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WASTE WATER TREATMENT

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Introduction:

Water quality and water pollution

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Water quality

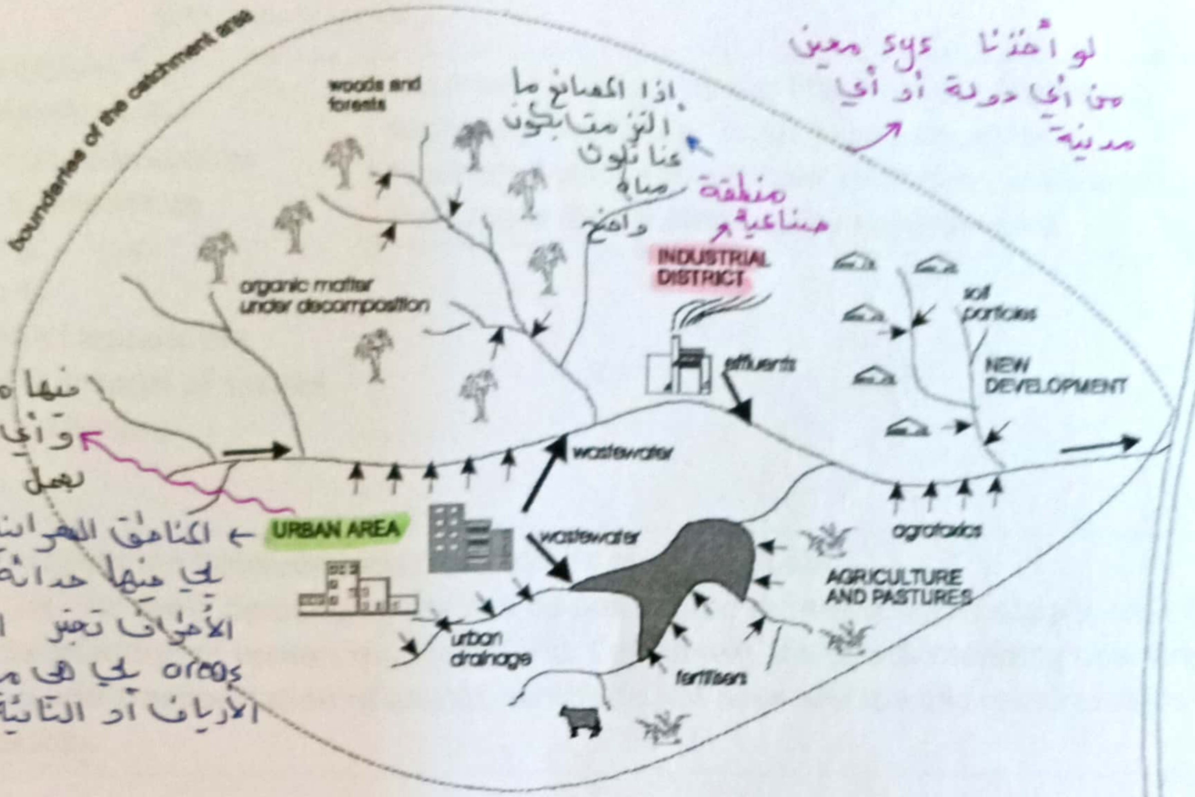
- Water is a solvent and has a capacity to transport particles,
- Water quality is a result of natural phenomena and the acts of human beings.
- Water quality is a function of land use in the catchment area, due to the following factors:

1. **Natural conditions:**
   - ✓ surface water quality is affected by run off and infiltration resulting from rainfall. The impact of these is dependent on the contact of the water with particles, substances and impurities in the soil.

2. **Interference of human beings:**
   - ✓ the interference of man manifests itself either in a concentrated form, such as in the discharge of domestic or industrial wastewater, or in a diffused form, such as in the application of fertilizers or pesticides onto the soil.
   - ✓ the form in which human beings use and occupy the land has a direct implication in the water quality.

* التلوثات سواء يلي بتجيبها مياه الأمطار أو مخلفات المنازل كلها هاي بتروح يا لا مفعن نفقة أو بتدخل بالتربة للمياه الجوفية أو بتروح على المياه الجارية زي قناة الملك عبدالله أو بحيرة طبرية .

➤ The interrelation between land use and water quality impacting agents



Desired water quality

- The desired quality for a water is a function of its intended use.
- In summary:
  - ➤ Existing water quality: function of the land use in the catchment area.
  - ➤ Desired water quality: function of the intended uses for the water.

الي يلي هنا بشكل عام شو المواصفة تبعتها

الغرض يلي بنستخدم منه المي بحدد شو المواصفة تبعته

The study of water quality is essential, not only to characterize the consequences of a certain polluting activity, but also to allow the selection of processes and methods that will allow compliance with the desired water uses.

Uses of Water

The main water uses are: القطاع السكني وما يحتويه من مولات ومدارس وجامعات

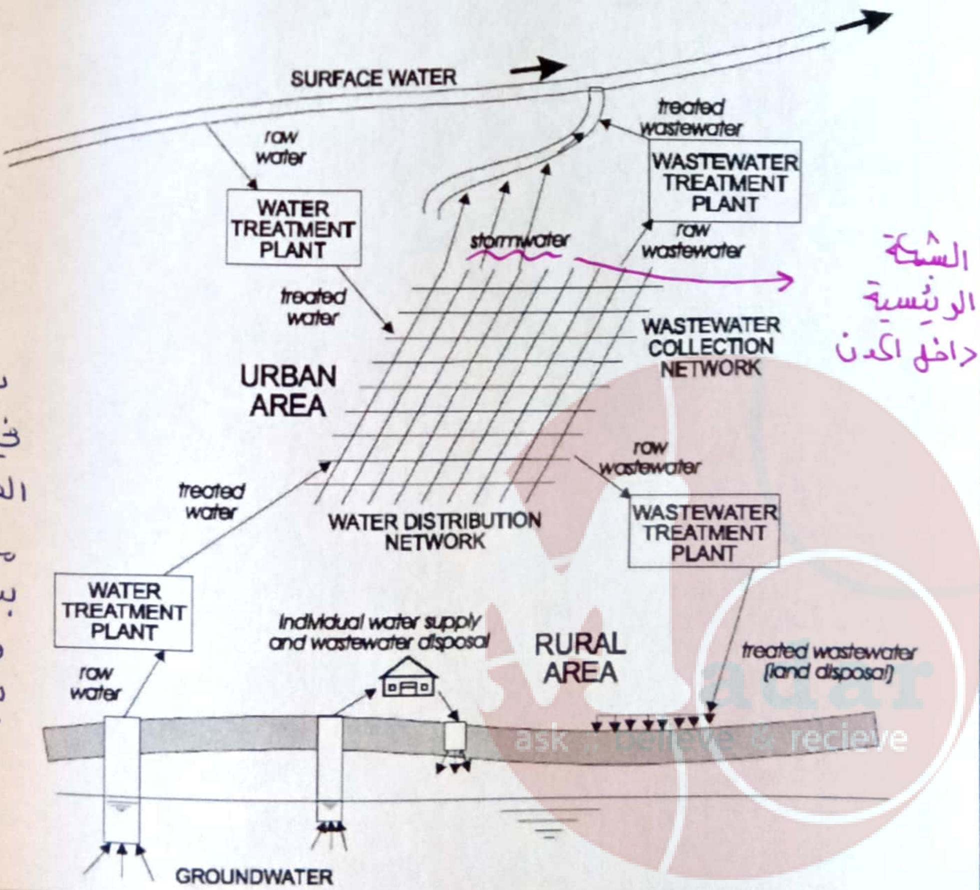
- ✓ domestic supply
- ✓ industrial supply → صناعة
- ✓ breeding of aquatic species
- ✓ generation of electricity
- ✓ irrigation → الري
- ✓ animal supply
- ✓ preservation of aquatic life
- ✓ dilution and transport of wastes
- ✓ recreation and leisure
- ✓ others

In general terms, only the first two uses (domestic supply and industrial supply) are frequently associated with a prior water treatment, in view of their more demanding quality requirements.

- ➢ There is a direct relation between water use and its required quality.
- ➢ In the above list, the most demanding use can be considered domestic water supply, which requires the satisfaction of various quality criteria. Conversely, the less demanding uses are simple dilution and transportation of wastes, which do not have any specific requirements in terms of quality.

Routes of water use and disposal

من مصدر المياه لغاية ما احنا نستخدمه بـ certain application وكيف نجمعها بعد ما نستخدمها (المياه المنزلية) بتروح كلها على الصرف الصحي المنزلي بعدين تنزل على الصرف الصحي لي في الشارع بتلتقي من شبكة الصرف الصحي الرئيسية وبتروح على محطة معالجة المياه العادمة والمي الطالعة بعدها تكون ضمن مواصفة معينة وتستخدمها لأغراض معينة أو نجمعها في نهر أو سد ...



- **Raw water:** Initially, water is abstracted from the river, lake or water table, and has a certain quality.
- **Treated water:** After abstraction, water undergoes transformations during its treatment to be able to comply with its intended uses (e.g. public or industrial water supply).
- **Raw wastewater:** The water, after being used, undergoes new transformations in its quality and becomes a liquid waste.
- **Treated wastewater:** Aiming at removing its main pollutants, wastewater undergoes treatment before being discharged into the receiving body. Wastewater treatment is responsible for the new modification in the quality of the liquid.
- **Stormwater:** Rain water flows on the ground, incorporates some pollutants, and is collected at stormwater systems before being discharged into the receiving body.
- **Receiving body:** Stormwater and the effluent from the wastewater treatment plant reach the receiving body where water quality undergoes new modifications, as a result of dilution and self-purification mechanisms.

Water use and quality requirements

General use	Specific use	Required quality
Domestic supply	–	– Free from chemical substances harmful to health – Free from organisms harmful to health – Low aggressiveness and hardness – Aesthetically pleasant (low turbidity, color, taste and odor; absence of macro-organisms)
Industrial supply	Water incorporated into the product (e.g. food, drinks, medicines)	– Free from chemical substances harmful to health – Free from organisms harmful to health – Aesthetically pleasant (low turbidity, color, taste and odor; absence of macro-organisms)
	Water that enters into contact with the product	– Variable with the product
	Water that does not enter into contact with the product (e.g. refrigeration units, boilers)	– Low hardness
Irrigation	Horticulture, products ingested raw or with skin	– Free from chemical substances harmful to health – Free from organisms harmful to health – Non-excessive salinity
	Other plantations	– Free from chemical substances harmful to the soil and plantations – Non-excessive salinity

 # Irrigation :. كنا زراعة معتمدة وغير معتمدة

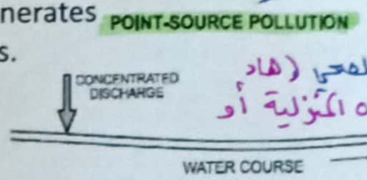
* الغير معتمدة بإمكانك تستعمل أي نوع من المياه للري لأن بعض الأشجار قادرة إنها تفلتر المي زي الزيتون .. أو المزارع بركب محطات تحلية لأن على الغالب المي مالحة (لأنو هيك الملوحة تزيد بتصير النبتة تعطي مي للتربة بدل ما تاخذ منها وبتموت النبتة).

* الزراعات المعتمدة الورقية (مش نفتح ميراميه جرجير) ممنوع أوروبيا أي نوع من المياه لازم نوع محدد وله مواصفة ، بنستخدم المياه العادمة المعالجة للري بس في زراعات الأعلاف والبرسيم.

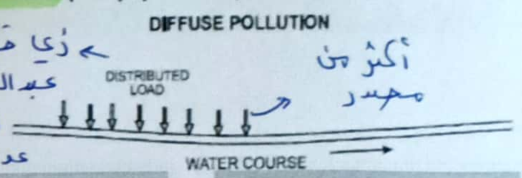
← لهيك على زراعة لها مواصفات محددة لمياه الري

Water pollution

- **Water pollution** is the addition of substances or energy forms that directly or indirectly alter the nature of the water body in such a manner that negatively affects its legitimate uses.
- This definition associates pollution with negative alterations and with water body uses, and is attributed by human beings.
- There are two ways in which the pollutant could reach the receiving body:
  - **point-source pollution:** the pollutants reach the water body in points concentrated in the space. Usually the discharge of domestic and industrial wastewater generates point-source pollution, since the discharges are through outfalls.



  - **diffuse pollution:** the pollutants enter the water body distributed at various locations along its length. This is the typical case of storm water drainage, either in rural areas (no pipelines) or in urban areas (storm water collection system, with multiple discharges into the water body).



Main pollutants, their source and effects

Pollutant	Main representative parameters	Source: Wastewater – Domestic	Source: Wastewater – Industrial	Source: Stormwater – Urban	Source: Stormwater – Agricultural and pasture	Possible effect of the pollutant
Suspended solids	Total suspended solids	XXX	←→	XX	X	• Aesthetic problems • Sludge deposits • Pollutants adsorption • Protection of pathogens
Biodegradable organic matter	Biochemical oxygen demand	XXX	←→	XX	X	• Oxygen consumption • Death of fish • Septic conditions
Nutrients	Nitrogen Phosphorus	XXX	←→	XX	X	• Excessive algae growth • Toxicity to fish (ammonia) • Illnesses in new-born infants (nitrate) • Pollution of groundwater
Pathogens	Coliforms	XXX	←→	XX	X	• Water-borne diseases
Non-biodegradable organic matter	Pesticides Some detergents Others	X	←→	X	XX	• Toxicity (various) • Foam (detergents) • Reduction of oxygen transfer (detergents) • Non-biodegradability • Bad odours (e.g.: phenols)
Metals	Specific elements (As, Cd, Cr, Cu, Hg, Ni, Pb, Zn, etc.)	X	←→	X		• Toxicity • Inhibition of biological sewage treatment • Problems in agriculture use of sludge • Contamination of groundwater
Inorganic dissolved solids	Total dissolved solids Conductivity	XX	←→		X	• Excessive salinity – harm to plantations (irrigation) • Toxicity to plants (some ions) • Problems with soil permeability (sodium)

x: small *xx: medium* *xxx: high* ←→: variable *empty:* usually not important

Wastewater Characteristics

لـ ما هي مواصفات وصفات المياه العادمة :

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* كل محافظة إلها محطة أو محطتين بتوصل منها الى عمان والزرقاء لخربة السمرة.

Separte sewerage — مياه الصرف الصحي بتودها لمحطة مياه عادمة لعمليات المعالجة بينما تصريف مياه الأمطار يتم إرسالها لأي water body زي الأنهر والبحيرات والسدود والبحار.

التدفق لمسئ من أعلى ارتفاع لأقل ارتفاع

بلش يحكي عن الأماكن يلي تولد فيه المكان يلي راح ييلغ فيه

Wastewater flowrates

أول صفة من صفات الـ waste water إنه الـ flowrate ثم يتم جمعه ليتم معالجته

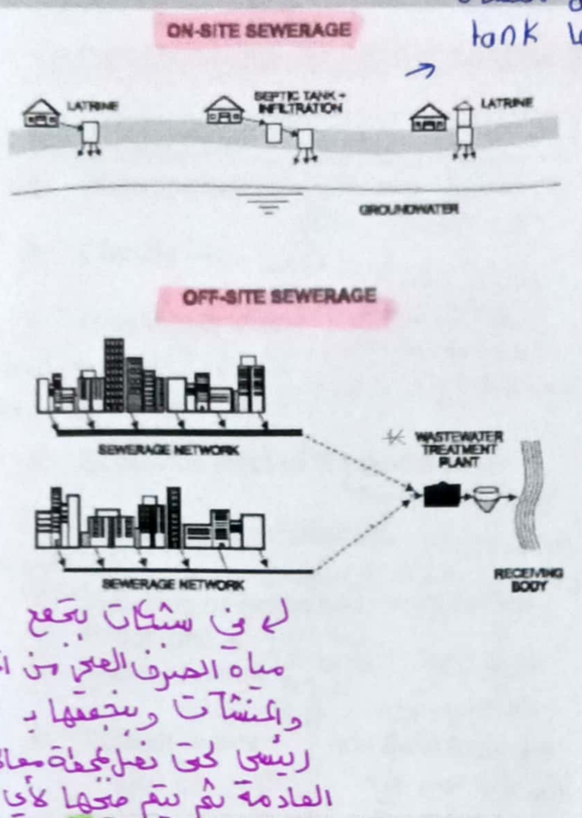
جمع ونقل المياه العادمة 2types

Wastewater sewerage systems:

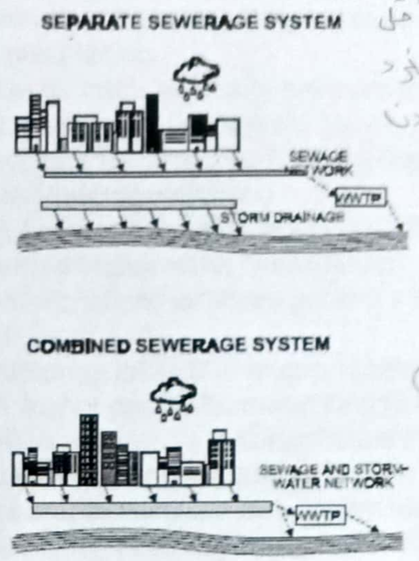
النقل خارج حدود المدينة

عبارة عن شبكة صرف صحي فيها Pipes مشتركة عن المنشآت ومن ثم يتم تجميعها لخطوط رئيسية ليتم إرسالها إلى محطة تنقية مياه عادمة.

- Off-site sewerage: with a waterborne sewerage collection and transportation network:
  - Separate sewerage system: which separates storm water from sewage, both being transported by independent pipeline systems.
    - نظام تصريف مياه الأمطار مفصول عن نظام الصرف الصحي للمياه العادمة يلي من المنازل والمنشآت.
    - هاد مش مطبق في الأردن :
  - Combined sewerage system: which directs sewage and storm water together into the same system. Storm water does contribute to the wastewater treatment plant (WWTP), and the pipelines have a larger diameter.
    - خليط بين مياه الصرف الصحي ومياه الأمطار وكله هاد مع بعض يتم إرساله على محطات معالجة المياه العادمة
    - يلي بميز الـ combined إنه الـ Pipes إلها diameter أكبر وبسبب هاد الـ d الكبير بكونا التدفق خلال هاد الـ d بطيء وبصير عمليات تحليل للمادة العضوية داخل مياه الصرف الصحي وهاد بسبب روائح وحرارة أي أعلى من حرارة الجو بسبب التحليل..
    - لـ بكونا sys بتعمل التدفق
- On-site sewerage: latrines and septic tanks.
  - هاي على شكل دائري
  - latrines: مستقبل أداة الحمام / لـ زي الحمامات — لـ الأدوش
  - في المكان يلي بتولد فيه المياه العادمة تتم معالجته
  - septic tanks: الأحواض الامتصاصية يلي عادة موجودة في المباني والمنشآت خارج شبكة الصرف الصحي — لـ مشاكلها ممكن تتسرب من للمياه الجوفية
  - بنجمع فيهم الى بعدين بنتقلهم على محطات المعالجة لتتم معالجتها



(a) Sewerage systems: on-site and off-site



(b) Off-site sewerage systems: separate and combined

Average water consumption

- Domestic flow is a function of the water consumption.
- Typical values of per capita water consumption for populations provided with household water connections are:

Community size	Population range (inhabitants)	Per capita water consumption (L/inhab.d)
Rural settlement	<5,000	90–140
Village	5,000–10,000	100–160
Small town	10,000–50,000	110–180
Average town	50,000–250,000	120–220
Large city	>250,000	150–300

Note: in places with severe water shortages, these values may be smaller
Source: Adapted from CETESB (1977; 1978), Barnes et al (1981), Dahlhaus & Damrath (1982), Hosang & Bischof (1984)

Typical ranges of per capita water consumption

Factors that influence water consumption

Influencing factor	Comment
Water availability	In locations of water shortage consumption tends to be less
Climate	Warmer climates induce a greater water consumption
Community size	Larger cities generally present a larger per capita water consumption (to account for strong commercial and institutional activities)
Economic level of the community	A higher economic level is associated with a higher water consumption
Level of industrialisation	Industrialised locations present a higher consumption
Metering of household consumption	Metering inhibits greater consumption
Water cost	A higher cost reduces consumption
Water pressure	High pressure in the distribution system induces greater use and wastage
System losses	Losses in the water distribution network imply the necessity of a greater water production

