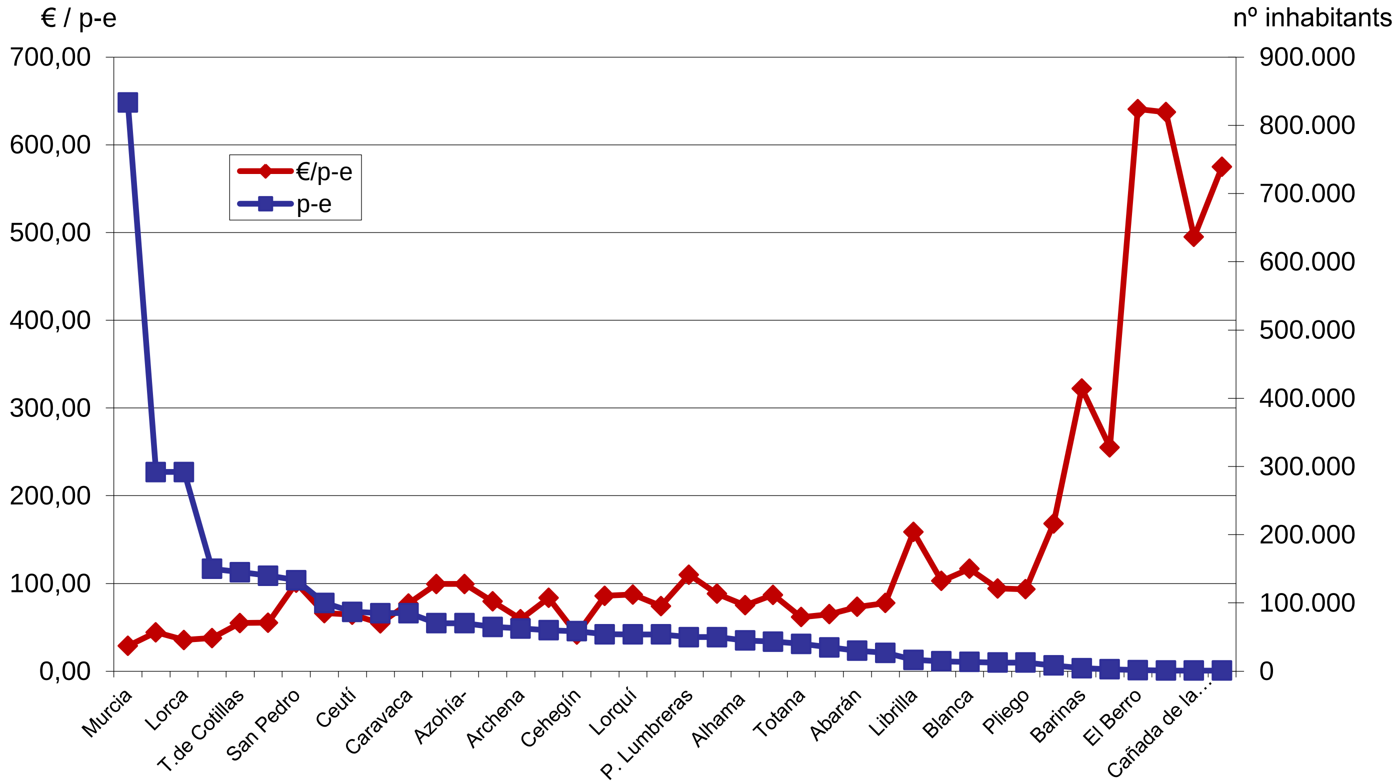
Social and environmental constraints

- Proximity to residential areas.
- Measures in order to reduce adverse effects on the environment.
  - ✓ Noise.
  - ✓ Odors.
- Landscape integration.
- Legal constraints.

Economic constraints

- Construction costs.
- Operating and maintenance costs.
  - ✓ Annual O&M cost.
  - ✓ Future replacement of equipment.
  - ✓ Implement systems to guarantee income for future operation and maintenance.

Conventional WWTP Construction Costs



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Available technologies

- Evaluating unit operations and processes.
- Selecting appropriate technologies.
  - ✓ Personnel requirements.
  - ✓ Operation complexity.

General issues in WWTP design

- Construction.
- Operation and maintenance.
- Safety of staff.
- Other issues.

General issues in WWTP design

- Construction:
  - ✓ Mechanical resistance.
  - ✓ Impermeability of elements.
  - ✓ Structural stability.
  - ✓ Materials resistant to corrosive environments.

General issues in WWTP design

- Operation and maintenance:
  - ✓ Several parallel facilities for each process.
  - ✓ Inlet and outlet gates or valves to remove elements from service for maintenance.
  - ✓ Dewatering of tanks and other elements.
  - ✓ Interchangeability of equipment.
  - ✓ Measurement and registration of flowrates.

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General issues in WWTP design

- Safety of staff.
  - ✓ Avoid, if possible, confined spaces.
  - ✓ Gas monitoring equipment.
  - ✓ Ventilation.
  - ✓ Fences and walls.

General issues in WWTP design

- Other issues.
  - ✓ Odor treatment systems.
  - ✓ Noise reduction.
  - ✓ Energy efficiency.
  - ✓ Emergency electric power generation.
  - ✓ Future treatment needs.

Conventional WWTP design

- Basic treatments.
  - ✓ Wastewater treatments.
  - ✓ Sludge treatments.
  - ✓ Gas treatments.

Wastewater treatments design

- Main unit processes in wastewater treatment.
  - ✓ Pretreatment.
  - ✓ Primary treatment. (Physical – Chemical treatment)
  - ✓ Secondary treatment. (Biological treatment)
  - ✓ Advanced secondary treatment. (Nutrient removal)
  - ✓ Tertiary treatment. (Water reuse)

Pretreatment

- Removal of coarse solids, grit and grease, that could damage sub-sequent process equipment, by physical and mechanical means.
- Design peak flowrate: 5 x $Q_{average}$
- Usually need odor treatment.
- Usual unit processes:
  - ✓ Large solid removal.
  - ✓ Screening.
  - ✓ Grit and grease removal.
  - ✓ Flow equalization.

Large solid removal

- Bottom sloped pit for collecting large solids, equipped with mechanical removal thereof.
- Design parameter:
  - ✓ Overflow rate : ≤ $300 m^3/m^2\ h\ (Q_{peak})$
  - ✓ Detention time: 0,5-1,0 min (Q_{peak})
  - ✓ Typical Depth: > 2 m

Screening

- Retain solids found in the influent wastewater by screens.
- Coarse Screens.
  - ✓ Bar racks → clear opening from 20 to 60 mm
  - ✓ Bar screens → clear opening from 6 to 12 mm
- Fine Screens.
  - ✓ Fine screens → clear opening from 0,25 to 3 mm

Coarse Screens

- Hand-Cleaned coarse screens → Small WWTP
- Mechanically Cleaned coarse screens.
- Several parallel devices or bypass channel to make maintenance possible.
- Design parameter:
  - ✓ Approach velocity → > 0,4 m/s ($Q_{minimum}$)
    > 0,9 m/s (Q_{peak})
  - ✓ Velocity through screen→ < 1,0 m/s ($Q_{minimum}$)
    < 1,4 m/s (Q_{peak})

Coarse Screens

- Design parameter :
  - ✓ Allowable headloss
    (30 % clogged) → 0,1 a 0,2 m (Bar racks)
    0,2 a 0,4 m (Bar screens)
  - ✓ Screen channel width:

$$W = \frac{Q}{V \times H} \times \frac{E+e}{E} \times C$$

W: Screen channel width (m)
Q: Peak flowrate through channel (m^3/s)
V: Peak velocity through screen (m/s)
H: Water level upstream screen (m)
e : Bar size width (m)
E: Clear spacing between bars (m)
C: Coefficient to account the degree of clogging, typically 1,3.

Fine screens

- Removal of BOD_5 between 10 – 15 %
- Self-washing continuous fine screen.
  - ✓ Total headloss → 0,1 a 0,4 m
- Step screens.
  - ✓ Total headloss → from 0,2 to 0,5 m
- Rotary drum screens.
  - ✓ Total headloss → to 2 m
- Wedge section screens.
  - ✓ Total headloss → 0,2 a 0,4 m

Grit and grease removal

- Remove grit (sand, gravel, cinder,…), fat, grease and other floating material.
- Usually grit and grease are removed at the same facility, but these process can be designed as independent facilities.
- Design parameter (Aerated G&G removal):
  - ✓ Overflow rate: < 35 m^3/m^2 h (Q_{peak})
  - ✓ Horizontal velocity: < 0,15 m/sec
  - ✓ Detention time: 10-15 min ($Q_{average}$)
  - ✓ Length-to-Width ratio: 3:1 – 5:1 (4:1, typically)