Typical water consumption in some commercial establishments

Establishment	Unit	Flow range (L/unit.d)
Airport	Passenger	8–15
Accommodation (lodging house)	Resident	80–150
Public toilet	User	10–25
Bar	Customer	5–15
Cinema/theatre	Seat	2–10
Office	Employee	30–70
Hotel	Guest	100–200
	Employee	30–50
Industry (sanitary sewage only)	Employee	50–80
Snack bar	Customer	4–20
Laundry – commercial	Machine	2,000–4,000
Laundry – automatic	Machine	1,500–2,500
Shop	Toilet	1,000–2,000
	Employee	30–50
Department store	Toilet	1,600–2,400
	Employee	30–50
	m^2 of area	5–12
Petrol station	Vehicle attended	25–50
Restaurant	Meal	15–30
Shopping centre	Employee	30–50
	m^2 of area	4–10

Source: EPA (1977), Hosang and Bischof (1984), Tchobanoglous and Schroeder (1985), Qasim (1985), Metcalf & Eddy (1991), NBR-7229/93

Typical water consumption in some institutional establishments

Establishment	Unit	Flow range (L/unit.d)
Rest home	Resident	200–450
	Employee	20–60
School	Student	50–100
– with cafeteria, gymnasium, showers	Student	40–80
– with cafeteria only	Student	20–60
– without cafeteria and gymnasium		
Hospital	Bed	300–1000
	Employee	20–60
Prison	Inmate	200–500
	Employee	20–60

Source: EPA (1977), Hosang and Bischof (1984), Tchobanoglous and Schroeder (1985), Qasim (1985), Metcalf & Eddy (1991)

Average domestic sewage flow calculation

The average domestic sewage flow calculation is given by:

$$Qd_{av} = \frac{Pop.L_{pcd}.R}{1000} \quad (m^3/d)$$

$$Qd_{av} = \frac{Pop.L_{pcd}.R}{86400} \quad (L/s)$$

where:

- Qdav= average domestic sewage flow (m3/d or L/s)
- Lpcd = per capita water consumption (L/inhab.d)
- R = sewage flow/water flow return coefficient

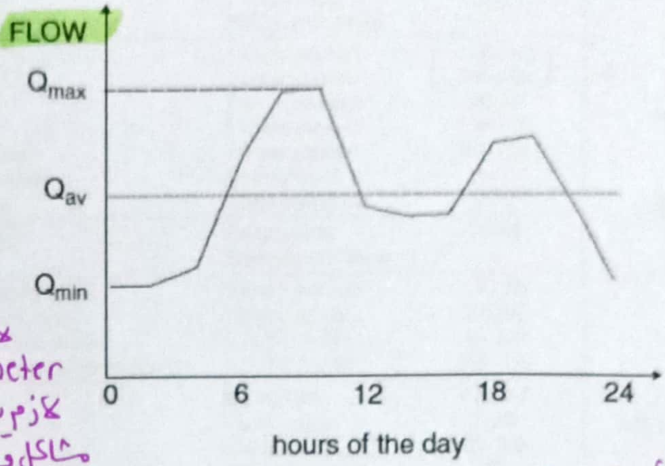
It is important to notice that the water flow to be considered is the flow actually consumed, and not the flow produced by the water treatment works. The water flow produced is higher than that consumed due to unaccounted water losses in the distribution system, which can vary typically from 20 to 50%. Thus in a locality where the loss is 30%, for each 100 m3 of water produced, 30 m3 are unaccounted for and only 70 m3 are consumed. Of this 70 m3, around 80% (56 m3/d) return in the form of sewage to the sewerage system.

Flow variations

- Water consumption and wastewater generation in a locality vary throughout the day (hourly variations), during the week (daily variations) and throughout the year (seasonal variations).

$$Q_{max} = Q_{av} \cdot K_1 \cdot K_2 = 1.8\,Q_{av}$$

$$Q_{min} = Q_{av} \cdot K_3 = 0.5\,Q_{av}$$



- $K_1 = 1.2$ (peak coefficient for the day with the highest water consumption)
- $K_2 = 1.5$ (peak coefficient for the hour with the highest water consumption)
- $K_3 = 0.5$ (reduction coefficient for the hour with the lowest water consumption)

Industrial wastewater flow

➢ Water consumption:

- Total volume consumed (per day or month)
- Volume consumed in the various stages of the process
- Internal recirculations
- Water origin (public supply, wells, etc.)
- Internal systems of water treatment

➢ Wastewater production:

- Total flow
- Number of discharge points (with the corresponding industrial process associated with each point)
- Discharge pattern (continuous or intermittent; duration and frequency) in each discharge point
- Discharge destination (sewerage system, watercourse)
- Occasional mixing of wastewater with domestic sewage and storm water

❑ Effluent flow measurements must be carried out throughout the working day, to record the discharge pattern and variations.

Specific average flows from some industries

Type	Activity	Unit	Water consumption per unit (m^3/unit) (*)
Food	Canned fruit and vegetables	1 tonne product	4–50
	Sweets	1 tonne product	5–25
	Sugar cane	1 tonne sugar	0.5 – 10.0
	Slaughter houses	1 cow or 2.5 pig	0.5–3.0
	Dairy (milk)	1000 L milk	1–10
	Dairy (cheese or butter)	1000 L milk	2–10
	Margarine	1 tonne margarine	20
	Brewery	1000 L beer	5–20
	Bakery	1 tonne bread	2–4
	Soft drinks	1000 L soft drinks	2–5
Textiles	Cotton	1 tonne product	120–750
	Wool	1 tonne product	500–600
	Rayon	1 tonne product	25–60
	Nylon	1 tonne product	100–150
	Polyester	1 tonne product	60–130
	Wool washing	1 tonne wool	20–70
	Dyeing	1 tonne product	20–60
Leather / tanneries	Tannery	1 tonne hide	20–40
	Shoe	1000 pairs of shoes	5
Pulp and paper	Pulp fabrication	1 tonne product	15–200
	Pulp bleaching	1 tonne product	80–200
	Paper fabrication	1 tonne product	30–250
	Pulp and paper integrated	1 tonne product	200–250
Chemical industries	Paint	1 employee	110 L/d
	Glass	1 tonne glass	3–30
	Soap	1 tonne soap	25–200
	Acid, base, salt	1 tonne chlorine	50
	Rubber	1 tonne product	100–150
	Synthetic rubber	1 tonne product	500
	Petroleum refinery	1 barrel (117 L)	0.2–0.4
	Detergent	1 tonne product	13
	Ammonia	1 tonne product	100–130
	Carbon dioxide	1 tonne product	60–90
	Petroleum	1 tonne product	7–30
	Lactose	1 tonne product	600–800
	Sulphur	1 tonne product	8–10
	Pharmaceutical products (vitamins)	1 tonne product	10–30

* Consumption in m3 per unit produced or L/d per employee

Source: CETESB (1976), Downing (1978), Arceivala (1981), Hosang and Bischof (1984), Imhoff & Imhoff (1985), Metcalf & Eddy (1991), Der´isio (1992)

Wastewater Composition

Quality parameters

- Domestic sewage contains approximately 99.9% water. The remaining part includes organic and inorganic, suspended and dissolved solids, together with microorganisms It is because of this 0.1% that water pollution takes place and the wastewater needs to be treated.
- The composition of the wastewater is a function of the uses to which the water was submitted. These uses, and the form with which they were exercised, vary with climate, social and economic situation and population habits.

Main characteristics of wastewater

The main physical, chemical and biological characteristics of domestic sewage:

Physical characteristics

Parameter	Description
Temperature	• Slightly higher than in drinking water • Variations according to the seasons of the years (more stable than the air temperature) • Influences microbial activity • Influences solubility of gases • Influences viscosity of the liquid
Colour	• Fresh sewage: slight grey • Septic sewage: dark grey or black
Odour	• Fresh sewage: oily odour, relatively unpleasant • Septic sewage: foul odour (unpleasant), due to hydrogen sulphide gas and other decomposition by-products • Industrial wastewater: characteristic odours
Turbidity	• Caused by a great variety of suspended solids • Fresher or more concentrated sewage: generally greater turbidity

Chemical characteristics

Parameter	Description
TOTAL SOLIDS	*Organic and inorganic; suspended and dissolved; settleable*
• *Suspended*	• Part of organic and inorganic solids that are non-filterable
• *Fixed*	• Mineral compounds, not oxidisable by heat, inert, which are part of the suspended solids
• *Volatile*	• Organic compounds, oxidisable by heat, which are part of the suspended solids
• *Dissolved*	• Part of organic and inorganic solids that are filterable. Normally considered having a dimension less than 10^{-3} µm.
• *Fixed*	• Mineral compounds of the dissolved solids.
• *Volatile*	• Organic compounds of the dissolved solids
• *Settleable*	• Part of organic and inorganic solids that settle in 1 hour in an Imhoff cone. Approximate indication of the settling in a sedimentation tank.
ORGANIC MATTER	*Heterogeneous mixture of various organic compounds. Main components: proteins, carbohydrates and lipids.*
Indirect determination	
• *BOD_5*	• Biochemical Oxygen Demand. Measured at 5 days and 20 °C. Associated with the biodegradable fraction of carbonaceous organic compounds. Measure of the oxygen consumed after 5 days by the microorganisms in the biochemical stabilisation of the organic matter.
• *COD*	• Chemical Oxygen Demand. Represents the quantity of oxygen required to chemically stabilise the carbonaceous organic matter. Uses strong oxidising agents under acidic conditions.
• *Ultimate BOD*	• Ultimate Biochemical Oxygen Demand. Represents the total oxygen consumed at the end of several days, by the microorganisms in the biochemical stabilisation of the organic matter.
Direct determination	
• *TOC*	• Total Organic Carbon. Direct measure of the carbonaceous organic matter. Determined through the conversion of organic carbon into carbon dioxide.

TOTAL NITROGEN	*Total nitrogen includes organic nitrogen, ammonia, nitrite and nitrate. It is an essential nutrient for microorganisms' growth in biological wastewater treatment. Organic nitrogen and ammonia together are called Total Kjeldahl Nitrogen (TKN).*
• *Organic nitrogen*	• Nitrogen in the form of proteins, aminoacids and urea.
• *Ammonia*	• Produced in the first stage of the decomposition of organic nitrogen.
• *Nitrite*	• Intermediate stage in the oxidation of ammonia. Practically absent in raw sewage.
• *Nitrate*	• Final product in the oxidation of ammonia. Practically absent in raw sewage.
TOTAL PHOSPHORUS	*Total phosphorus exists in organic and inorganic forms. It is an essential nutrient in biological wastewater treatment.*
• *Organic phosphorus*	• Combined with organic matter.
• *Inorganic phosphorus*	• Orthophosphates and polyphosphates.

Parameter	Description
pH	*Indicator of the acidic or alkaline conditions of the wastewater. A solution is neutral at pH 7. Biological oxidation processes normally tend to reduce the pH.*
ALKALINITY	*Indicator of the buffer capacity of the medium (resistance to variations in pH). Caused by the presence of bicarbonate, carbonate and hydroxyl ions.*
CHLORIDES	*Originating from drinking water and human and industrial wastes.*
OILS AND GREASE	*Fraction of organic matter which is soluble in hexane. In domestic sewage, the sources are oils and fats used in food.*

Biological characteristics

ال microorg (الأحياء الدقيقة) → البكتيريا والطحالب الفطريات الأميبا الفيروسات وأنواع مختلفة من الديدان

Organism	Description
Bacteria	• Unicellular organisms • Present in various forms and sizes • Main organisms responsible for the stabilisation of organic matter • Some bacteria are pathogenic, causing mainly intestinal diseases
Archaea	• Similar to bacteria in size and basic cell components • Different from bacteria in their cell wall, cell material and RNA composition • Important in anaerobic processes
Algae	• Autotrophic photosynthetic organisms, containing chlorophyll • Important in the production of oxygen in water bodies and in some sewage treatment processes • In lakes and reservoirs they can proliferate in excess, deteriorating the water quality
Fungi	• Predominantly aerobic, multicellular, non-photosynthetic, heterotrophic organisms • Also of importance in the decomposition of organic matter • Can grow under low pH conditions
Protozoa	• Usually unicellular organisms without cell wall • Majority is aerobic or facultative • Feed themselves on bacteria, algae and other microorganisms • Essential in biological treatment to maintain an equilibrium between the various groups • Some are pathogenic
Viruses	• Parasitic organisms, formed by the association of genetic material (DNA or RNA) and a protein structure • Pathogenic and frequently difficult to remove in water or wastewater treatment
Helminths	• Higher-order animals • Helminth eggs present in sewage can cause illnesses

Note: algae are normally not present in untreated wastewater, but are present in the treated effluent from some processes (e.g. stabilisation ponds)

Main parameters defining the quality of wastewater

للداخل والطالع من محطة inbet. أو

The main parameters predominantly found in domestic sewage that deserve special consideration are:

- Solids
- Indicators of organic matter → قديش عندي مادة عضوية
- Nitrogen
- Phosphorus
- Indicators of faecal contamination

الحمل الأكبر يلي بالمي بعد الاستخدام لمايصير waste water ويمشي بالصرف الصحي هو فضلات الإنسان

بصفي على كل unit آخذ عينة وأشوف مؤشراتها وأقارنها بال Process أول الي قبلها حتى أعرف ال eff تبعها ال unit قديش

Solids

- All the contaminants of water, with the exception of dissolved gases, contribute to the solids load.

- In wastewater treatment, the solids can be classified according to:

  - Classification by size and state
    - ✓ Suspended solids
    - ✓ Dissolved solids

  - Classification by chemical characteristics
    - ✓ Volatile solids (organic)
    - ✓ Fixed solids (inorganic)

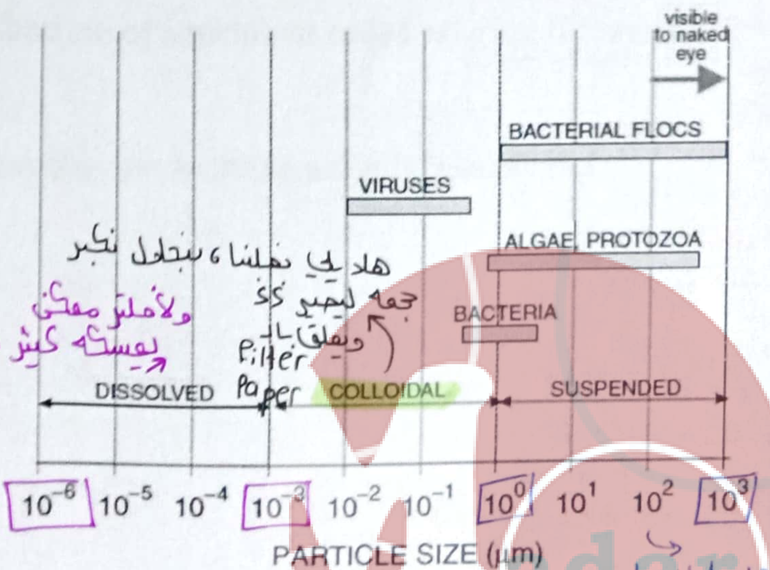
  - Classification by settleability
    - ✓ Settleable suspended solids
    - ✓ Non-settleable suspended solids

Solids: Classification by size

- Particles of smaller dimensions capable of passing through a filter paper of a specific size correspond to the **dissolved solids**, while those with larger dimensions and retained by the filter are considered **suspended solids**.

- Sometimes the term particulate is used to indicate that the solids are present as **suspended solids**. In this context, expressions as particulate BOD, COD, phosphorus, etc. are used, to indicate that they are linked to suspended solids. In contrast, soluble BOD, COD and phosphorus are associated with **dissolved solids.**

DISTRIBUTION OF SOLIDS BY SIZE



Solids: Classification by chemical characteristics

- If the solids are submitted to a high temperature (550°C), the organic fraction is oxidized (volatilized), leaving after combustion only the inert fraction (unoxidized).
- The volatile solids represent an estimate of the organic matter in the solids, while the non-volatile solids (fixed) represent the inorganic or mineral matter.

Total solids
- ↗ Volatile solids (organic matter)
- ↘ Fixed solids (inorganic matter)

Solids: Classification by settleability

- Settleable solids are considered those that are able to settle in a period of 1 hour.
- The volume of solids accumulated in the bottom of a recipient called an Imhoff Cone is measured and expressed as mL/L.
- The fraction that does not settle represents the non-settleable solids (usually not expressed in the results of the analysis).

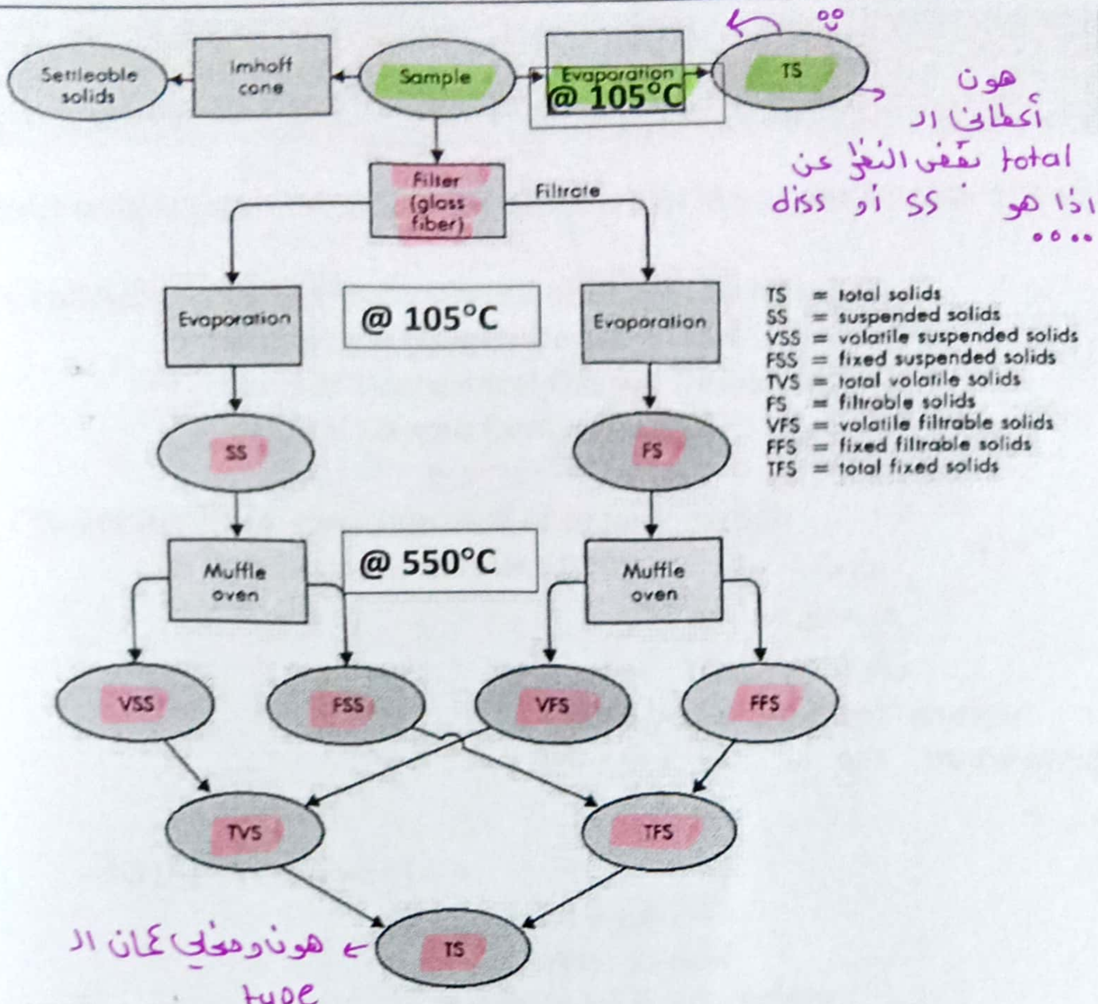


FIGURE 2.7

Interrelationships of solids found in water and wastewater. In much of the water quality literature, the solids passing through the filter are called dissolved solids.