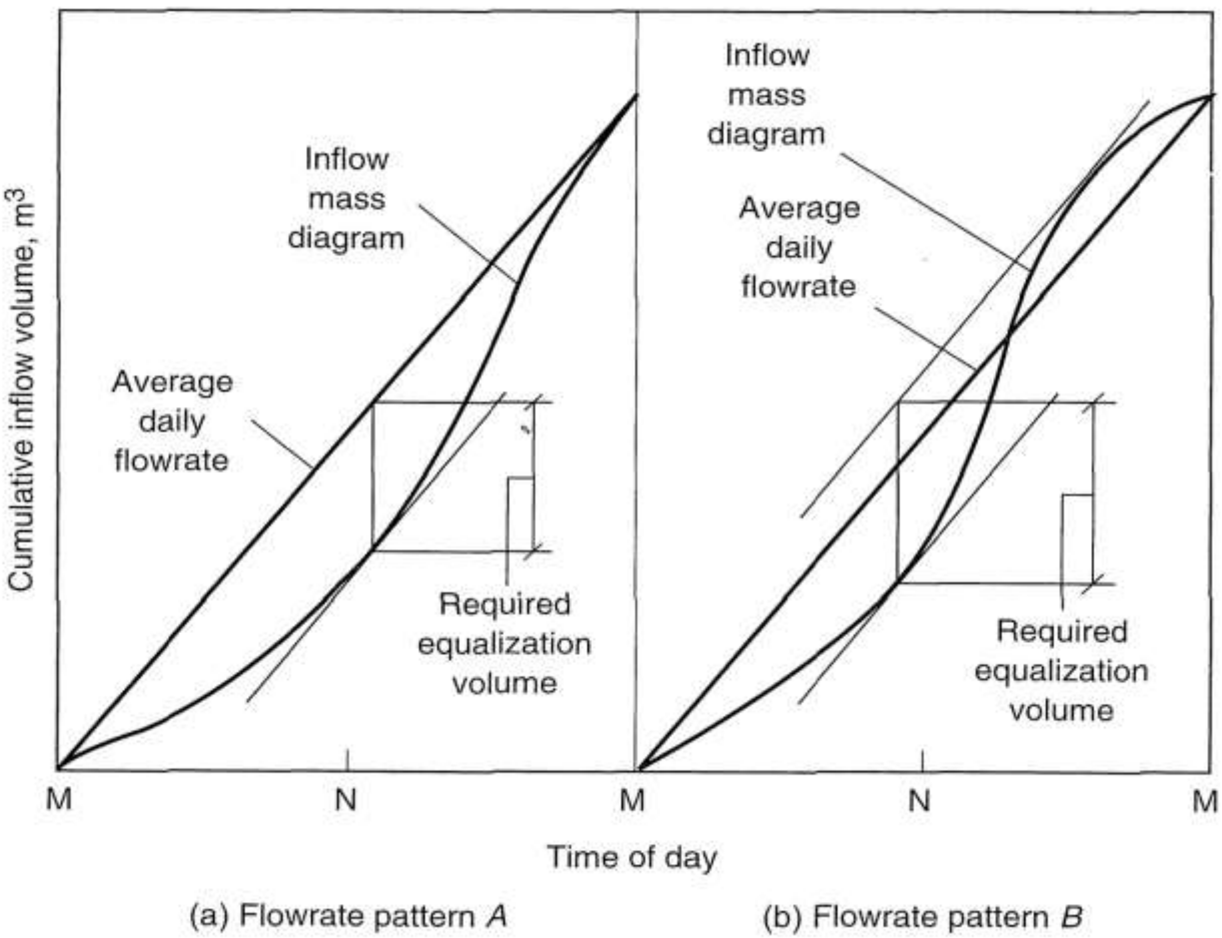
Grit and grease removal

- Design parameter (Aerated G&G removal):
  - ✓ Width-to-depth ratio: 1:1 – 5:1. (1,5–1 typically)
  - ✓ Depth: 2-5 meters
  - ✓ Estimated air supply: 5-8 m^3/h
  - ✓ Organic material in the grit: < 5%
- Complementary treatment :
  - ✓ Grit Classifier.
  - ✓ Grease concentrator.