Carbonaceous organic matter

- The organic matter present in sewage is a characteristic of substantial importance, being the cause of one of the main water pollution problems: consumption of dissolved oxygen by the microorganisms in their metabolic processes of using and stabilizing the organic matter.
- The organic substances present in sewage consist mainly of:
  - Protein compounds (≈ 40%)
  - Carbohydrates (≈ 25 to ≈ 50%)
  - Oils and grease (≈ 10%)
  - Urea, surfactants, phenols, pesticides and others (lower quantity)
- The carbonaceous organic matter (based on organic carbon) present in the influent sewage to a WWTP can be divided into the following main fractions:
  - classification: in terms of form and size
    - ✓ Suspended (particulate)
    - ✓ Dissolved (soluble)
  - classification: in terms of biodegradability
    - ✓ Inert
    - ✓ Biodegradable

- Direct or indirect methods can be adopted for the quantification of organic matter:
  - Indirect methods: measurement of oxygen consumption
    - ✓ Biochemical Oxygen Demand (BOD)
    - ✓ Ultimate Biochemical Oxygen Demand (BOD_u)
    - ✓ Chemical Oxygen Demand (COD)
  - Direct methods: measurement of organic carbon
    - ✓ Total Organic Carbon (TOC)

Biochemical Oxygen Demand (BOD)

- The main ecological effect of organic pollution in a water body is the decrease in the level of dissolved oxygen.
- Similarly, in sewage treatment using aerobic processes, the adequate supply of oxygen is essential, so that the metabolic processes of the microorganisms can lead to the stabilization of the organic matter.
- This quantification could be obtained through stoichiometric calculations based on the reactions of oxidation of the organic matter. If the substrate was, for example, glucose ($C_6H_{12}O_6$), the quantity of oxygen required to oxidize the given quantity of glucose could be calculated through the basic equation of respiration. This is the principle of the so-called **Theoretical Oxygen Demand (TOD).**
- In practice, however, a large obstacle is present: the sewage has a great heterogeneity in its composition, and to try to establish all its constituents in order to calculate the oxygen demand based on the chemical oxidation reactions of each of them is totally impractical.
- The solution found was to measure in the laboratory the consumption of oxygen exerted by a standard volume of sewage or other liquid, in a predetermined time. It was thus introduced the important concept of **Biochemical Oxygen Demand (BOD).**

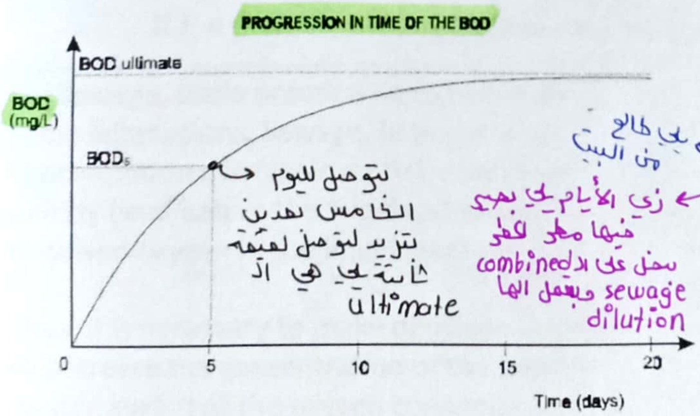
- The BOD represents the quantity of oxygen required to stabilize through biochemical processes, the carbonaceous organic matter. It is an indirect indication, therefore, of the biodegradable organic carbon.

- Complete stabilization takes, in practical terms, various days (around 20 days or more for domestic sewage). This corresponds to the **Ultimate Biochemical Oxygen Demand (BOD_u)**. However, to shorten the time for the laboratory test, and to allow a comparison of the various results, some standardizations were established:

  - the determination is undertaken on the 5th day. For typical domestic sewage, the oxygen consumption on the fifth day can be correlated with the final total consumption (BOD_u);

  - the test is carried out at a temperature of 20°C, since different temperatures interfere with the bacteria's metabolism, modifying the relation between BOD at 5 days and BOD Ultimate.

Ultimate Biochemical Oxygen Demand (BOD_u)



Origin	BOD_u/BOD_5
High concentration sewage	1.1–1.5
Low concentration sewage	1.2–1.6
Primary effluent	1.2–1.6
Secondary effluent	1.5–3.0

Source: Calculated using the coefficients presented by Fair et al (1973) and Arceivala (1981)

Various referencess adopt the ratio BODu/BOD5 equal to 1.46. This means that, in the case of having a BOD5 of 300 mg/L, the BODu is assumed to be equal to

1.46 × 300 = 438 mg/L.

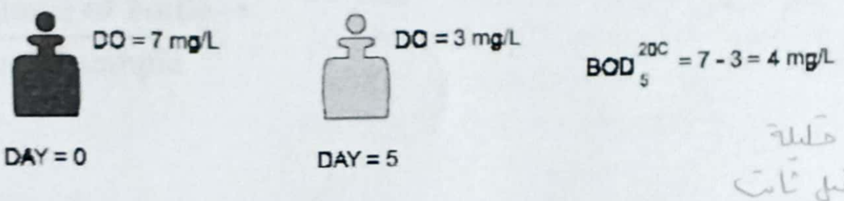
BOD test

- The BOD test can be understood in this simplified way: on the day of the sample collection, the concentration of dissolved oxygen (DO) in the sample is determined. Five days later, with the sample maintained in a closed bottle and incubated at 20∘C, the new DO concentration is determined.
- For example:

  * DO on day 0: 7 mg/L
  * DO on day 5: 3 mg/L

  $BOD_5 = 7 - 3 = 4$ mg/L

BOD—Biochemical Oxygen Demand



Special Case:

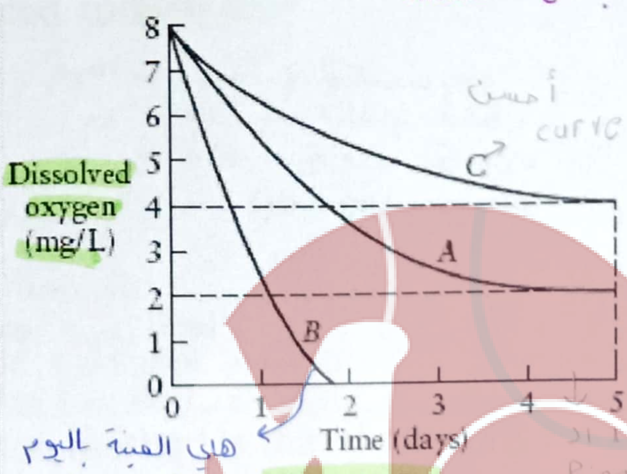
What if the F is =0?

Dilution of the sample is required when F = 0.

If F = 0 we don't know how much DO would have been used.

For sewage, some practical aspects require some adaptations. Sewage, having a large concentration of organic matter, consumes quickly (well before the five days) all the dissolved oxygen in the liquid medium.

Thus, it is necessary to make dilutions in order to decrease the concentration of the organic matter, such that the oxygen consumption at 5 days is numerically less than the oxygen available in the sample (the sample is lost if, at day 5, the DO concentration is zero, because it will not be possible to know when the zero concentration was reached)



$BOD_5 = I - F$

Where;

I = initial DO, mg/L

F = final DO, mg/L

Dilution

$$BOD = (I - F)D$$

where, D = dilution

$$D = \frac{\text{total volume of bottle}}{[\text{total volume of bottle}] - [\text{volume of dilution water}]}$$

$$D = \frac{\text{Total volume of bottle}}{\text{Volume of sample}}$$

Example

Determine the BOD_5 for a 15 ml sample that is diluted with dilution water to a total volume of 300 ml when the initial DO concentration is 8 mg/l and after 5 days, has been reduced to 2 mg/l.

I=8

F=2

D= 300/15=20

BOD_5 = (8-2)*20= 120

Remark: The assumption in the dilution method is that the results from each dilution of a single sample will yield the same BOD value (No Sliding Scale)

Examples: 9.4 9.5

* مرات بناخذ عينة من ال ww لكن كمية ال microorg. فيها قليلة وبالتالي التفاعل راح يكون بطئ أو ممكن يوقف، حتى يصير ال BOD5 أو Bio chem. rxn بدي water و org matter و ك ثابتة (20) و microor. اذا وحدة منهم اختلفت راح تأثر على ال Bio chem rxn

Seeding: The addition of active microorganisms that take up oxygen

كاملة، لهيك لما ال microorg تكون قليلة بنعمل seeding

بزيد ال microorg. ∴ ← لأنشط عملية التحلل

- May be required in samples that do not have their own,
- it is usually necessary to introduce a seed, containing microorganisms, to allow a faster start of the decomposition process,
- If seeding is necessary, any BOD that is contributed by the seed must be subtracted,

ثانية كان فيها dilution bottle و water بدنا نشوف قديش ال microorg اسهلك DO seeding

$$BOD_t = \left[(I-F) - (I'-F')\left(\frac{X}{Y}\right)\right]D$$

ل ال sample بتبقى ال exp

seeding ↓ بدخل جوا العينة microorg بروح على أي محطة لمعالجة المياه العادمة ومن ال aeriation tank باخذ عينة هاي العينة هي عبارة عن seeding لل microorg، ما بروح أشتري بكتيريا من المختبر بدي بكتيريا أ كتا تعودت على ال ww يلي بالصرف الصحي ∴ هاد ال seeding ← استهلك جزء من ال DO

where BOD_t = biochemical oxygen demand measured at some time, t, mg/L
I = initial DO of bottle with sample and seeded dilution water, mg/L
F = final DO of bottle with sample and seeded dilution water, mg/L
I' = initial DO of bottle with only seeded dilution water, mg/L
F' = final DO of bottle with only seeded dilution water, mg/L
X = seeded dilution water in sample bottle, mL
Y = volume of BOD bottle, mL
D = dilution of sample

* يعني عندي 2 bottles وحدة فيها ال sample بتحقق ووحدة dilution مع microorg كل وحدة منهم بقيس الها ال initial وال final بعد 5 أيام ال volume لل sample بتبقى محزونة ولل dilution water أنا محزوتها منخرن مع دعندي ال D ومنهم بحسب ال BOD5

التالي حتى أوصل العينة ل 300 معناها ال initial sample 10 (300/30) ضفت عليها 290 ml لتصار 300

Example

Standard BOD test with a 1:30 dilution with seeded dilution water is run. Both bottles begin at saturation, 9.2 mg/L. After five days, the bottle with waste has a DO of 2 mg/L, while the DO of the seed = 8 mg/L. Find the BOD_5.

$\frac{300}{10} = 30$ Dilution Factor

نقص ال DO من 9.2 ل 8 نتيجة النشاط البكتيري

ال dilution يلي ضفته لل 10 لأوصل ل 300 (مي مخلوطة ببكتيريا)

$$BOD_t = \left[(9.2-2) - (9.2-8)\left(\frac{290}{300}\right)\right]30$$

$$= 181\ \text{mg/L}$$

نقصان ال microorg يعني ما في نشاط بكتيري

BOD Kinetics

→ بورجينا العلاقة بين استهلاك ال DO وال formation ل BOD5

أو دلالة ال Param. يتبع ال BOD5

Thus the mass balance is: بيلهم علاقة عكسية (كلما قل ال DO كلما زاد ال BOD5)

Rate of DO Accum. = Rate of DO consumed

dz/dt = -r

z = dissolved oxygen, mg/L

Assume that it is a first-order reaction

$$\frac{dz}{dt} = -k_1 z \Rightarrow \frac{dz}{z} = -k_1 dt \Rightarrow z = z_o e^{-k_1 t}$$

As O_2 is used, the amount still to be used is **z**, the amount already used is **y**

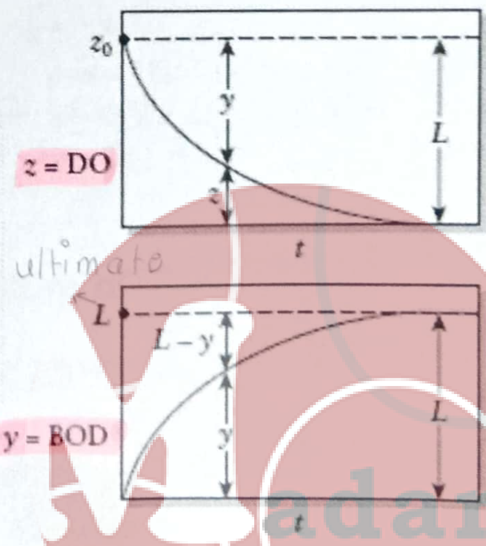
L = y + z @ t=0 , y=0 , L=$z_{t=0}$

Where, **L**= ultimate demand

$$z = L - y$$

$$L - y = z_o e^{-k_1 t}, \; z_o = L$$

$$\# \quad y = L - Le^{-k_1 t} = L(1 - e^{-k_1 t})$$



Where;

y = BOD at any time t

L = ultimate BOD

k_1 = deoxygenation constant, day^{-1}

↪ or dearation

Average k

TABLE 1.4
Average BOD rate constants at 20°C

Substance	k_{10}, day^{-1}
*Untreated wastewater	0.15–0.28
High-rate filters and anaerobic contact	0.12–0.22
High-degree biotreatment effluent	0.06–0.10
Rivers with low pollution	0.04–0.08

Numerical value of the rate constant k depends on:

1. Nature of waste
2. Ability of organisms in the system to use the waste
3. Temperature

Temperature Effect on k

- The BOD rate constant is adjusted to the temperature of receiving water using this:

$$k_T = k_{20}(\theta)^{T-20}$$

- Where;
  - k_t = BOD rate constant at the temperature of interest
  - k_{20} = BOD rate constant determined at 20°C
  - T = temperature in °C
  - Θ = Temperature coefficient (For domestic WW, 1.135 and 1.024 for reaeration)

Example 9.8: Find the BOD_5 for a waste with an ultimate BOD = 282 mg/L and a k_1 = 0.348 /day

الزمن بالأيام   بالامتحان بجيب نفعل correlation لـ K

$$y = L(1 - e^{-k_1 t})$$

$$= 282\ mg/L(1 - e^{-0.348/day*5})$$

$$= 50\ mg/L$$

✓ Example 9.8   9.9

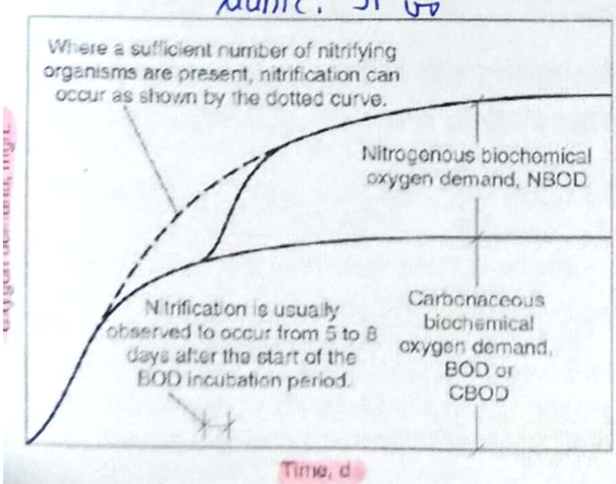
* اذا بدك تحسب فقط الـ BOD5 للـ carbon. في الـ sample لازم تدخل على الـ inhibitor أو مادة تفعل nutralization لأي org matter. nitrog. هاد اذا بدي اياه بس لـ carbon، ممكن أطلع الـ BOD5 لـ carbon والـ nitrogen مع بعض.

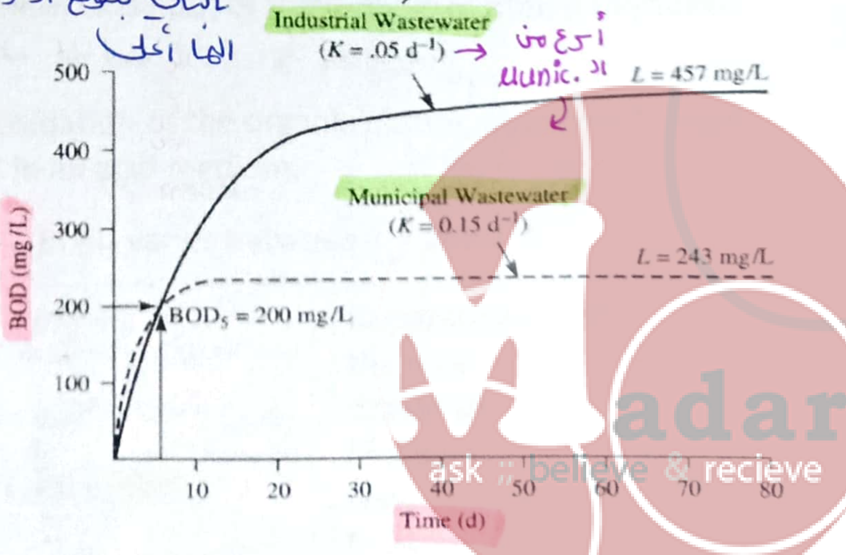
المحتوى العضوي إما يكون carbonaceous أو nitrogenous، النباتات والإنسان عالية الكربون والنيتروجين بكونو domenant

To measure only the carbonaceous oxygen demand, an inhibitor for nitrification (nitrogenous oxygen demand, associated with the oxidation of ammonia to nitrate) can be added.

مش ثابت حسب المكان لي بطلع الـ waste

* مش شرط دائماً يكون الـ indu. أعلى من الـ munic.   المحتوى العضوي أعلى البتالي بنتوقع الـ BOD5 الها أعلى





Ref: Davis, Cornwell, 1998, Introduction to Environmental Engineering

BOD test: Advantages

The main advantages of the BOD test are related to the fact that the test allows:

- ✓ an approximate indication of the biodegradable fraction of the wastewater;
- ✓ an indication of the degradation rate of the wastewater;
- ✓ an indication of the oxygen consumption rate as a function of time;
- ✓ an approximate determination of the quantity of oxygen required for the biochemical stabilization of the organic matter present.
- ✓ the design criteria for many wastewater treatment processes are frequently expressed in terms of BOD;
- ✓ the legislation for effluent discharge in many countries, and the evaluation of the compliance with the discharge standards, is normally based on BOD.

Chemical Oxygen Demand (COD)

- The COD test measures the consumption of oxygen occurring as a result of the chemical oxidation of the organic matter. The value obtained is, therefore, an indirect indication of the level of organic matter present.
- The main difference with the BOD test is clearly found in the nomenclature of both tests. The BOD relates itself with the biochemical oxidation of the organic matter, undertaken entirely by microorganisms.
- The COD corresponds to the chemical oxidation of the organic matter, obtained through a strong oxidant (potassium dichromate) in an acid medium.
- For raw domestic sewage, the ratio COD/BOD_5 varies between 1.7 and 2.4.

- *Low COD/BOD_5 ratio* (less than 2.5 or 3.0):
  - the biodegradable fraction is high
  - good indication for biological treatment
- *Intermediate COD/BOD_5 ratio* (between 2.5 and 4.0):
  - the inert (non-biodegradable) fraction is not high
  - treatability studies to verify feasibility of biological treatment
- *High COD/BOD_5 ratio* (greater than 3.5 or 4.0):
  - the inert (non-biodegradable) fraction is high
  - possible indication for physical–chemical treatment

Depending on the value of the ratio, conclusions can be drawn about the biodegradability of the wastewater and the treatment process to be employed

COD: advantages and limitations

The main **advantages** of the COD test are:

- the test takes only two to three hours;
- because of the quick response, the test can be used for operational control;
- the test results give an indication of the oxygen required for the stabilization of the organic matter;
- the test allows establishment of stoichiometric relationships with oxygen;
- the test is not affected by nitrification, giving an indication of the oxidation of the carbonaceous organic matter only (and not of the nitrogenous oxygen demand).

The main **limitations** of the COD test are:

- in the COD test, both the biodegradable and the inert fractions of organic matter are oxidized. Therefore, the test may overestimate the oxygen to be consumed in the biological treatment of the wastewater;
- the test does not supply information about the consumption rate of the organic matter along the time;
- certain reduced inorganic constituents could be oxidized and interfere with the result.

(BOD_u/BOD_5 and COD/BOD_5) Indication

Relationship between the representative parameters of oxygen consumption:

In samples of raw and treated domestic sewage, the usual ratios between the main representative parameters of oxygen consumption (BOD_u/BOD_5 and COD/BOD_5) indicate the following:

- The ratios can never be lower than 1.0.
- The ratios increase, from the condition of untreated to biologically treated wastewater.
- The higher the treatment efficiency, the higher the value of the ratio.

otal Organic Carbon (TOC)

In this test the organic carbon is directly measured, in an instrumental test, and not indirectly through the determination of the oxygen consumed, like BOD, COD, etc.

The TOC test measures all the carbon released in the form of CO_2.

To guarantee that the carbon being measured is really organic carbon, the inorganic forms of carbon (like CO_2, HCO^{-3} etc) must be removed before the analysis or be corrected when calculated.