Flow equalization

- Damping of flowrate variations to achieve a constant or nearly constant flowrate.
- In-Line or Off-Line.
- The volume required is determined by using an inflow cumulative volume diagram.
- Design issues:
  - ✓ Geometry should be arranged to minimize short circuits.
  - ✓ Generally requires proper mixing and aeration.
  - ✓ Facilities for flushing solids and grease accumulated on the tank.
  - ✓ Removal of floating material.
  - ✓ Separate odor control facilities.

Module V : Infrastructures - Conventional WWTP Design



Schematic mass diagrams for the determination of the required equalization basin storage volume for two typical flowrate patterns.

Primary Treatment

- Reduce the suspend solids content by sedimentation with optional physical–chemical treatment.
- Efficiency with respect to the removal of BOD and TSS varies with type of treatment.
- Design peak flowrate: 2,5 x $Q_{average}$
- Usual unit processes:
  - ✓ Solid-liquid separation → Primary Sedimentation
  - ✓ Complementary processes → Coagulation-Flocculation

Primary Sedimentation

- Remove settleable solids and floating material by gravity separation.
- BOD and T.S.S. removal:
  - ✓ BOD_5 → 30 – 35 %
  - ✓ T.S.S. → 60 – 65 %
- Types of primary sedimentation tanks:
  - ✓ Conventional clarifiers:
    - Circular.
    - Rectangular.
  - ✓ Stacked clarifiers.
  - ✓ Lamella plate clarifiers.

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Primary Sedimentation

- Main design parameters:
  - ✓ Overflow rate → < 1,3 m/h ($Q_{average}$)
    < 2,5 m/h (Q_{peak})
  - ✓ Detention time → > 2 h ($Q_{average}$)
    > 1 h (Q_{peak})
  - ✓ Weir loading → < 40 m^3/h/m
  - ✓ Sidewall depth → 2 – 3,5 m
  - ✓ Bottom slope → Circular 5 - 10 %
    Rectangular 1 - 2 %

Coagulation - Flocculation

- Improve performance of primary sedimentation increasing removal of T.S.S. and BOD.
- Coagulation.
  - ✓ The chemical destabilization of colloids to bring about their aggregation during flocculation.
- Flocculation.
  - ✓ Form aggregates or flocs from finely divided particles and from chemical destabilized particles that can be removed readily by sedimentation.
- BOD and T.S.S. removal:
  - ✓ BOD_5 → 50 – 75 %
  - ✓ T.S.S. → 65 – 90 %

Coagulation - Flocculation

- Design parameters:
  - ✓ Detention time mixing and flocculation → > 15 min.
  - ✓ Tip speed flocculation → 0,6 – 1,5 m/s
- Chemical dosage for coagulation:

Chemical	Dosage range (mg/l)
Lime [$Ca(OH)_2$]	150 - 500
Aluminum sulfate [$Al_2(SO_4)_3$]	75 - 250
Ferric chloride [$FeCl_3$]	35 - 150
Cationic polymers	2 - 5
Anionic polymers and nonionic	0,25 - 1

Secondary treatment

- Transform or remove dissolved and particulate biodegradable constituents, colloidal solids or nutrients by biological means.
- Many processes in a WWTP are designed to mimic the natural treatment processes that occur in the natural water bodies or ground.
- Types of biological wastewater treatment:
  - ✓ Attached-growth processes.
  - ✓ Suspend-growth processes.
  - ✓ Combined processes.
  - ✓ Lagoon processes.

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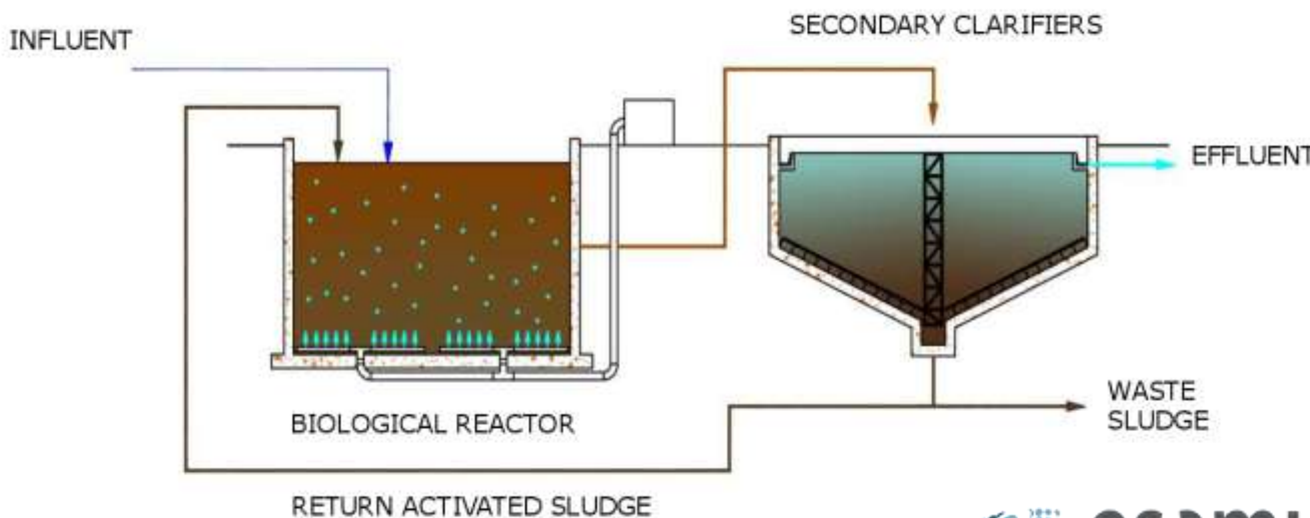
Conventional activated-sludge

- The most common suspended growth process used for municipal wastewater treatment.
- Characteristics:
  - ✓ Reliable.
  - ✓ Flexible.
  - ✓ High performance.
  - ✓ Relatively high operating and maintenance cost.
- Multiples types of processes:
  - ✓ Aerobic, anaerobic, anoxic processes.
  - ✓ Carbonaceous BOD removal, nitrification, denitrification, phosphorous removal.

Conventional activated-sludge

- Basic operations:
  - ✓ Biological degradation.
  - ✓ Liquid – solids separation.
  - ✓ Return of activated sludge.



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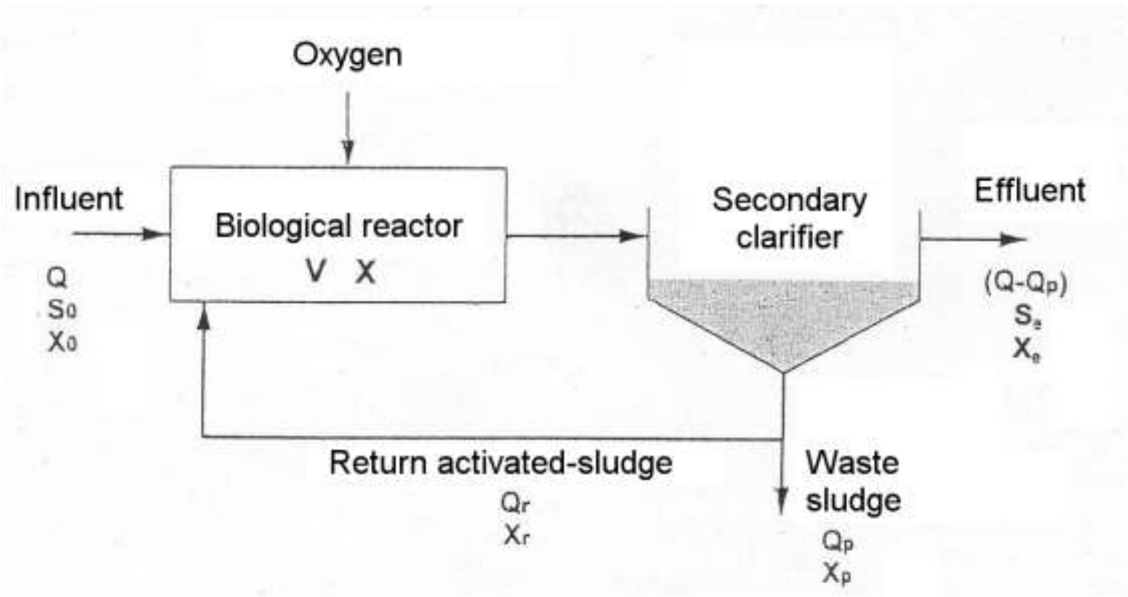
Biological degradation

- Microorganisms consume substrate (carbon and energy sources) and nutrients to carry out oxidation-reduction reactions to produce new cells.
- General considerations:
  - ✓ Substrate characteristics.
  - ✓ Nutrients.
  - ✓ Oxygen transfer requirements.
  - ✓ Temperature, ph y salinity.
  - ✓ Toxic or inhibitory substances.