Nitrogen

Nitrogen is a component of great importance in terms of generation and control of the water pollution, principally for the following aspects:

- **Water pollution**

✓ nitrogen is an essential nutrient for algae leading, under certain conditions, to the phenomenon of eutrophication of lakes and reservoirs;
✓ nitrogen can lead to dissolved oxygen consumption in the receiving water body due to the processes of the conversion of ammonia to nitrite and this nitrite to nitrate;
✓ nitrogen in the form of free ammonia is directly toxic to fish;
✓ nitrogen in the form of nitrate is associated with illnesses such as methaemoglobinaemia

- **Sewage treatment**

✓ nitrogen is an essential nutrient for the microorganisms responsible for sewage treatment;
✓ nitrogen, in the processes of the conversion of ammonia to nitrite and nitrite to nitrate (nitrification), which can occur in a WWTP, leads to oxygen and alkalinity consumption;
✓ nitrogen in the process of the conversion of nitrate to nitrogen gas (denitrification), which can take place in a WWTP, leads to (a) the economy of oxygen and alkalinity (when occurring in a controlled form) or (b) the deterioration in the settleability of the sludge (when not controlled).

Forms of nitrogen under different conditions

Condition	Prevailing form of nitrogen
Raw wastewater	• Organic nitrogen ⊙ Ammonia
Recent pollution in a water course	• Organic nitrogen • Ammonia
Intermediate stage in the pollution of a water course	• Organic nitrogen • Ammonia • Nitrite (in lower concentrations) • Nitrate
Remote pollution in a water course	⊙ Nitrate
Effluent from a treatment process without nitrification	• Ammonia
Effluent from a treatment process with nitrification	⊙ Nitrate
Effluent from a treatment process with nitrification/denitrification	• Low concentrations of all forms of nitrogen

Note: organic nitrogen + ammonia = TKN (Total Kjeldahl Nitrogen)

TKN can be subdivided in a soluble fraction (dominated by ammonia) and a particulate fraction (associated with the organic suspended solids – nitrogen participates in the constitution of practically all forms of particulate organic matter in sewage).

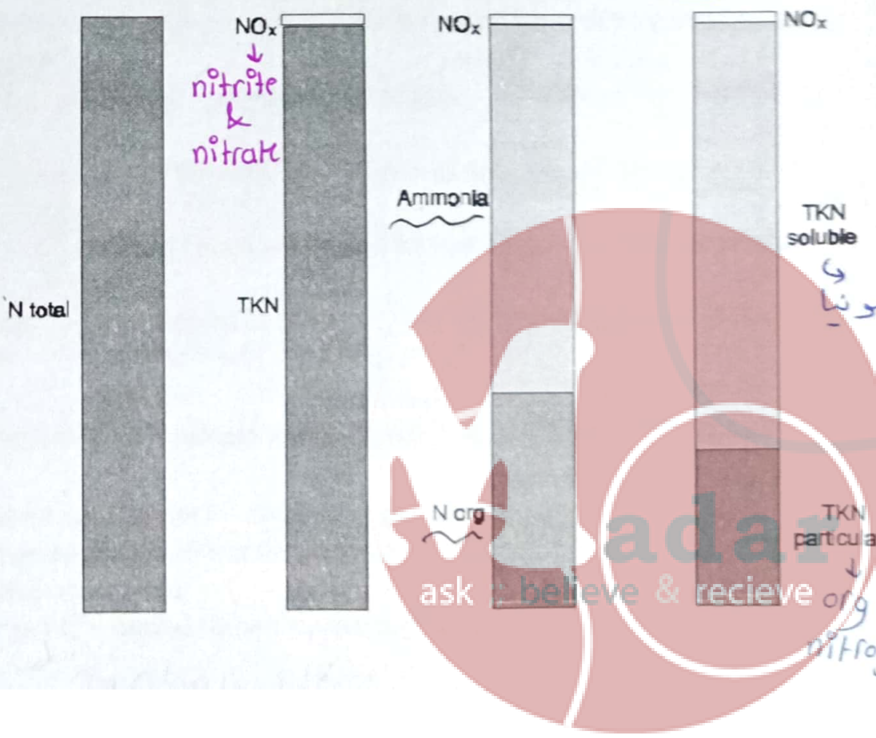
- TKN = ammonia + organic nitrogen *(prevailing form in domestic sewage)*
- $TN = TKN + NO_2^- + NO_3^-$ *(total nitrogen)*

In a watercourse or in a WWTP, the ammonia can undergo subsequent transformations:

In the process of **nitrification** the ammonia is oxidized to nitrite and the nitrite to nitrate.

In the process of **denitrification** the nitrates are reduced to nitrogen gas.

NITROGEN DISTRIBUTION IN RAW DOMESTIC SEWAGE



- Ammonia exists in solution in the form of the ion (NH_4^+) and in a free form, not ionized (NH_3), according to the following dynamic equilibrium:

$$NH_3 + H^+ \leftrightarrow NH_4^+$$

free ammonia — ionised ammonia

- The relative distribution has the following values, as a function of the pH values.

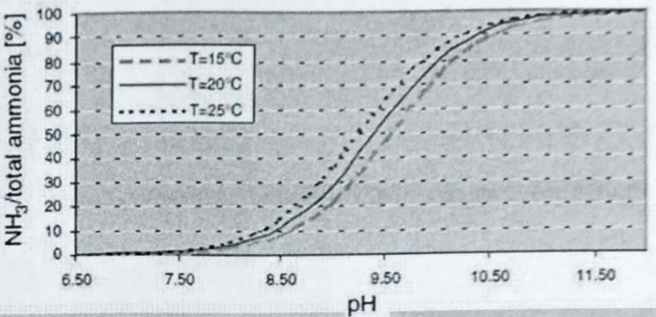
Distribution between the forms of ammonia

- pH < 8 — Practically all the ammonia is in the form of NH_4^+
- pH = 9.5 — Approximately 50% NH_3 and 50% NH_4^+
- pH > 11 — Practically all the ammonia in the form of NH_3

$$\frac{\text{Free } NH_3}{\text{Total ammonia}}(\%) = \{1 + 10^{0.09018+[2729.92/(T+273.20)]-pH}\}^{-1} \times 100$$

where:

T = liquid temperature (°C)

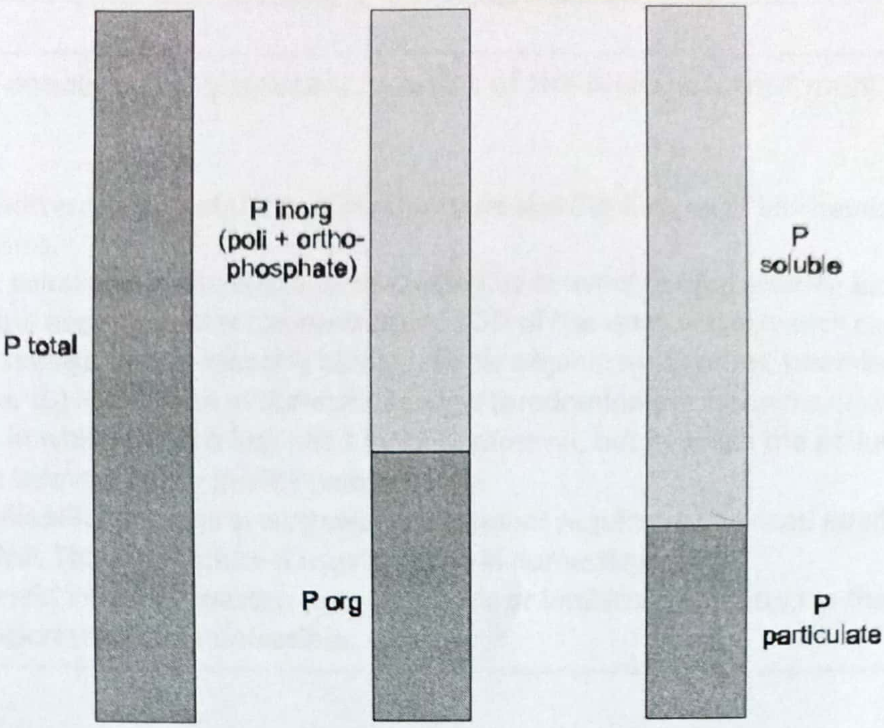


Phosphorus

- Total phosphorus in domestic sewage is present in the form of phosphates, according to the following distribution:
  - **inorganic** (polyphosphates and orthophosphates) – main source from detergents and other household chemical products.
  - **organic** (bound to organic compounds) – physiological origin.
- Phosphorus in detergents is present, in raw sewage, in the form of soluble polyphosphates or, after hydrolysis, as orthophosphates.
- Orthophosphates are directly available for biological metabolism without requiring conversion to simpler forms.
- The forms in which orthophosphates are present in the water are pH dependent, and include PO_4^{3-}, HPO_4^{2-}, $H_2PO_4^-$, H_3PO_4.

- Another way of fractionating phosphorus in wastewater is with respect to its form as solids:
  - **soluble phosphorus** (predominantly inorganic) – mainly polyphosphates and orthophosphates (inorganic phosphorus), together with a small fraction corresponding to the phosphorus bound to the soluble organic matter in the wastewater
  - **particulate phosphorus** (all organic) – bound to particulate organic matter in the wastewater

DISTRIBUTION OF PHOSPHORUS IN RAW SEWAGE



Physical–chemical characteristics of raw domestic sewage

Parameter	Per capita load (g/inhab.d) Range	Typical	Concentration (mg/L, except pH) Range	Typical
TOTAL SOLIDS	120–220	180	700–1350	1100
Suspended	35–70	60	200–450	350
• *Fixed*	7–14	10	40–100	80
• *Volatile*	25–60	50	165–350	320
Dissolved	85–150	120	500–900	700
• *Fixed*	50–90	70	300–550	400
• *Volatile*	35–60	50	200–350	300
Settleable	–	–	10–20	15
ORGANIC MATTER				
BOD_5	40–60	50	250–400	300
COD	80–120	100	450–800	600
BOD ultimate	60–90	75	350–600	450
TOTAL NITROGEN	6.0–10.0	8.0	35–60	45
Organic nitrogen	2.5–4.0	3.5	15–25	20
Ammonia	3.5–6.0	4.5	20–35	25
Nitrite	≈ 0	≈ 0	≈ 0	≈ 0
Nitrate	0.0–0.3	≈ 0	0–2	≈ 0
PHOSPHORUS	0.7–2.5	1.0	4–15	7
Organic phosphorus	0.7–1.0	0.3	1–6	2
Inorganic phosphorus	0.5–1.5	0.7	3–9	5
pH	-	-	6.7–8.0	7.0
ALKALINITY	20–40	30	100–250	200
HEAVY METALS	≈ 0	≈ 0	≈ 0	≈ 0
TOXIC ORGANICS	≈ 0	≈ 0	≈ 0	≈ 0

Sources: Arceivala (1981), Jordão & Pessoa (1995), Qasim (1985), Metcalf & Eddy (1991), Cavalcanti et al (2001) and the author's experience.

Characteristics of industrial wastewater

- The generalization of typical industrial wastewater characteristics is difficult because of their wide variability from time to time and from industry to industry.

The following concepts are important in terms of the biological treatment of industrial wastewater:

- **Biodegradability:** capacity of the wastewater to be stabilized through biochemical processes by microorganisms.
- **Treatability:** suitability of the waste to be treated by conventional or existing biological processes.
- **Biodegradable organic matter concentration:** BOD of the wastewater, which can be: (a) higher than in domestic sewage (predominantly biodegradable organic wastewater, treatable through biological processes), or (b) lower than in domestic sewage (predominately inorganic or unbiodegradable wastewater, in which there is less need for BOD removal, but in which the pollution load can be expressed in terms of other quality parameters).
- **Nutrient availability:** biological wastewater treatment requires a balanced equilibrium between the nutrients C:N:P. This equilibrium is usually found in domestic sewage.
- **Toxicity:** certain industrial wastewaters have toxic or inhibitory constituents that can affect or render biological treatment unfeasible.

Pollutants of importance in industrial wastewaters

- Industrial effluents, depending on the type of the industrial process, can contain in greater or lesser degrees, the various pollutants:

a) **Metals:** the main implications of metals are:

- Toxicity to human beings and other forms of plant or animal life, as a result of the discharge or disposal of wastewaters to receiving water bodies or land.
- Inhibition to the microorganisms responsible for the biological treatment of wastewater.

- Heavy metals can be understood as those that, under certain concentrations and exposure time, offer risks to human health and the environment, impairing the activity of living organisms, including those responsible for the biological treatment of wastewater.
- The main chemical elements that fit into this category are: Ag, As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Sb, Se and Zn. These elements may be naturally found in soils or waters in variable concentrations, but lower than those ones considered toxic to different living organisms. Among these, As, Co, Cr, Cu, Se and Zn are essential to organisms in certain small quantities, while others have no function in biological metabolism, being toxic to plants and animals.

Treatability :-

↓

بعض ال ww الطالع من industry زي مصانع الزيتون
(معاصر الزيتون مثلاً) لما نعصر الزيتون بنستقبل مي على ال sys
فبطلع ww بنسميه الزيبار هاد يعتبر من أكثر ال ww
الصناعية يلي فيه mix من ال hazards wast
& chemical ما بنقدر نعالجها ، هيك يجمع هاد الزيبار من
معاصر الزيتون وبنوديه على برك وبنبخر (الحل الوحيد له هو
التبخير) للموسم يلي بعده وبنزل جرافات وأجرف ال sludge
وخلص منه في مكبات النفايات الخطرة.

Biodegradable organic matter concentration :-

لما نحكي BOD إنت بتحكي عن الصناعات يلي بتتعامل معها
في عنا صناعات ما بتعطي BOD على الإطلاق زي مصانع الدهانات
ال COD من ال solvent ومش BOD ، الصناعات الغذائية
والزراعية يلي بتعتمد على المواشي هدول ال ww يلي طالع ال BOD فيهم
بكون أعلى (لهيك أول اشي بدك تعرف شو صناعتك وبناءً عليها
تحدد إذا ال BOD وال COD أعلى أو أقل)

Toxicity :-

① ال waste الجاي من القطاع الزراعي بنخاف يكون فيه
مبيدات.

② مصانع المنظفات معظم ال waste يكون فيه كلور بإذا كان
فيه free chlorine.

③ صناعات الورق ، يلي بيعيدو تصنيع الورق بحطوا عليهم كلور ليبيض
ويشيل الحبر يلي عليهم ويعطي لون أبيض للب تبع الورق ويصنعو
مرة ثانية لهيك المي يلي بتطلع منها free chlorine عالي
وهو مادة معقمة وقاتلة للبكتيريا

Biosphere →
- Atmosphere (air)
- lithosphere (soil)
- hydrosphere (water)

Sources of contamination and the effects on human health by metals

etal	Sources of contamination	Effects on health
admium	Refined flours, cigarettes, odontological materials, steel industry, industrial gaseous effluents, fertilisers, pesticides, fungicides, coffee and tea treated with agrotoxics, ceramics, seafood, bone meal, welding, casting and refining of metals such as zinc, lead and copper. Cadmium derivatives are used in pigments and paintings, batteries, electroplating processes, accumulators, PVC stabilisers, nuclear reactors.	Carcinogenic, causes blood pressure rise and heart swelling. Immunity decreases. Prostate growth. Bone weakening. Joint pains. Anaemia. Pulmonary emphysema. Osteoporosis. Smell loss. Decrease in sexual performance.
ead	Car batteries, paints, fuels, plants treated with agrotoxics, bovine liver, canned foods, cigarettes, pesticides, hair paint, lead-containing gas, newsprint and colour advertisements, fertilisers, cosmetics, air pollution.	Irritability and aggressiveness, indisposition, migraines, convulsions, fatigue, gum bleed, abdominal pains, nausea, muscular weakness, loss of memory, sleeplessness, nightmares, unspecific vascular cerebral accident, alterations of intelligence, osteoporosis, kidney illnesses, anaemia, coagulation problems. It affects the digestive and reproductive system and is a teratogenic agent (causes genetic mutation).
ercury	Thermometers, pesticides and agrotoxics, dental alloy, water, mining, polishers, waxes, jewels, paints, sugar, contaminated tomato and fish, explosives, mercury fluorescent lamps, cosmetic products, production and delivery of petroleum by-products, salt electrolysis cells for chlorine production.	Depressive illness, fatigue, tremors, panic syndrome, paresthesias, lack of motor control, side walking, speech difficulties, loss of memory, loss of sexual performance, stomatitis, loose teeth, pain and paralysis in the edges, headache, anorexia in children, hallucination, vomiting, mastication difficulties, sweating, and pain sense loss.

Metal	Sources of contamination	Effects on health
Arsenic	Fuel oil, pesticides and herbicides, metallurgy, sea plants and animals.	Gastrointestinal disturbances, muscular and visceral spasms, nausea, diarrhoea, inflammation of mouth and throat, abdominal pains.
Aluminium	Water, processed cheese, white wheat flour, aluminium kitchenware, cosmetics, anti-acids, pesticides and antiperspirant, baker's yeast, salt.	Intestinal constipation, loss of energy, abdominal colics, infantile hyperactivity, loss of memory, learning difficulties, osteoporosis, rickets and convulsions. Related diseases: Alzheimer's and Parkinson's.
Barium	Polluted water, agrotoxics, pesticides and fertilisers.	Arterial hypertension, cardiovascular diseases, fatigue and discouragement.
Nickel	Kitchenware, nickel–cadmium batteries, jewels, cosmetics, hydrogenated oils, pottery works, cold permanent wave, welding.	Carcinogenic, may cause: contact dermatitis, gingivitis, skin rash, stomatitis, dizziness, joint pains, osteoporosis and chronic fatigue.
Zinc	Metallurgy (casting and refining), lead recycling industries.	Sense of sweetish taste and dryness in the throat, cough, weakness, panalgia, shivering, fever, nausea, vomiting.
Chromium	Leather tanning, electroplating.	Dermatitis, cutaneous ulcers, nose inflammation, lung cancer and perforation in the nose septum.

Sources: http://www.rossetti.eti.br; http://www.greenpeace.org.br

هاد السلايد ما بجيبه الامتحان (قراءة ذاتية ☺)

hazardous (الفئة الكبرى) → toxic, flammable, corrosive, reactive

hazardous يعني org أي اشي مواد خطرة — toxic ← السمية جزء من الـ hazardous

b) Toxic and dangerous organic compounds:

إذا كان combine يعني شايفين الطالوع المصانع على الصرف الصحي المنزلي هون ممكن يكون toxic org comp تدخل على الـ municipal ww

- Toxic and dangerous organic compounds, even though they usually do not represent a concern in domestic sewage, may be of concern in municipal wastewaters that receive industrial effluents.

للوم عنا مدن كبيرة بترمي الـ ww بتبعها على البحر بتعمل dilution هاد ها حرام

- When wastewaters containing toxic organic compounds are disposed of in the receiving water body without adequate treatment, severe damage may occur, both to the aquatic life and to human beings, who use it as a source of water supply.

إذا احنا ما اخذناه متأثرة ناخذه عن طريق الأكل سواء المحاصيل أو الكائنات البحرية يلي بنجيبها أو المي يلي بنشربها.

Persistant org Pollutants

- Most of these compounds are very slowly biodegraded, persisting in the environment for a long period.

بالكتمات الغير قابلة للتحلل هاي إذا وصلت أجسامنا سهل مفاصل وممكن الأم تنقله للجنين

مواد تركيزها بالـ ppm وفي مواد بالـ Piko (10^{12}) يعني حتى لو تركيز قليل بس بيدخل الجسم باستمرار مع الوقت راح يسبب أضرار.

- These compounds are able to penetrate the food chain and, even if they are not detectable in the receiving body, they may be present in large quantities in the higher trophic levels, owing to their bioaccumulation characteristics.

- Besides, since wastewaters have a complex composition and normally contain more than one organic pollutant, synergistic effects may take place (the combined effect may be higher than the sum of the individually exerted effects).

قوة جماعية — الاشي ككل تأثيره أكبر من مجموع أجزاءه.

معظم الـ org أي عضوية تتطاير ، جزء من معالجة المياه العادمة تستخدم فيها التهوية
بالتالي أي حدا حولين هاي الـ tanks راح ياخذ المواد ويستنشق ، وإذا المواد ... بالهواء
تجمع ستكاين بر ... راح ياخذ هاي المواد يلي هي مسببات ثابتة لا تتحلل.

- Several dangerous pollutants are volatile because of their low solubility, low molecular weight and high vapor pressure. Therefore, they may be transferred to the atmosphere in open units in the WWTP, such as aeration tanks, equalization tanks and clarifiers, and also pumping stations. If adequate control means are not taken, their volatilization represents a potential health risk to the population and workers who are frequently exposed to it.