Activated-sludge design



Q = Secondary influent flowrate (m^3/day)
So = [BOD_5] Secondary influent (mg/l)
Xo = [TSS] Secondary influent (mg/l)
Se = [BOD_5] Effluent (mg/l)
Xe = [TSS] Effluent (mg/l)
V = Biological reactor volume (m^3)
X = [VSS] Mixed-liquor (mg/l)
Qr = Return sludge flowrate (m^3/h)
Xr = [TSS] Return sludge (mg/l)
Qp = Waste sludge flowrate (m^3/h)
Xp = [TSS] Waste sludge (mg/l) (Xp = Xr)

Activated-sludge design

- Design parameters:
  - ✓ Food to microorganism ratio (F/M) → $F/M = Q \times S_o / V \times X$
  - ✓ Cell resident time (θ_c) → $\theta_c = V \times X / Q_p \times X_r$
  - ✓ Detention time (RT) → $RT = V/Q$
  - ✓ Performance (P) → $P = (S_o - S_e)/S_o$

Activated-sludge design

- Volume reactor.
  - ✓ Using cell resident time .
  - ✓ Using Food to microorganism ratio.
  - ✓ Mixed Liquor Suspended Solids [MLSS]:
    - Conventional → 2.500-3.500 mg/l
    - Extended aeration → 3.000-5.000 mg/l
- Oxygen requirements.
  - ✓ Carbonaceous material oxidation.
  - ✓ Endogenous Respiration.
  - ✓ Nitrogenous material oxidation.

Nitrification - Denitrification

- Nitrification.
  - ✓ Two-step biological process in which ammonia (NH_4-N) is oxidized to nitrite (NO_2-N) and nitrite is oxidized to nitrate (NO_3-N).
    - The process needs much longer hydraulic and solid retention time.
    - Requires a higher amount of oxygen.
    - Ph (7,2 – 8,5) and alkalinity (> 40 g CO_3Ca/l).
- Denitrification.
  - ✓ Biological reduction of nitrate to nitric oxide, nitrous oxide, and nitrogen gas.
    - Requires a carbon source (3 g BOD/g N-NO_3).
    - Requires anoxic conditions.
    - Ph (7 - 8).

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Design of physical facilities for A-S processes

- Rectangular shape left open to the atmosphere.
- Geometry should be arranged to avoid short circuits.
- Depth of wastewater between 4 – 9 m.
- Freeboard >0,5 m.
- Shall permit the peak hourly flowrate to be carried with any single aeration tank out of service.
- Equalizing the distribution of flow and air to aeration tanks.
- Froth control system.

Liquid – solids separation

- Secondary clarification.
  - ✓ Settle the biological floc to produce water containing low levels of organic material and suspended matter.
  - ✓ Thicken sludge to return to aeration tank.
  - ✓ Limit sludge detention time to prevent uncontrolled denitrification or anaerobic conditions.
- Settling tanks types.
  - ✓ Circular tanks with bottom scrapper system.
  - ✓ Circular tanks with sludge suction system.
  - ✓ Rectangular tanks with scrapper.
  - ✓ Lamella plate clarifiers.

Secondary clarification

- Main design parameters:
  - ✓ Overflow rate (m^3/m^2 h)
  - ✓ Solids loading (kg S.S./m^2 h)
  - ✓ Weir loading (m^3/m h)
  - ✓ Sidewall depth.
  - ✓ Sludge volume index.
- Other design issues:
  - ✓ Flow distribution.
  - ✓ Scum removal.

Return of activated-sludge and Sludge wasting

- Return of activated sludge.
  - ✓ Maintain a sufficient concentration of activated sludge in the aeration tank.
  - ✓ Return sludge concentration → 6 - 8 g/l (scrappers)
    5 – 6 g/l (suction)
  - ✓ Return sludge pumping → 75 – 100 % (conventional)
    100 -150 % (extended aeration)
- Sludge wasting.
  - ✓ Remove the excess activated sludge produced each day to sludge treatment.