- The structural integrity of the sewerage collection system is also affected, because many compounds are corrosive, inflammable and explosive (methanol, methyl-ethylketone, hexane, benzene, among others).

- Other pollutants are adsorbed and concentrated in the biological flocs in the treatment process, and might cause inhibition to sludge digestion or generate sludge with dangerous characteristics which, if not adequately disposed of, could contaminate groundwater.

- Consequently, the treatment plant effluent may still contain these pollutants and, when discharged into the receiving body, may cause damages to the aquatic life and human beings.

محطات معالجة المياه العادمة سواء صناعية
أو منزلية تتعامل ال ppm إذا كنا مواد جزء بالمليار ما بنقدر
نعالجها لهيك بترجع هاي المي تروح على السيول وعلى السدود وتدخل الـ
food chain مرة ثانية.

➢ **The main sources of organic compounds are:**

- Chemical and plastic industries,
- mechanical products,
- pharmaceutical industries,
- pesticide formulation,
- cast houses and steel industries,
- oil industry,
- laundries and lumber industries.

غير قابل للمعالجة لأن الفينول قاتل للبكتيريا

➢ **The most commonly found organic pollutants in industrial effluents are:**

Phenol, methyl chloride, 1,1,1-trichloroethane, toluene, ethyl benzene, trichloroethylene, tetrachloroethylene, chloroform, bis-2-ethyl-hexyl phthalate, 2,4-dimethyl phenol, naphthalene, butylbenzylphthalate, acrolein, xylene, cresol, acetophenone, methyl-sobutyl-acetone, diphenylamine, aniline and ethyl acetate.

تابع لسلايد 55

※ بال clarifier عادة بنعمل coagu. و flac وبطلع sludge من ال bottom لل clarifer سواء بالترسيب أو بال chemical بعد الهضم ، ال floc يلي هي particle تجمعت مع بعض وكبر حجمها ونزلت تحت (ترسبت) هاي مادة solid ممكن تعمل adsorbtion لل org فبنخص جزء منها بس إذا كانت هاي ال chemical سامة لل microorg بتعمل تثبيط لل treatment .Bio يعني عنا مشاكل بال sludge treat.

⇐ في concern عالمي انه ليش المستشفيات مربوطة على نظام الصرف الصحي المنزلي زي مستشفى الحسن مربوط مع الصرف الصحي المنزلي وبروح على السمرة وبتعالج دفي أشياء زي المواد لشفة ما بتعالج ، برضو مشاكلنا الأكبر يلي بيعنو مطاعيم للحيوانات (الطب البيطري) إذا كانو مشبوكين على الصرف الصحي أكلنا هوا ؛ لأنه هدول بيسموهم مواد كيميائية طارئة إذا دخلت جسمنا مشكلة كبيرة .

Relationship between load and concentration

- **Per capita load** represents the average contribution of each individual (expressed in terms of pollutant mass) per unit time.
  - A commonly used unit is grams per inhabitant per day (g/inhab.d).
  - For example, when the BOD contribution is 54 g/inhab.d, it is equivalent to saying that every individual discharges 54 grams of BOD on average, per day.
  - The influent load to a WWTP corresponds to the quantity of pollutant (mass) per unit time.

In this way, import relations are

$$\text{load (kg/d)} = \frac{\text{population (inhab)} \times \text{per capita load (g/inhab.d)}}{1000\ \text{(g/kg)}}$$

or

$$\text{load} = \text{concentration} \times \text{flow}$$

$$\text{load (kg/d)} = \frac{\text{concentration (g/m}^3) \times \text{flow (m}^3\text{/d)}}{1000\ \text{(g/kg)}}$$

Note: $g/m^3 = mg/L$

- **The concentration** of a wastewater can be obtained through the rearrangement of the same dimensional relations:

$$\text{concentration} = \text{load/flow}$$

$$\text{concentration (g/m}^3) = \frac{\text{load (kg/d)} \times 1000\ \text{(g/kg)}}{\text{flow (m}^3\text{/d)}}$$

Example

Calculate the total nitrogen load in the influent to a WWTP, given that:

- concentration = 45 mgN/L
- flow = 50 L/s

Solution:

Expressing flow in m^3/d, :

$$Q = \frac{50 \text{ L/s} \times 86400 \text{ s/d}}{1000 \text{ L/m}^3}$$

The nitrogen load is:

$$\text{load} = \frac{45 \text{ g/m}^3 \times 4320 \text{ m}^3\text{/d}}{1000 \text{ g/kg}} = 194 \text{ kgN/d}$$

b) In the same works, calculate the total phosphorus concentration in the influent, given that the influent load is 40 kgP/d.

$$\text{concentration} = \frac{40 \text{ kg/d} \times 1000 \text{ g/kg}}{4320 \text{ m}^3\text{/d}} = 9.3 \text{ gP/m}^3 = 9.3 \text{ mgP/L}$$

Population equivalent

- Population equivalent (PE) is an important parameter for characterizing industrial wastewaters.
- PE reflects the equivalence between the polluting potential of an industry (commonly in terms of biodegradable organic matter) and a certain population, which produces the same polluting load.
- For instance, when an industry is said to have a population equivalent of 20,000 habitants, it is the equivalent to saying that the BOD load of the industrial effluent corresponds to the load generated by a community with a population of 20,000 inhabitants.
- The formula for the calculation of population equivalent based on BOD is:

$$\text{PE (population equivalent)} = \frac{\text{BOD load from industry (kg/d)}}{\text{per capita BOD load (kg/inhab.d)}}$$

- In the case of adopting the value frequently used in the international literature for the per capita BOD load of 54 gBOD/inhab.d, PE may be calculated by:

$$\text{PE (population equivalent)} = \frac{\text{BOD load from industry (kg/d)}}{0.054 \text{ (kg/inhab.d)}}$$

النقطة الثالثة سلايد 60

مثلاً المدينة الصناعية في سحاب التلوث الناتج عنها يعادل تلوث ناجم عن تجمع سكاني منه 20 000 شخص (بدنا نشوف المنطقة الصناعية التلوث الطالع منها كم يعادل هذا التلوث من الأشخاص) ∴ 6 كنا منطقة صناعية التلوث الطالع منها ك BOD يعادل التلوث لـ ww الناجم عن نشاطات 20 000 شخص هذا بلغة الـ BOD eff الناجم عن هاي المنطقة الصناعية.

Example

Calculate the Population Equivalent (PE) of an industry that has the following data:

- flow = 120 m^3/d
- BOD concentration = 2000 mg/L

Solution:

The BOD load is:

$$\text{load} = \text{flow} \times \text{concentration} = \frac{120\ m^3/d \times 2000\ g/m^3}{1000\ g/kg} = 240\ \text{kgBOD/d}$$

The Population Equivalent is:

$$PE = \frac{\text{load}}{\text{per capita load}} = \frac{240\ kg/d}{0.054\ kg/hab.d} = 4{,}444\ \text{inhab}$$

Thus, the wastewater from this industry has a polluting potential (in terms of BOD) equivalent to a population of 4,444 inhabitants.

…aracteristics of the wastewater from some industries

	Activity	Unit of production	Specific wastewater flow (m^3/unit)	Specific BOD load (kg/unit)	BOD population equivalent [inhab/(unit/d)]	BOD concentration (mg/L)
	Canning (fruit/vegetables)	1 t processed	4–50	30	500	600–7,500
	Pea processing	1 t processed	13–18	16–20	85–400	300–1,350
	Tomato processing	1 t processed	4–8	1–4	50–185	450–1,600
	Carrot processing	1 t processed	11	18	160–390	800–1,900
	Potato processing	1 t processed	7.5–16	10–25	215–545	1,300–3,300
	Citrus fruit processing	1 t processed	9	3	55	320
	Chicken meat processing	1 t produced	15–60	4–30	70–1600	100–2400
	Beef processing	1 t processed	10–16	1–24	20–600	200–6,000
	Fish processing	1 t processed	5–35	3–55	300–2300	2,700–3,500
	Sweets / candies	1 t produced	5–25	2–8	40–150	200–1,000
	Sugar cane	1 t produced	0.5–10	2.5	50	250–5,000
	Dairy (without cheese)	1000 L milk	1–10	1–5	20–100	300–5,000
	Dairy (with cheese)	1000 L milk	2–10	5–40	100–800	500–8,000
	Margarine	1 t produced	20	30	500	1,500
	Slaughter house	1 cow / 2.5 pigs	0.5–3	0.5–5	10–100	1,000–5,000
	Yeast production	1 t produced	150	1100	21,000	7,500
…ed animal …ng	Pigs	live t.d	0.2	2	35–100	10,000–50,000
	Dairy cattle (milking room)	live t.d	0.02–0.08	0.05–0.10	1–2	370–2,300
	Cattle	live t.d	0.15	1.6	65–150	10,000–50,000
	Horses	live t.d	0.15	4–8	65–150	20,000–50,000
	Poultry	live t.d	0.38	0.9	15–20	2,000–3,000
-alcohol	Alcohol distillation	1 t cane processed	60	220	4,000	3,500
s	Brewery	1 m^3 produced	5–20	8–20	150–350	500–4,000
	Soft drinks	1 m^3 produced	2–5	3–6	50–100	600–2,000
	Wine	1 m^3 produced	5	0.25	5	

	Wool	1 t pr[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Rayon	1 t produced	25–60	30	550	[illegible]
	Nylon	1 t produced	100–150	45	800	350
	Polyester	1 t produced	60–130	185	3,700	1,500–3,000
	Wool washing	1 t produced	20–70	100–250	2,000–4,500	2,000–5,000
	Dyeing	1 t produced	20–60	100–200	2,000–3,500	2,000–5,000
	Textile bleaching	1 t produced	–	16	250–350	250–300
er and tanneries	Tanning	1 t hide processed	20–40	20–150	1,000–3,500	1,000–4,000
	Shoes	1000 pairs produced	5	15	300	3,000
nd paper	Pulp	1 t produced	15–200	30	600	300
	Paper	1 t produced	30–270	10	100–300	
	Pulp and paper integrated	1 t produced	200–250	60–500	1,000–10,000	300–10,000
cal industry	Paint	1 employee	0.110	1	20	10
	Soap	1 t produced	25–200	50	1000	250–2,000
	Petroleum refinery	1 barrel (117 L)	0.2–0.4	0.05	1	120–250
	PVC	1 t produced	12.5	10	200	800
etallic industry	Glass and by-products	1 t produced	50	–	–	–
	Cement (dry process)	1 t produced	5	–	–	–
orks	Foundry	1 t pig iron produced	3–8	0.6–1.6	12–30	100–300
	Lamination	1 t produced	8–50	0.4–2.7	8–50	30–200

ata not filled in (-) means non-significant data or data not obtained; t = metric ton (1000 kg)
us cases the water consumption is considered equal to the wastewater flow produced
: CETESB (1976), Braile and Cavalcanti (1977), Arceivala (1981), Hosang & Bischof (1984), Salvador (1991), Wentzel (without date), Mattos (1998)

xample

(مسلخ) laughterhouse processes 30 heads of cattle, Estimate the characteristics of the effluent.
opting an average value of 3.0 kgBOD/cattle slaughtered

ال range بالجدول 0.5→3 شو آخذ؟ حسب السؤال اذا حكا آخذ ave ave (0.5+3)/2 ، اذا حكا max آخذ ال 3 ، اذا حكا min باخذ ال 0.5

) **BOD load produced**

أعطانا ال load مباشرة لوما أعطانا بدي اروح لل table وبا باخذ ال ave يا باخذ الأعلى

$$\text{cows: } \frac{3\text{ kgBOD}}{\text{cow}} \cdot \frac{30\text{ cow}}{\text{d}} = 90\text{ kgDBO/d}$$

بدنا نطلع ال load per day

) **Population Equivalent (PE)**

$$PE = \frac{\text{BODload}}{\text{per capita BODload}} = \frac{90\text{ kgDBO/d}}{0.054\text{ kgDBO/inhab.d}} = 1.777\text{ Inhab}$$

→ ال 30 بقرة الموجودين بهاد المسلخ لما بدي أذبحهم وأطلعهم للسوق ال ww الطالع من هاي ال process وال load ك BOD بيعادل التلوث الناتج عن 1777 شخص في اليوم :

Wastewater flow

adopting an average value of 2.0 m³/cattle slaughtered
or for 2.5 pigs slaughtered): ← من الجدول

$$\text{cows: } \frac{2.0\text{ m}^3}{\text{cow}} \cdot \frac{30\text{ cow}}{\text{d}} = 60\text{ m}^3/\text{d}$$

) **BOD concentration in the wastewater**

$$\text{concentration} = \frac{\text{load}}{\text{flow}} = \frac{90\text{ kgDBO/d}}{100\text{ m}^3/\text{d}} \cdot 1000\text{ g/kg} = 1,500\text{ g/m}^3$$

$$= 1,500\text{ mg/L}$$

* بالإمتحان بجيب أكثر من case مع بعض من الجدول مثلاً Food و Paper وهيك ، ومعطى معلومات وبطلع load و flow ولكل هاي الأشياء وبسألنا من كل هدول ال cases جد بش الكون بيعادل التلوث الناتج من كم شخص ، يعني بحسب ال load وال PE لكل case كلها ونجمعهن كل ال PE مع بعض هيك بتكون كلها هاد التلوث بيعادل التلوث عن كم شخص وبرجع لطلب ال overall load برجع نطلع لكل case وبعدين بنجمع :

Conversion processes of organic and inorganic matter

Bio chemical

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1. substrate.
2. solids.
3. Biomass.
4. microbial cells.

Characterization of substrate and solids

- The microbial action starts in the sewerage system and reaches its maximum in the sewage treatment works.
- In treatment plants, the conversion of organic matter to more oxidized or reduced forms takes place.
- Under aerobic conditions there is the oxidation of the organic matter (carbonaceous matter), that is, the organic carbon is converted into its most oxidized form (CO_2: carbon in the oxidation state of 4+).
- Under anaerobic conditions, the conversion reaction of the organic matter leads to the most oxidized form of carbon (CO_2), but also to its most reduced form (CH_4: carbon with an oxidation state of 4−).
- In sewage treatment under aerobic conditions, the conversion of ammonia (nitrogenous matter) into more oxidized forms of nitrogen (NO^{3-}) can take place, and, under anoxic
- conditions, the subsequent conversion of these to reduced forms (N^2) can also happen.

nitrification rxn

Characterisation of the carbonaceous matter

The carbonaceous matter (based on organic carbon) present in the wastewater to be treated can be divided in terms of biodegradability into

- The **inert organic matter** (non-biodegradable) passes through the treatment system without changing its form. Two fractions can be identified with respect to the physical state:
  - **Soluble.** The non-biodegradable soluble organic matter does not undergo transformations and leaves the system with the same concentration that it entered.
  - **Particulate.** The non-biodegradable particulate organic matter (suspended) is involved by the biomass and is removed together with the sludge (excess sludge or the sludge that settles at the bottom of the reactors).
- The **biodegradable organic matter** is changed in its passage through the system. Two fractions can be identified, related to the biodegradability, which is also dependent on the physical state:
  - **Rapidly biodegradable.** This fraction is usually in a soluble form and consists of relatively simple molecules.
  - **Slowly biodegradable.** This fraction is usually in a particulate form, although slowly biodegradable soluble organic matter may be present. The slowly-biodegradable matter consists of relatively complex molecules that are not directly used by the bacteria. For this to occur, the conversion into soluble matter is necessary, through the action of extracellular enzymes. This conversion mechanism, called hydrolysis, does not involve the use of energy, but results in the delay in the consumption of the organic matter.

Characterisation of the nitrogenous matter

- **The inorganic nitrogen** is represented by ammonia, either in its free form (NH_3) or in its ionized form (NH^{+4}). Ammonia is present in the influent sewage because the hydrolysis and ammonification reactions have already started in the sewerage system.
- **The organic nitrogen** is divided in a similar form to the carbonaceous matter, as a function of the biodegradability: (a) inert and (b) biodegradable.
  - **Inert.** The inert fraction is divided into two fractions, according to the physical state:
    - Soluble. This part is usually negligible and does not need to be considered.
    - Particulate. This part is associated with the non-biodegradable carbonaceous organic matter, being involved by the biomass and removed with the excess sludge.
  - **Biodegradable.** The biodegradable fraction can be subdivided into the following three components:
    - Rapidly biodegradable. The rapidly-biodegradable organic nitrogenous matter is in a soluble form and is converted by heterotrophic bacteria into ammonia, through the process of ammonification.
    - Slowly biodegradable. The slowly-biodegradable organic nitrogenous matter is in a particulate form, being converted into a soluble form (rapidly biodegradable) through hydrolysis. This hydrolysis occurs in parallel with the hydrolysis of the carbonaceous matter.
    - Ammonia. Ammonia (inorganic nitrogen) results from the hydrolysis and ammonification processes described above. Ammonia is used by heterotrophic and autotrophic bacteria.

Suspended and attached biomass growth

- Dispersed growth: the biomass grows in a dispersed form in the liquid medium, without any supporting structure Systems:
  - stabilization ponds and variants
  - activated sludge and variants
  - upflow anaerobic sludge blanket reactors (receiving wastewaters containing suspended solids)

- Attached growth: the biomass grows attached to a support medium, forming a biofilm. The support medium can be immersed in the liquid medium or receive continuous or intermittent liquid discharges. The support medium can be a solid natural (stones, sand, soil) or artificial (plastic) material or consist of an agglomerate of the biomass itself (granules). Systems with a solid support for attachment:
  - trickling filters
  - rotating biological contactors
  - submerged aerated biofilters
  - anaerobic filters
  - land disposal systems

Representation of the biomass

- Not all the solids mass participates in the conversion of the organic substrate, as there is an inorganic fraction that does not play an active role in biological treatment.

- The unit of mass of the microbial cells is normally expressed in terms of suspended solids (SS), since the biomass consists of solids that are suspended in the reactor (in the case of dispersed growth).

- The biomass is frequently expressed in terms of volatile suspended solids (VSS). These represent the organic fraction of the biomass – the organic matter can be volatized, that is, converted into gas by combustion (oxidation).

- The volatile suspended solids can be divided into an active and an inactive fraction. The active fraction is that which has the real participation in the conversion of the substrate.

Rotating Biological Contactors (RBCs) :-

↓

cylinder وبتلف ، جزء من لفتها بدخل بالمي وجزء بالهواء بالتالي هو تفاعل في نوع من التهوية كلما لفت ال cylinder ودخلت بالمي راح ياخذ من ال org matter على ال surface تبعتها وتطلع بتهوى وبرجع على المي وهيك بتصير عمليات ال conversion على السطح هاد ال cylinder .

Submerged aerated biofilters :-

↓

عندي تهوية لـ biofilters يلي هو أشبه ما يكون للـ Packed bed عمليات ال absor. بكون عندي trays مجزوءة هاي التجزئة حتى ال liq يمر منها ومن ال bottom بكون في هواء طالع بالتالي عندي تهوية وعلى ال mesh او ال screen بكون ال org matter مع البكتيريا بتعمل عمليات هضم

* كل ال Attached growth بدها surface area ، كلما زادت ال surface area كلما ال contact بين ال reactants زاد يلي هي ال Bio content والبكتيريا كلما أعطيناهم مساحة ليلتقوا ويصير تفاعل كلما كان ال Kinetics أسرع وال conversion ᶜ yeild أعلى ما يمكن .

Representation of the organic matter/ Substrate

- Influent substrate So (influent BOD_5 or COD). Represents the total BOD_5 (soluble BOD + particulate BOD) or total COD (soluble COD + particulate COD) influent to the biological reactor.
  - Even in systems with primary sedimentation, around 1/3 of the suspended solids are not removed in this stage and enter the biological reactor.
  - In the reactor, suspended solids are adsorbed by the biomass and are converted into soluble solids by hydrolysis mechanisms, after which they undergo the conversion reactions. Therefore, in the influent to the reactor, the soluble substrate as well as the particulate substrate must be computed as the influent substrate to be removed.
- Effluent substrate S (effluentBOD_5 or COD). Represents the effluent soluble BOD_5 or soluble COD from the reactor.
  - Even though the effluent from the reactor could contain a high concentration of suspended solids (biological solids that compose the biomass), these solids are largely removed in the subsequent settling stage, when existent (e.g. secondary sedimentation tank or sedimentation lagoons).
  - The quality of the final effluent from the treatment plant depends on the (a) soluble BOD or COD: reactor performance; (b) particulate BOD or COD: performance of the final settling unit (when existent).

Conversion of the carbonaceous matter

Aerobic conversion

- Stabilization of the organic matter (conversion to inert products, such as carbon dioxide and water).
- Utilization of oxygen.
- Production of carbon dioxide.
- Release of energy.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{Energy}$$

organic matter

$$C_xH_yO_z + \frac{1}{4}(4x + y - 2z)\,O_2 \rightarrow x\,CO_2 + \frac{y}{2}H_2O$$

Anaerobic conversion

- Non-exclusivity of the oxidation. The carbon of CO_2 is present in its highest state of oxidation (+4). However, the opposite occurs with CH_4, in which the carbon is in its most reduced state (−4), subsequently being able to be oxidized (for example, by combustion – methane is inflammable).
- No utilization of oxygen.
- Production of methane and carbon dioxide.
- Release of energy (less than in aerobic respiration).

$$\underset{\text{organic matter}}{C_6H_{12}O_6} \longrightarrow 3\,CH_4 + 3\,CO_2 + \text{Energy}$$

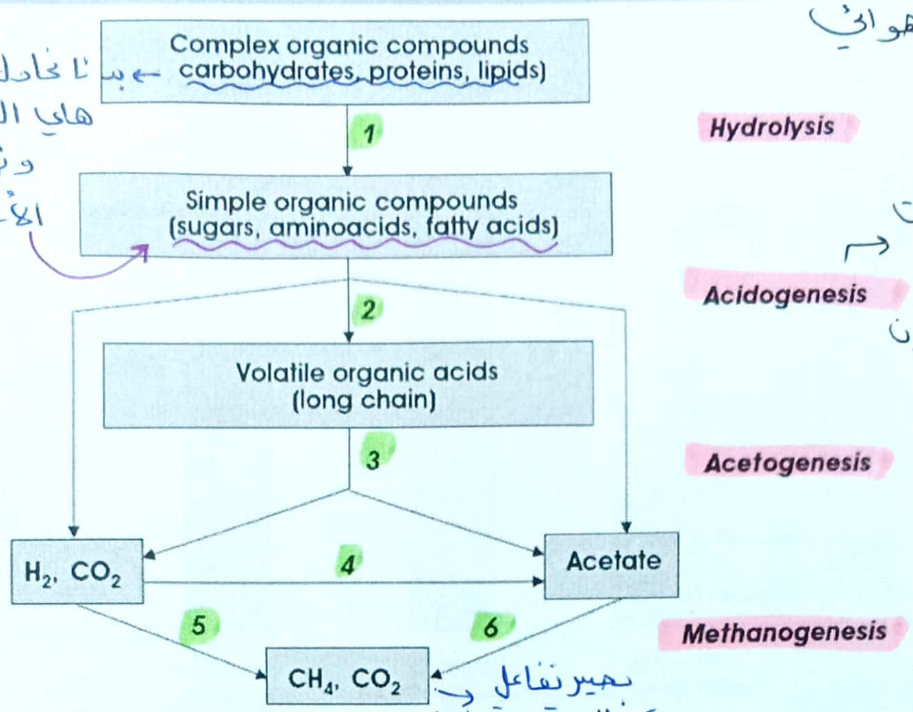
$$C_xH_yO_z + \frac{4x-y-2z}{4}H_2O \rightarrow \frac{4x-y+2z}{8}CO_2 + \frac{4x+y-2z}{8}CH_4$$

The anaerobic conversion occurs in two stages:

- Acidogenic phase: conversion of the organic matter into organic acids by acidogenic organisms (acid-forming organisms). In this stage, there is only the conversion of organic matter, but no removal.
- Methanogenic phase: conversion of the organic acids into methane, carbon dioxide and water by methanogenic organisms (methane-forming organisms). The organic matter is converted again, but because CH_4 is transferred to the atmosphere, there is the removal of the organic matter.

Before the acidogenesis stage, the complex organic compounds (carbohydrates proteins, and lipids) need to be converted into simple organic compounds, through the mechanism of hydrolysis.

Metabolic sequences and microbial groups



1, 2: hydrolytic fermentative organisms
3: hydrogen-producing acetogenic organisms
4: hydrogen-consuming acetogenic organisms
5: hydrogen-utilising methanogenic organisms
6: acetoclastic methanogenic organisms

Conversion of nitrogenous matter

Oxidation of ammonia (nitrification)

- In domestic sewage, the organic nitrogen is converted into ammonia, through the process of **ammonification**. This process does not change the quantity of nitrogen (TKN) in the wastewater, has no consumption of oxygen, and starts in the sewerage system itself, continuing in the primary and biological treatment units. In the end of the treatment, the quantity of organic nitrogen is small.

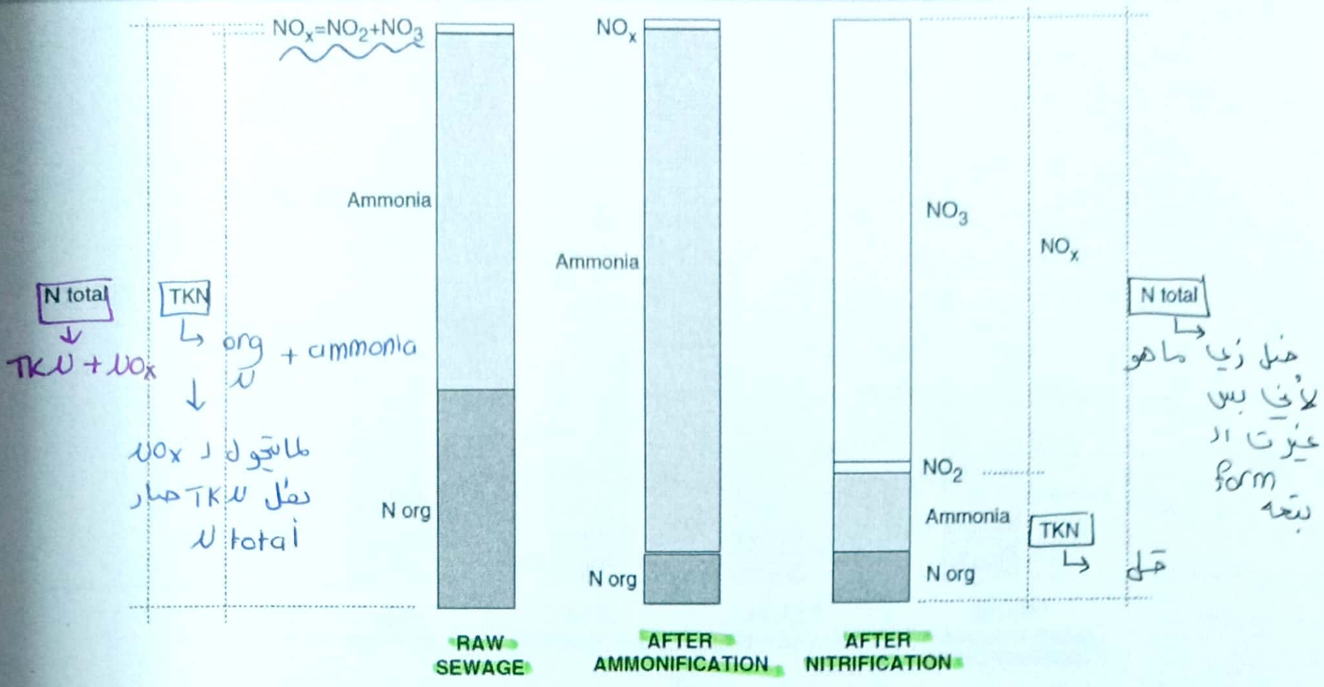
- An important oxidation reaction that occurs in some wastewater treatment processes is the **nitrification**, in which the ammonia is transformed into nitrites and these nitrites into nitrates. Only some treatment processes are able to support a significant nitrification, because of their capacity of maintaining sufficient concentrations of the nitrifying bacteria.

$$2NH_4^+ + 3O_2 \xrightarrow{Nitrosomonas} 2NO_2^- + 4H^+ + 2H_2O$$

$$2NO_2^- + O_2 \xrightarrow{Nitrobacter} 2NO_3^-$$

Global reaction
$$NH_4^+ + 2O_2 \longrightarrow NO_3^- + 2H^+ + H_2O$$

Distribution of nitrogen in a treatment system with nitrification



- The oxidized forms of nitrogen (nitrites and nitrates) are collectively called NOx.
- It is seen that with nitrification there is no removal of nitrogen (total nitrogen remains the same), but only conversion of the nitrogen forms.

Reduction of nitrate (denitrification)

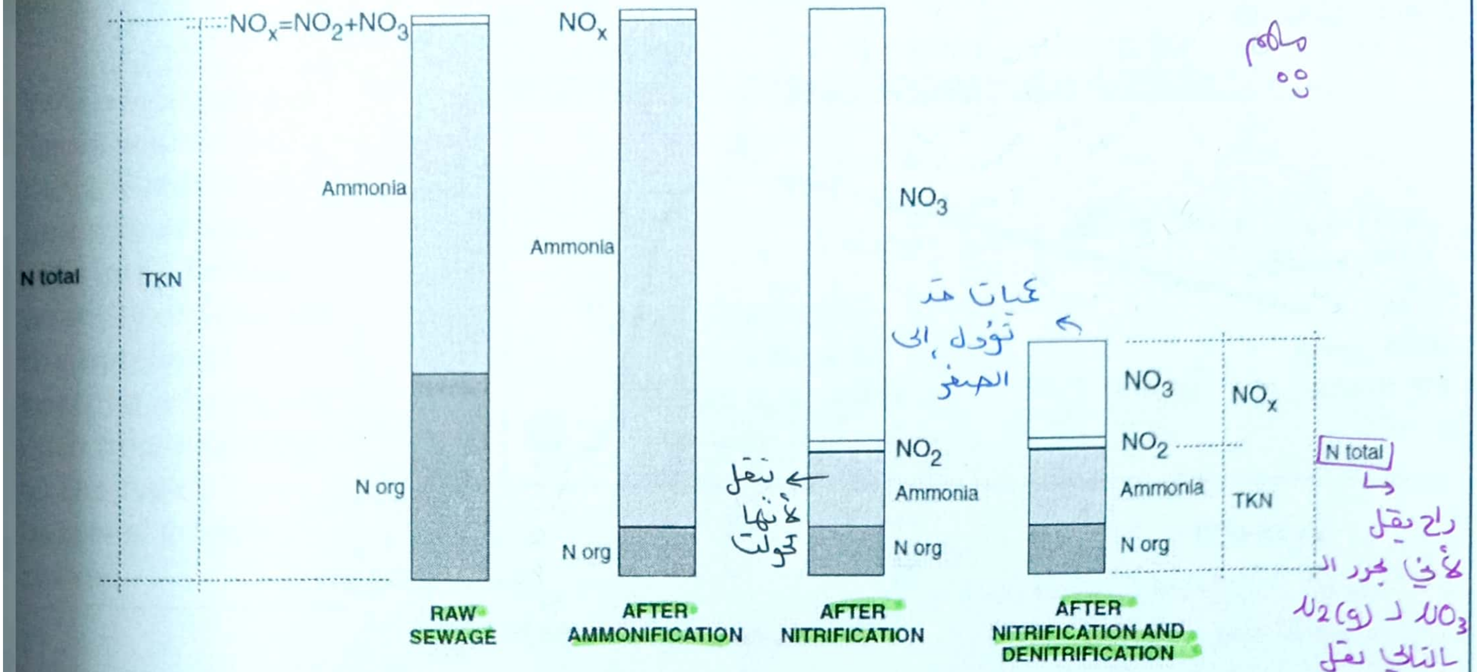
- In anoxic conditions (absence of oxygen, but in the presence of nitrates), the nitrates are used by heterotrophic organisms as an electron acceptor instead of oxygen. In this process, called denitrification, nitrate is reduced to nitrogen gas:

$$2\,NO_3^- + 2\,H^+ \longrightarrow N_2 + 2.5\,O_2 + H_2O$$

With the denitrification reaction, the following points should be noted:

- Economy of oxygen (the organic matter can be stabilized in the absence of oxygen)
- Consumption of H+, implying an economy of the alkalinity and an increase in the buffer capacity of the medium

Distribution of nitrogen in a treatment system with nitrification and denitrification

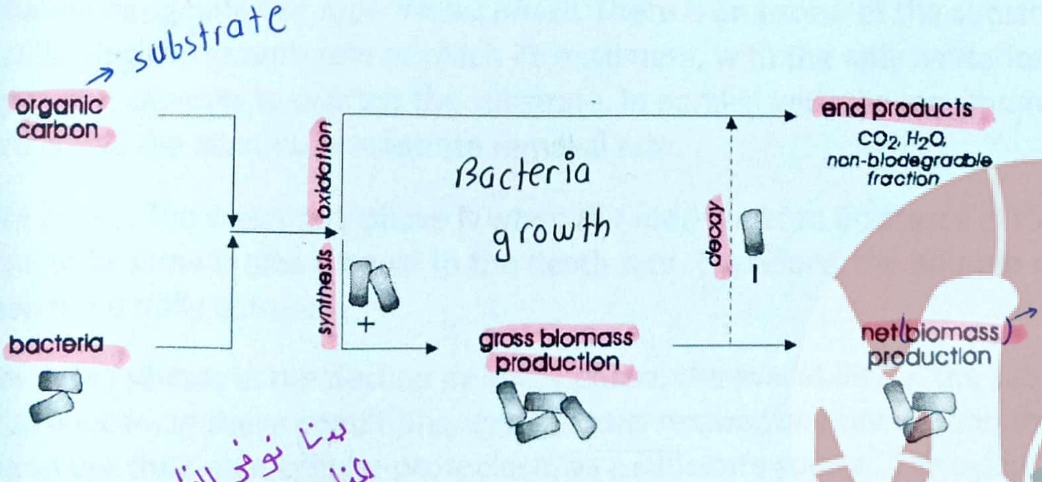


Besides the conversion in the forms of nitrogen, there is also the removal of nitrogen (total nitrogen is decreased). In other words, denitrification leads to an effective removal of nitrogen from the liquid, corresponding to the nitrate that is converted to nitrogen gas, which escapes to the atmosphere.

Principles of Bacterial Growth

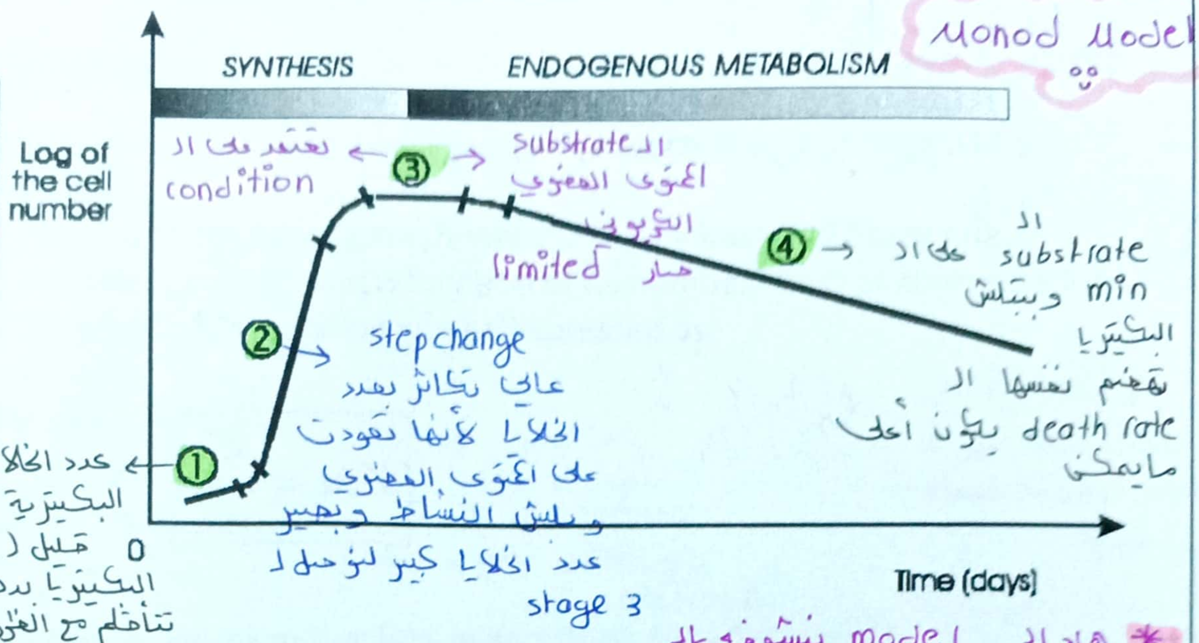
Bacterial-growth curve

- The main reproduction mode for bacteria is by binary fission, in which, when the cell reaches a certain size, it splits into two cells, which will subsequently generate four new cells and so on.
- Thus, after n divisions the number of cells formed is 2^n



Typical bacterial-growth curve

When inoculating a liquid volume with a certain initial quantity of bacterial cells and a limited quantity of substrate, the number of bacteria will progress with time according to the typical bacterial growth-curve



1. Lag or adaptation phase
2. Logarithmic phase (exponential growth)
3. Stationary phase (growth = decline)
4. Decline or death phase (exponential decay)

Bacterial-growth phases

Lag phase. The lag phase is a period for enzymatic adaptation of the bacteria to the new substrate supplied. This phase can be reduced in the case of typical domestic sewage, in which the bacteria have already acquired the necessary enzymatic equipment.

Exponential-growth phase. In the exponential growth phase the cells divide themselves at a constant rate. Plotted on a logarithmic scale, the number of cells grows linearly, justifying the alternative designation of *logarithmic phase*. There is an excess of the substrate in the medium, allowing the growth rate to reach its maximum, with the only limitation by the microorganisms' capacity to process the substrate. In parallel with the maximum growth rate, there is also the maximum substrate removal rate.

Stationary phase. The stationary phase is when the food starts to be scarce in the medium, and the bacterial growth rate is equal to the death rate. Therefore, the number of cells is maintained temporally constant.

Decline or decay phase. In the decline or decay phase, the availability of the substrate in the medium is reduced. In these conditions, *endogenous respiration* prevails, and the bacteria

Kinetics of bacterial growth

Specific gross bacterial growth

- The bacterial growth can be expressed as a function of the bacteria concentration at a given time in the reactor.
- The net growth rate is equal to the gross growth rate minus the bacterial decay rate.
- The growth rate of a bacterial population is a function of its number, mass or concentration at a given time. Mathematically, this relation can be expressed as:

$$\frac{dX}{dt} = \mu . X$$

where:

X = concentration of the microorganisms in the reactor, SS or VSS (g/m^3)

μ = specific growth rate (d^{-1})

t = time (d)

- The bacterial growth is a function of the availability of the substrate in the medium. When the substrate is present at a low concentration, the growth rate is proportionally low.
- In sewage treatment, the carbonaceous matter is usually the limiting growth factor.