Design parameters summary

Aeration tank		Conventional	Extended aeration
Food to microorganism ratio	(kg BOD_5 day/ kg MLSS day)	0,2 - 0,4	< 0,1
Cell resident time	(kg MLSS / kg waste sludge day)	4 - 10	10 - 30
MLSS concentration	(mg/l)	2.500 - 3.500	3.000 - 5.000
Detention time	(h)	3 - 8	18 - 36

Return of activated sludge		Conventional	Extended aeration
Return sludge pumping rate	(% Q_r / Q)	75 - 100	100 - 150

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Design parameters summary

Secondary Clarification		Conventional	Extended aeration
Overflow rate	Qaverage ($m^3/m^2 \cdot h$)	≤ 0,7	≤ 0,5
	Qpeak ($m^3/m^2 \cdot h$)	≤ 1,4	≤ 0,9
Solids loading	Qaverage (kg SS/$m^2 \cdot h$)	≤ 2,4	≤ 1,8
	Qpeak (kg SS/$m^2 \cdot h$)	≤ 4,5	≤ 3,2
Weir loading	Qaverage ($m^3/m \cdot h$)	≤ 6	
	a Qpeak ($m^3/m \cdot h$)	≤ 12	
Sidewall depth	(m)	> 3,0	
Sludge volume index		100 - 150	75 - 100

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Tertiary treatment

- Additional treatment needed to remove suspended, colloidal and dissolved constituents remaining after conventional secondary treatment.
- Usually to meet more stringent discharge and reuse requirements and wastewater disinfection.
- Usual unit processes:
  - ✓ Flow equalization
  - ✓ Coagulation – Flocculation
  - ✓ Sedimentation (Lamellar)
  - ✓ Filtration
  - ✓ Cl_2 or UV disinfection

Tertiary physical–chemical treatments

- Flow equalization.
  - ✓ Damping of flowrate variations to achieve a constant flowrate.
  - ✓ Cover equalization tank to avoid algae proliferation with sunlight.
- Coagulation – Flocculation.
  - ✓ Similar than primary treatment.
- Lamellar sedimentation.
  - ✓ Conventional lamellar overflow rate → < 10 m/h
  - ✓ Ballasted lamellar overflow rate → < 40 m/d

Filtration

- Removal of particulate material suspended in a liquid by passing the liquid through a filter medium.
- Depth Filtration .
  - ✓ Filter bed comprised of a granular medium.
  - ✓ Design data:
    - Sand Depth → 900 – 1.000 (typical 1.200 mm)
    - Filtration rate → 80 – 400 l/m^2 min (typical 200 l/m^2 min)
    - Backwash rates → 1750 – 1500 m^3/m^2 h (Air)
      25 – 50 m^3/m^2 h (Water)
    - Allowable headloss.
- Surface filtration.
  - ✓ Mechanical sieving by passing the liquid through a thin septum.
  - ✓ Design data by manufacturer.

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Disinfection

- Partial destruction of disease-causing organisms.
- Chemical agents.
  - ✓ Chlorine and its compounds (typical), bromine, iodine, ozone and others.
  - ✓ Design chlorine disinfection data: [1]
    - Chlorine dose → 8 – 16 mg/l
    - Contact time → ≥ 30 min.

    [1] Filtered nitrified effluent and total coliform disinfection requirement of ≤ 2,2 MPN/100 ml.
- Physical agents.
  - ✓ Light (UV radiation), heat and sound waves.
  - ✓ UV disinfection system configurations:
    - Open and close channel system.
    - Design data by manufacturer. [2]

    [2] Pay attention to UV transmittance.

References

- ATV-DVWK- A131 E (2000). Dimensionamiento de plantas de fangos activados de una etapa.
- J. A. CORTACANS (2010). Fangos activados. Eliminación de nutrientes. 2ª edición.
- DEGREMONT (1991). Water treatment handbook. Degremont.
- A. HERNÁNDEZ (1999). Depuración de aguas residuales
- C.P. LESLIE-G.T. DAIGGER-H.C. LIM (1999). Biological Wastewater Treatment
- METCALF-EDDY (2004). Wastewater Engineering. Treatment and Reuse.

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Thank you for your attention

Merci pour votre attention

For additional information please contact:
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