- The specific growth rate μ must be therefore expressed as a function of the substrate concentration. Monod presented this relation according to the following empirical formula:

$$\mu = \mu_{max} \cdot \frac{S}{K_s + S}$$

where:

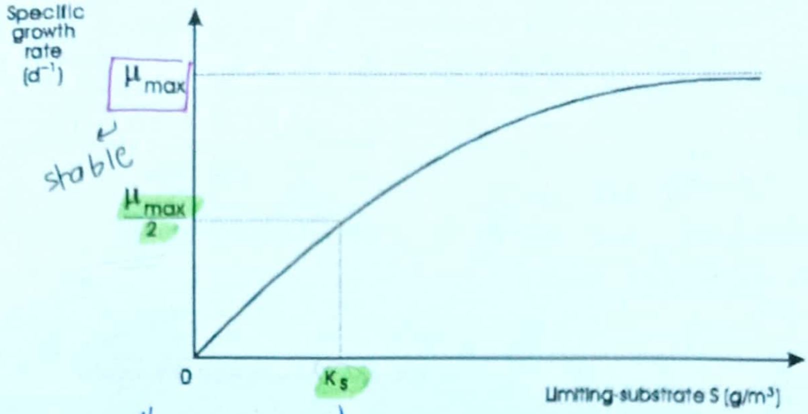
μ_{max} = maximum specific growth rate (d^{-1})

S = concentration of the limiting substrate or nutrient (g/m^3)

K_s = half-saturation coefficient, which is defined as the substrate concentration for which $\mu = \mu_{max}/2$ (g/m^3)

Two constants are used to describe the growth rate:

- μ (mg/L) is the maximum growth rate constant (the rate at which the substrate concentration is not limiting)
- K_s is the half-saturation constant (mg/L) (i.e., concentration of S when μ = $\mu/2$



لـ نحسب μ_{max} ونقسمه على 2 ونتقاطع مع ال curve وبنزل على السينات وبنطلع Ks ، أو إذا المعروفة هي ال Ks بنرجع رجوع لنوصل للـ μ_{max}

Values of K_s and μ_{max} in the following ranges have been reported:

- *Aerobic treatment (Metcalf & Eddy, 1991):*

* بجيب سؤال نقارن بينهم مين أكبر شو المهم وهيك

μ_{max} = 1.2 to 6 d^{-1}

K_s = 25 to 100 mg BOD_5/l
or
K_s =15 to 70 mgCOD/l

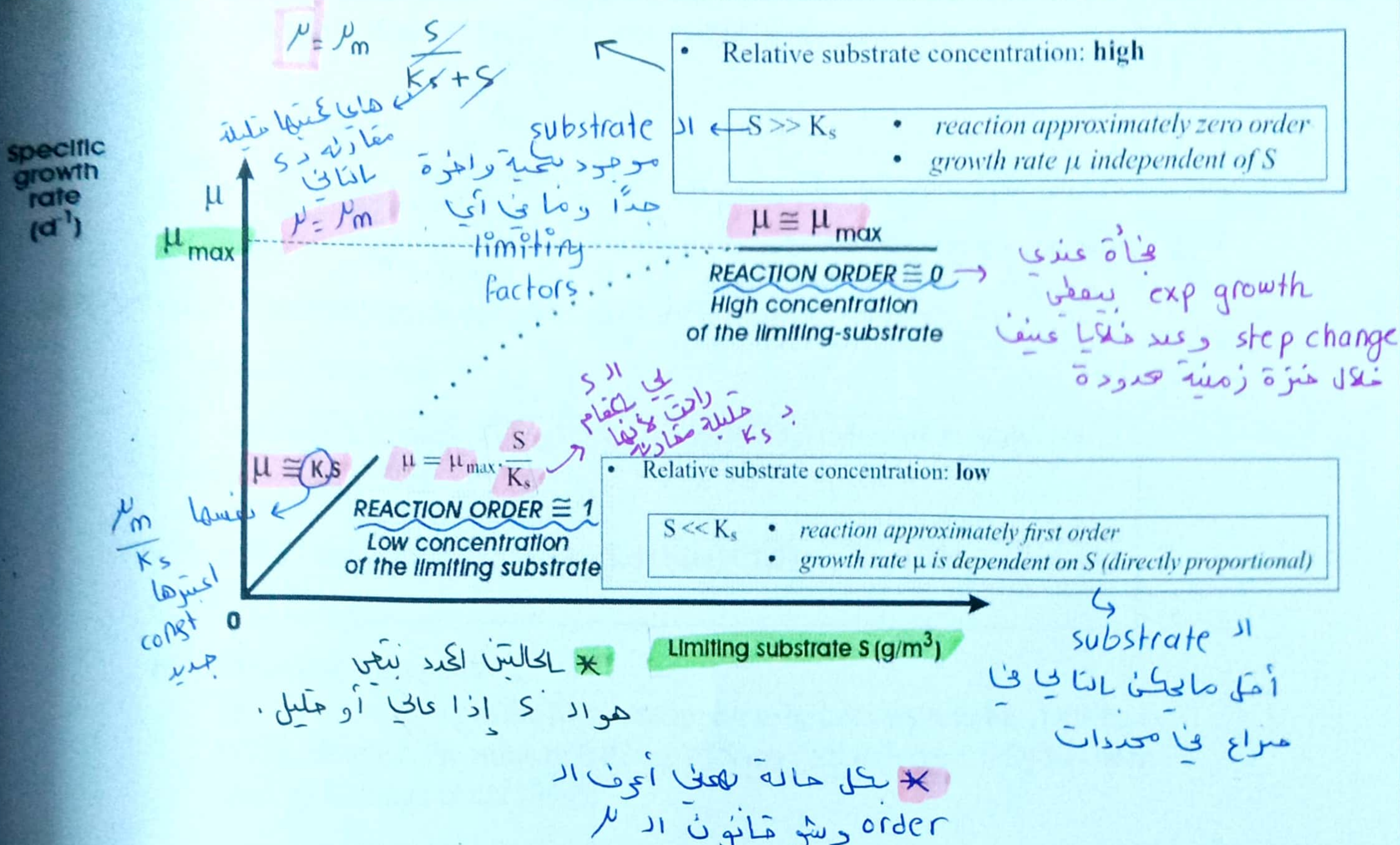
- *Anaerobic treatment (van Haandel and Lettinga, 1994; Chernicharo, 1997):*

μ_{max} = 2.0 d^{-1} (acidogenic organisms)
μ_{max} = 0.4 d^{-1} (methanogenic organisms)
μ_{max} = 0.4 d^{-1} (combined biomass)

overall

K_s ≈ 200 mgCOD/l (acidogenic organisms)
K_s ≈ 50 mgCOD/l (methanogenic organisms)

Extreme conditions in the saturation reaction (Monod kinetics)



Example

Express μ as a function of μ_{max} for the following conditions:

- domestic sewage; S = 300 mg/L (adopt K_s = 40 mg/L)

↳ $S > K_s$ بالتالي zero order

Domestic sewage (S = 300 mg/L)
From Equation 3.13:

$$\mu = \mu_{max} \cdot \frac{S}{K_s + S} = \mu_{max} \cdot \frac{300}{40 + 300} = 0.88\mu_{max}$$

Hence, $\mu = 0.88\ \mu_{max}$

In these conditions, in which S is large in comparison with K_s, the growth rate μ is close to μ_{max}. There is a great availability of the limiting nutrient and the population presents a high growth rate. The reaction is approximately zero order. This situation is not very frequent in the treatment of domestic sewage and occurs at the head of a plug-flow reactor, where the substrate concentration is still high.

Bacterial decay

- The decay rate can be expressed as a first-order reaction:

$$\frac{dX}{dt} = -K_d.X$$

where:

K_d = endogenous respiration coefficient, or bacterial decay coefficient (d^{-1})

- For typical domestic sewage, K_d varies in the following ranges:
  - *Aerobic treatment:*

K_d = 0.04 to 0.10 mgVSS/mgVSS.d (base: BOD_5) (Metcalf & Eddy, 1991; von Sperling, 1997)
or
K_d = 0.05 to 0.12 mgVSS/mgVSS.d (base: COD) (EPA, 1993; Orhon and Artan, 1994)

  - *Anaerobic treatment:*
    The values available in the literature appear to be not very reliable (Lettinga, 1995), although the value of 0.02 mgVSS/mgVSS.d (base: COD) has been cited by Lettinga et al (1996).

Net bacterial growth

$$\frac{dX}{dt} = \mu.X - K_d.X$$

$$\frac{dX}{dt} = \mu_{max}.\frac{S}{K_s + S}.X - K_d.X$$

Gross biological solids production

- Bacterial growth, that is, biomass production, can be also expressed as a function of the substrate used.
- The greater the substrate assimilation, the greater the bacterial growth rate.
- This relation can be expressed as:

Growth rate = Y (Substrate removal rate)

$$\frac{dX}{dt} = Y\frac{dS}{dt}$$

where:

X = concentration of microorganisms, SS or VSS (g/m^3)

Y = yield coefficient, or coefficient of biomass production; biomass (SS or VSS) produced per unit mass of substrate removed (BOD or COD) (g/g)

S = concentration of BOD_5 or COD in the reactor (g/m^3)

t = time (d)

- The value of Y can be obtained in laboratory tests with the wastewater to be treated.
- For the biological treatment of domestic sewage, the Y value for the bacteria responsible for the removal of the carbonaceous matter varies between:

  - *Aerobic treatment:*

Y = 0.4 to 0.8 g VSS/g BOD_5 removed (Metcalf & Eddy, 1991)
or
Y = 0.3 to 0.7 g VSS/g COD removed (EPA, 1993; Orhon and Artan, 1994)

  - *Anaerobic treatment:*

Y ≈ 0.15 gVSS/gCOD (*acidogenic bacteria*) (van Haandel and Lettinga, 1994)
Y ≈ 0.03 gVSS/gCOD (*methanogenic archaea*) (van Haandel and Lettinga, 1994)
Y ≈ 0.18 gVSS/gCOD (*combined biomass*) (Chernicharo, 1997)

Net solids production

→ بنحكي بلغة ال Biomass

When including the endogenous respiration, the net solids production becomes:

$$\frac{dX}{dt} = Y\frac{dS}{dt} - K_d.X$$

→ ما الى دخل فيها لأنه تهمنم بعض

تعبيرنا عن ال growth بال substrate بدل ال dX

Substrate removal rate

The substrate removal is associated with the gross biomass growth

$$* \quad \frac{dS}{dt} = \frac{1}{Y}.\frac{dX}{dt}$$

Substituting dX/dt for μ.X

اعادة ترتيب

$$\frac{dS}{dt} = \frac{\mu}{Y}.X$$

or (expressing μ)

$$\frac{dS}{dt} = \mu_{max}.\frac{S}{K_s + S}.\frac{X}{Y}$$

* طبيعة الأسئلة اما كيرفات نطلع منها جنم ، اما values نعوضها بالمعادلات ونحسب ونعبر اذا هو zero order ولا first order ، كيف نعبر عن العلاقة بين ال S removel وال bacterial growth وال net equ.

Activated sludge sys

Modeling of ASS (CSTR): Substrate and Biomass Mass Balance

aeration tank عبارة عن
Bio chem rxn بصير فيه
secondary clarifier بتتبع
physical sys يلي هو
settling بس بصير فيه
أول reactor بكون tank
لأنه فيه Bioconversion
والثاني settling tank
شغلنا كله راح يصير بال aeration
tank لا دخلنا ال sec. عشان ناخذ من ال
bottom ← stream ونعمل recycle لل reactor

Prof. Motasem Saidan

m.saidan@gmail.com

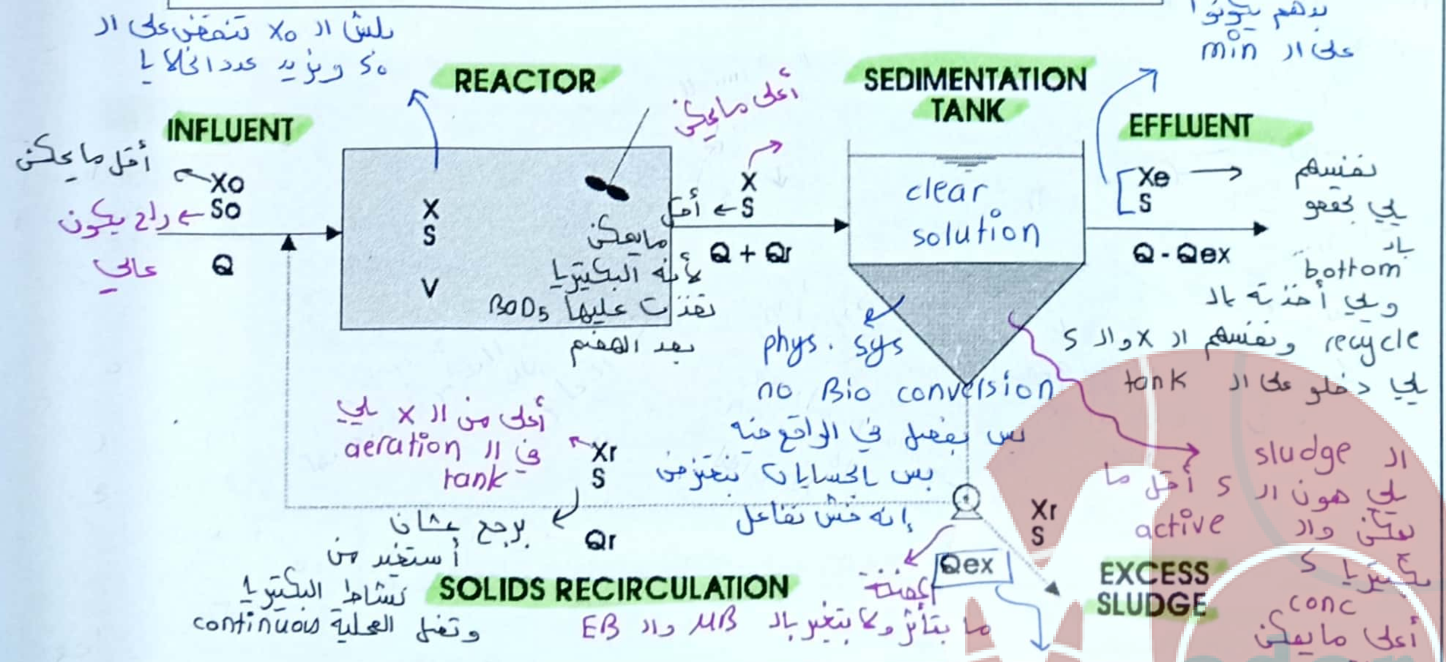
* يلي بترسب بال bottom
بال sec. clarifier بكون
active لهيك بنرجعه على ال
tank لأنه همي ال growth
بكون أول ماكنى لتصير عملية الهضم لل
substrate

Activated Sludge System Design

- One of the characteristics of the ideal complete-mix reactor (CSTR) is that the effluent leaves with the same concentration as in the liquid in any part of the reactor. This implies that the value of S and X are the same in the reactor, as well as in the effluent.
- X is the concentration of the solids. In the reactor, these solids are mainly biological solids, represented by the biomass (microorganisms) produced in the reactor at the expense of the available substrate.
- In contrast, in the influent to the reactor, the solids are those present in the wastewater, and the presence of biological solids is frequently neglected in the general mass balance. For simplicity, it is usually considered that $X_0 = 0$ mg/L (although this assumption does not apply in all situations).
- Two mass balances can be done, one for the substrate and the other for the biomass. These mass balances are essential for design and operational control of the biological reactor, and are detailed in this section.

AS Systems with solids recirculation

Reactor with a final sedimentation unit and with solids recirculation

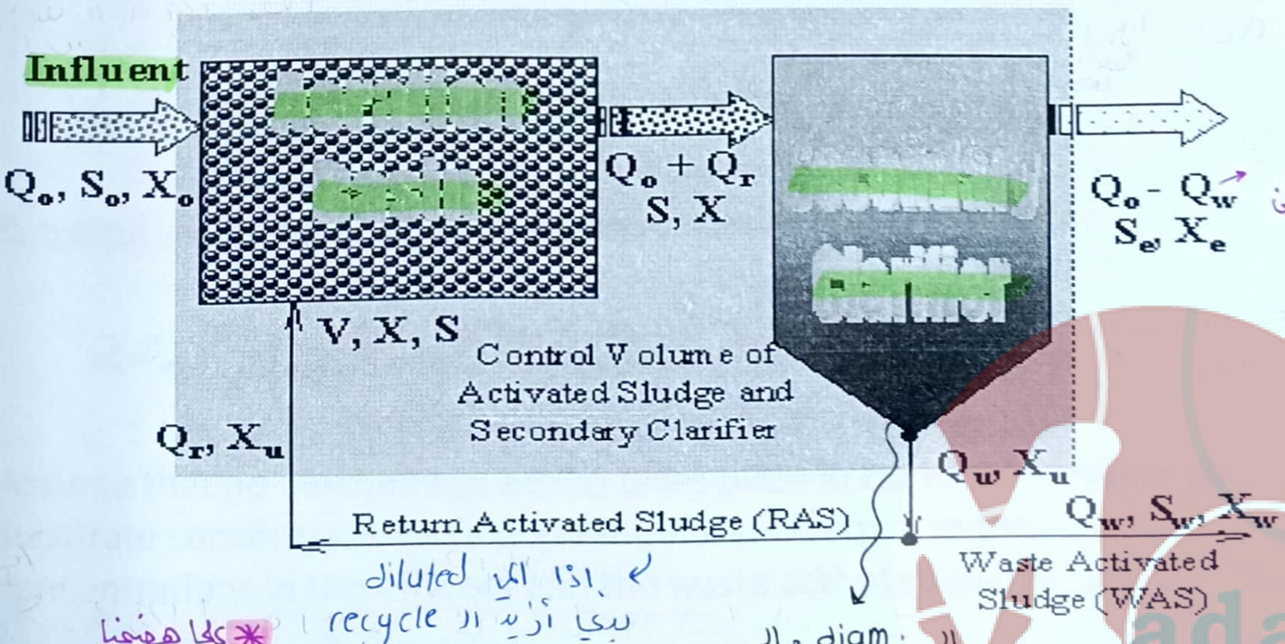


Q_r	=	recycle or return sludge flow (m³/d)
Q_{ex}	=	excess (surplus or waste) sludge flow (m³/d)
X_r	=	concentration of suspended solids in the return sludge (mg/L or g/m³)

AAS with solids recirculation

- The sludge accumulated up to a certain period at the bottom of the settling unit consists mainly of bacteria that are still active in terms of their capacity to assimilate organic matter.
- The greater the biomass concentration, the greater the substrate utilization or, in other words, the greater the BOD removal.
- Therefore, if the settled sludge is returned, with a concentration higher than in the reactor, the system will be able to assimilate a much higher BOD load.
- This recirculation has also the important role of increasing the average time in which the microorganisms remain in the system. The recirculation of biomass is the basic principle of systems, such as activated sludge, which is accomplished by a recirculation pumping station.
- The value of X_r is higher than X, that is, the return sludge has a greater suspended solids concentration, what allows the increase of SS concentration in the reactor.
- there is another flow line, which corresponds to the excess sludge. This is based on the concept that the biomass production (bacterial growth) must be compensated for by the wastage of an equivalent quantity, for the system to be maintained in equilibrium. If there were no such a wastage, the mass of suspended solids in the reactor would progressively increase, and these solids would then be transferred to the settling tank, until a point when the settler would become overloaded.

AS Design Equations



سلايد 4 نقطة 4

داخل ال aeration tank داخل liq flow جوانه 10 لـ 20%

من ال solid particles طلعو من ال aer. tank وراحو لل sec. clarifier

من ال top أخذنا flow بتع ال liq ومن ال bottom رجعنا ال sludge

يلي فيه Biomass، صار عندي two retention time واحد لل liq وواحد

لل solid، ال retention time للـ solid particles أعلى من ال retention time

بتع ال liq flow.

Mass balance of biomass production (CSTR)

Influent biomass + biomass production = effluent biomass + sludge wasted

X_o & X_e → مهمل

$$Q_o X_o + V\frac{dX}{dt} = (Q_o - Q_w)X_e + Q_w X_w$$

Substitute biomass production equation

$$Q_o X_o + V\left(\frac{\mu_m S}{K_s + S} X - k_d X\right) = (Q_o - Q_w)X_e + Q_w X_w$$

→ $\frac{dX}{dt}$

Assume that influent and effluent biomass concentrations are negligible and solve

$$\frac{\mu_m S}{K_s + S} = \frac{Q_w X_w}{VX} + k_d$$

Mass balance of food substrate

Influent substrate + substrate consumed = effluent substrate + sludge wasted substrate

$$Q_o S_o + V\frac{dS}{dt} = (Q_o - Q_w)S_e + Q_w S_w$$

Substitute substrate removal equation

$$Q_o S_o + \frac{V}{Y}\left(\frac{\mu_m X S}{K_s + S}\right) = (Q_o - Q_w)S_e + Q_w S_w$$

→ dS/dt

Assume that no biochemical action takes place in clarifier. Therefore the substrate concentration in the aeration basin is equal to the substrate concentrations in the effluent and the waste activated sludge. Solve:

$$\frac{\mu_m S}{K_s + S} = \frac{Q_o Y}{VX}(S_o - S)$$

هاد الجزء مشترك بالمعادلتين التاني اذا عرفت وحدة بحسب الثانية بدلالتها

Hydraulic detention time and solids retention time

In a system with solids recycling, the solids are separated and concentrated in the final settling unit and subsequently returned to the reactor.

The liquid, on the other hand, in spite of the recirculation (which is internal in the system), does not vary quantitatively, apart from the withdrawal of the excess sludge flow, which is negligible in the overall calculation ($Q_{ex} \approx 0$).

Therefore, only the solids are retained in the system, owing to the separation, thickening and recycling. Thus, the solids remain longer in the system than the liquid. It is thus necessary to distinguish the concepts of solids retention time and hydraulic detention time.

The hydraulic detention time t (or hydraulic retention time – HRT) given by:

Since the volume of liquid that enters is the same as the one that leaves, the following generalization can be made:

$$\text{hydraulic detention time} = \frac{\text{volume of liquid in the system}}{\text{volume of liquid removed per unit time}}$$

$$t = \frac{V}{Q}$$

Similarly, the **solids retention time SRT** (or mean cell residence time – MCRT or **sludge age** - θ_c) is given by:

$$\text{sludge age} = \frac{\text{mass of solids in the system}}{\text{mass of solids produced per unit time}}$$

In the steady state, the quantity of solids removed from the system is equal to the quantity of sludge produced. Hence, the sludge age can also be expressed as:

$$\text{sludge age} = \frac{\text{mass of solids in the system}}{\text{mass of solids removed per unit time}}$$

$$\theta_c = \frac{1}{\mu - K_d}$$

Depending on inclusion or not of sludge recycle, the following two conditions are obtained:

- Systems without solids retention: $t = \theta_c$
- Systems with solids retention: $t < \theta_c$

Overall equations

- Combine the mass balance equations for food and biomass:

$$\frac{Q_w V_w}{VX} + k_d = \frac{Q_o Y}{VX}(S_o - S)$$

→ دمجنا معادلات ال S وال X
لي طلعناهم قبل
وطلعنا تعريف جديد
لل θ_c

The cell residence time is:

$$\theta_c = \frac{VX}{Q_w X_w}$$

And the hydraulic retention time is, $\theta = V/Q_o$

Substitute and rearrange:

$$X = \frac{\theta_c (Y)(S_o - S)}{\theta(1 + k_d \theta_c)}$$

عند أي θ بقدر
أعرف شو ال X يلي
بال sys

The fact that the biomass stays longer than the liquid in the system justifies the greater efficiency of systems with solids recirculation, compared with systems without solids recirculation. مهم

It can also be said that, for the same removal efficiency, systems with solids recirculation require much smaller reactor volumes than the systems without recirculation.

The biochemical reactions occur only in the reactor. The reactions of the conversion of organic matter and of cellular growth in the settling unit can be neglected.

The biomass is assumed to be present only in the reactor. In the calculation of the sludge age, the solids present in the final settling unit and in the recirculation line have not been considered.

The mechanisms take place according to the steady state. In the dynamic state, the mass of solids produced is not equal to the mass wasted, which alters the interpretation of the sludge age concept.

Example

culate the hydraulic detention time and the sludge age in the sewage treat-
it system ! (without a settling tank and solids re-
ulation). The main relevant data

ctor volume: $V = 9{,}000\ m^3$

it and output variables:

Influent flow: $Q = 3{,}000\ m^3/d$

Influent substrate (BOD_5 total): $S_o = 350$ mg/L

Effluent substrate (BOD_5 soluble): $S = 9.1$ mg/L

del coefficients:

Maximum specific growth rate: $\mu_{max} = 3.0\ d^{-1}$

Half-saturation coefficient: $K_s = 60$ mg/L

Endogenous respiration coefficient: $K_d = 0.06\ d^{-1}$

ition:

a) Hydraulic detention time

$$t = \frac{V}{Q} = \frac{9{,}000\ m^3}{3{,}000\ m^3/d} = \boxed{3.0\ d}$$

b) Sludge age

The value of μ is

$$\mu = \mu_{max} \cdot \frac{S}{K_s + S} = 3.0 \cdot \frac{9.1}{60 + 9.1} = 0.395\ d^{-1}$$

The sludge age is

$$\theta_c = \frac{1}{\mu - K_d} = \frac{1}{0.395 - 0.06} = \boxed{3.0\ d}$$

As expected, in the present example $t = \theta_c$, since the system has no solids recirculation.

oading rates on biological reactors

Sludge load (food-to-microorganism ratio)

- A relationship widely used by designers and operators of wastewater treatment plants is the **sludge load** or **F/M (food-to-microorganism) ratio**.
- It is based on the concept that the quantity of food or substrate available per unit mass of microorganisms is related to the efficiency of the system.
- Hence, it can be understood that, the higher the BOD load supplied per unit value of the biomass (high F/M ratio), the lower is the substrate assimilation efficiency, but, on the other hand, the lower is the required reactor volume.
- Conversely, when less BOD is supplied to the bacteria (low F/M ratio), the demand for food is higher, which implies a greater BOD removal efficiency and a larger reactor volume requirement.
- In a situation in which the quantity of food supplied is very low, the mechanism of endogenous respiration becomes prevalent.

The food load supplied is given by: $F = Q.S_0$

The microorganism mass is calculated as: $M = V.X_v$

where:

Q = influent flow (m^3/d)

S_0 = influent BOD_5 concentration (g/m^3)

V = reactor volume (m^3)

X_v = volatile suspended solids concentration (g/m^3)

Thus, the F/M ratio is expressed as:

$$\frac{F}{M} = \frac{Q.S_0}{V.X_v}$$

where:

F/M = sludge load ($gBOD_5$ supplied per day/g VSS)

Example

Calculate the values of F/M in a wastewater treatment plant with sludge recirculation, as described in Data:

$S_0 = 300\ gBOD_5/m^3$

$S = 15\ gBOD_5/m^3$

$t = 0.25\ d$

$X_v = 2{,}540\ gVSS/m^3$

Solution:

a) Calculation of F/M

From Equation

$$\frac{F}{M} = \frac{S_o}{t.X_v} = \frac{300\ gBOD_5/m^3}{0.25\ d\ .\ 2{,}540\ gVSS/m^3} = 0.47 d^{-1}$$

$F/M = 0.47\ kgBOD_5/kgVSS.d$

Ref. Book: Vesilind

Example: 11.1
Example: 11.2
Example: 11.3
Example: 11.4
Example: 11.5

Wastewater Treatment Plant and Process

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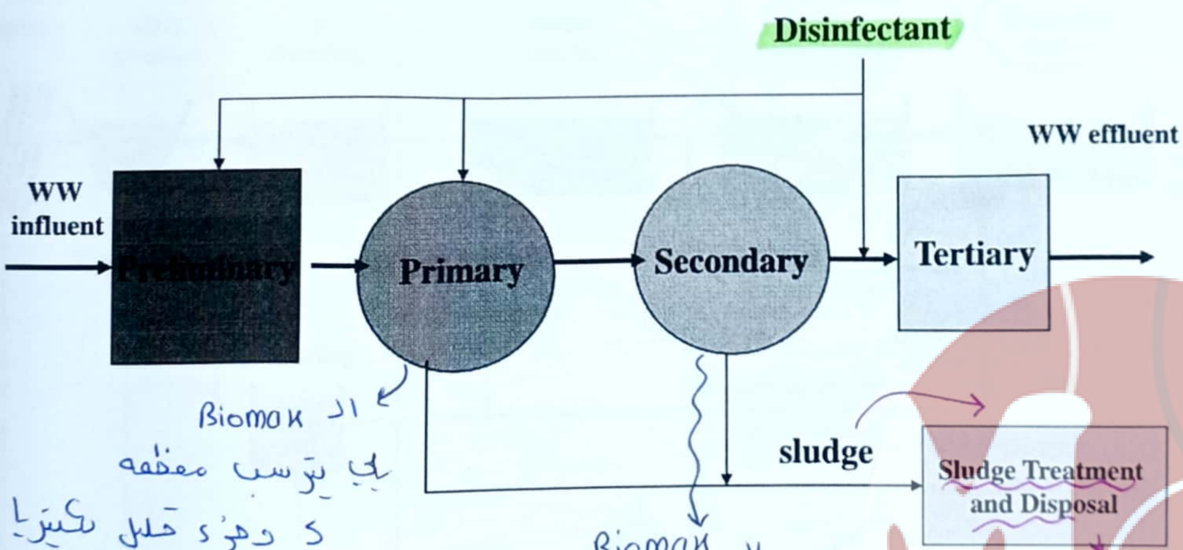
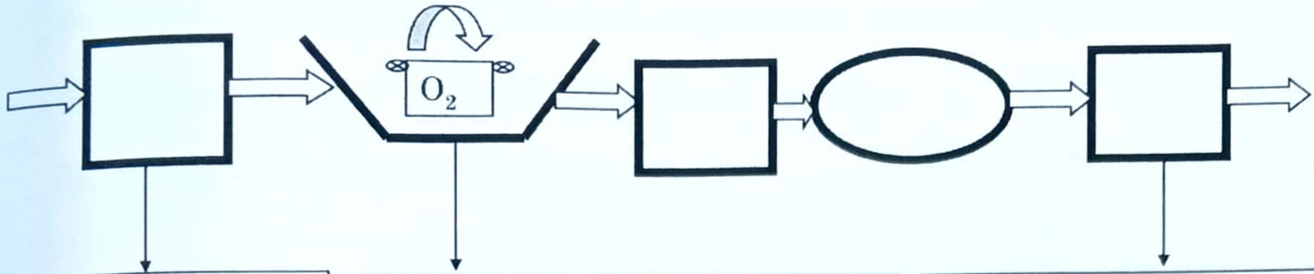
Types of Treatments

- **Mechanical treatment** → Primary (physical)
  - Influx (Influent)
  - Removal of large objects
  - Removal of sand and grit
  - Primary Sedimentation
- **Biological treatment** → secondary
  - Trickling bed filter
  - Activated sludge
- **Chemical treatment** → tertiary
  - Disinfection

Wastewater treatment stages



Wastewater Treatment Processes

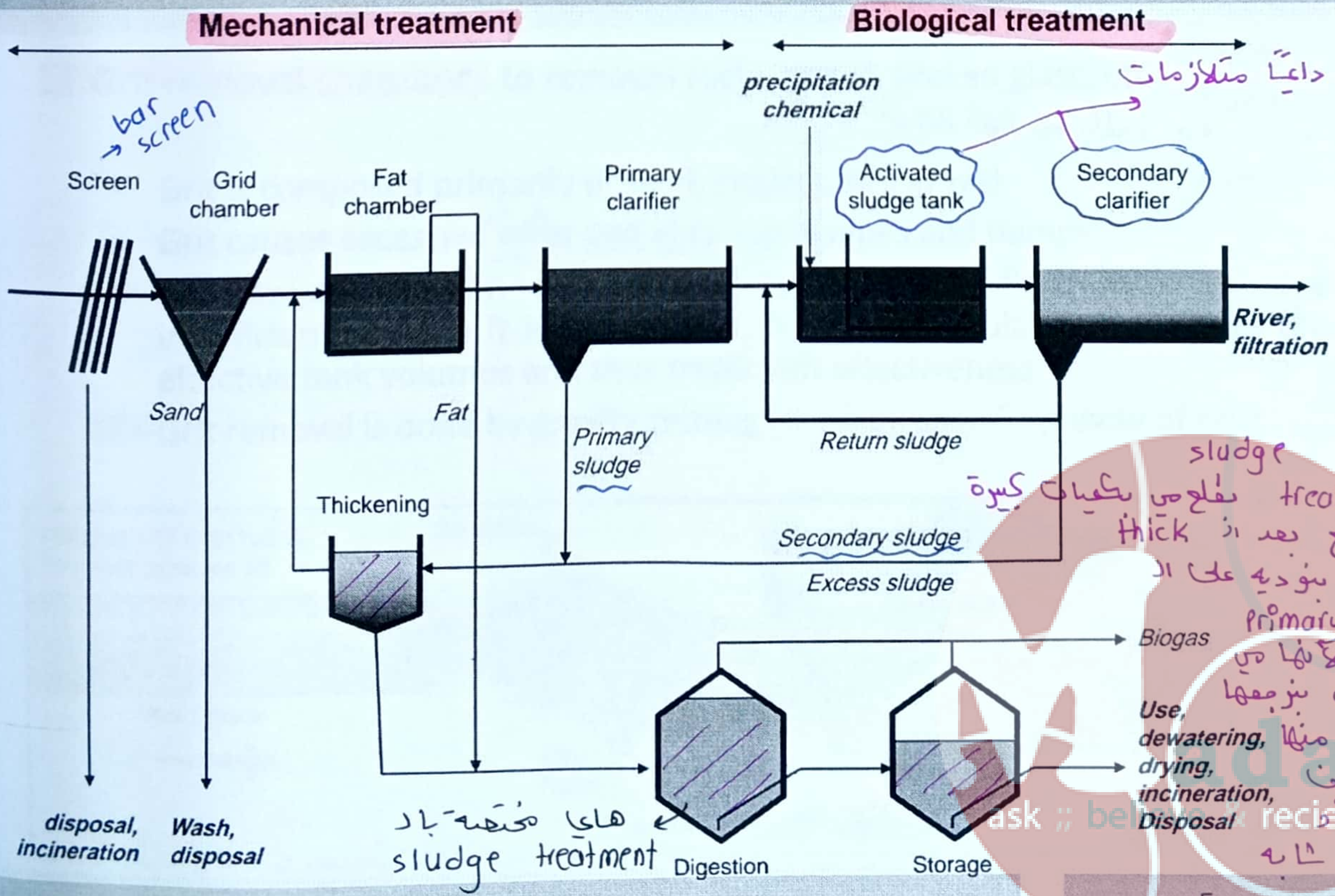


Primary treatment
- screening
- grit removal
- removal of oil
- sedimentation

Secondary treatment
- Aerobic, anaerobic lagoons
- Trickling filter- activated sludge-oxidation ditch
- Mostly BOD removal technology

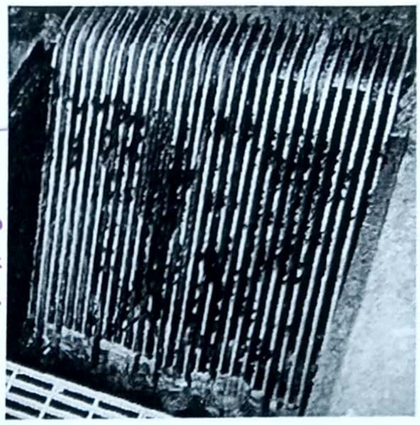
Tertiary treatment
- Nitrate removal
- Phosphorus removal
- Disinfection

Layout of a WWTP



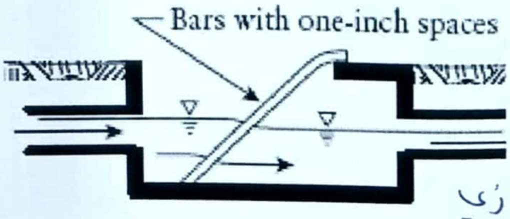
Preliminary Treatment

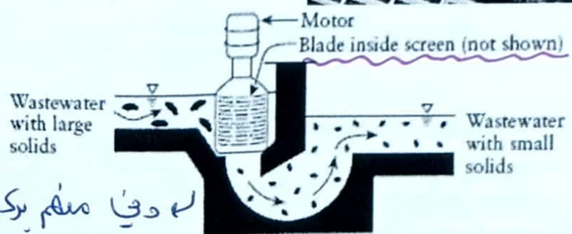
- removes large objects and non-degradable materials
- protects pumps and equipment from damage
- bar screen and grit chamber



❑ Bar Screen

catches large objects that have gotten into sewer system such as bricks, bottles, pieces of wood, etc

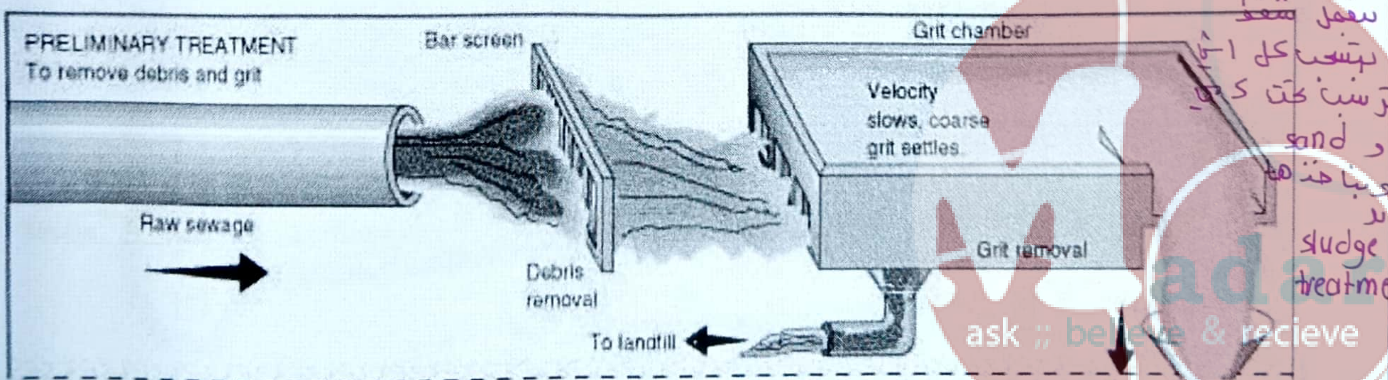




Preliminary Treatment

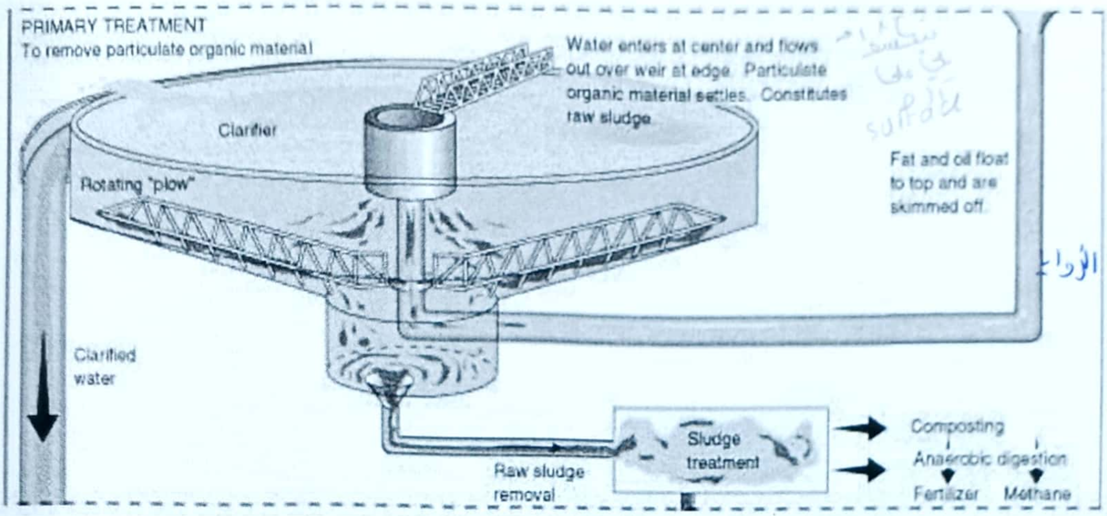
❑ **Grit removal chamber** : to removes rocks, gravel, broken glass, etc.

- Grit is composed primarily of sand, cinders, and gravel
- Grit causes excessive wear and abrasion in pipes and pumps
- Grit accumulates in downstream tanks where flow velocities are insufficient to keep it in suspension. As grit accumulates, it reduces the effective tank volumes and thus treatment effectiveness
- Grit removal is done by gravity settling (the high specific gravity of grit)



Primary Treatment

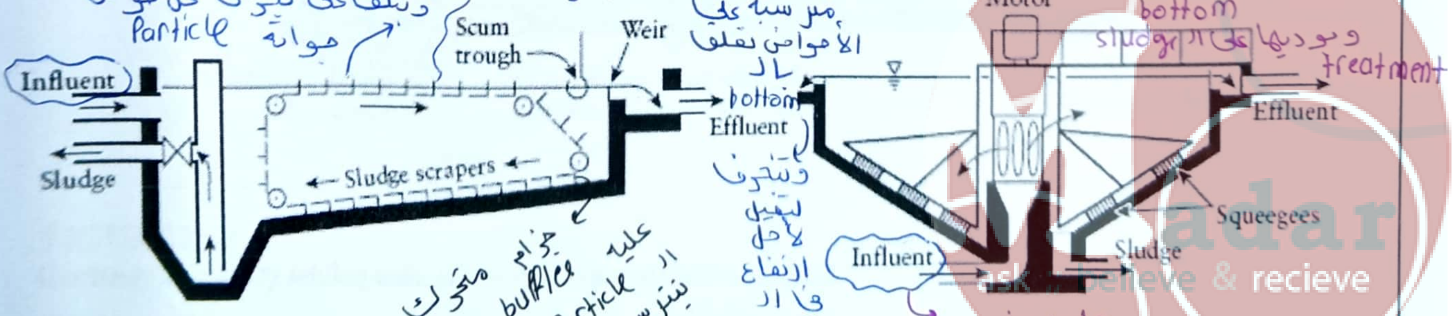
- a physical process
- wastewater flow is slowed down and suspended solids settle to the bottom by gravity
- the material that settles is called sludge or biosolids



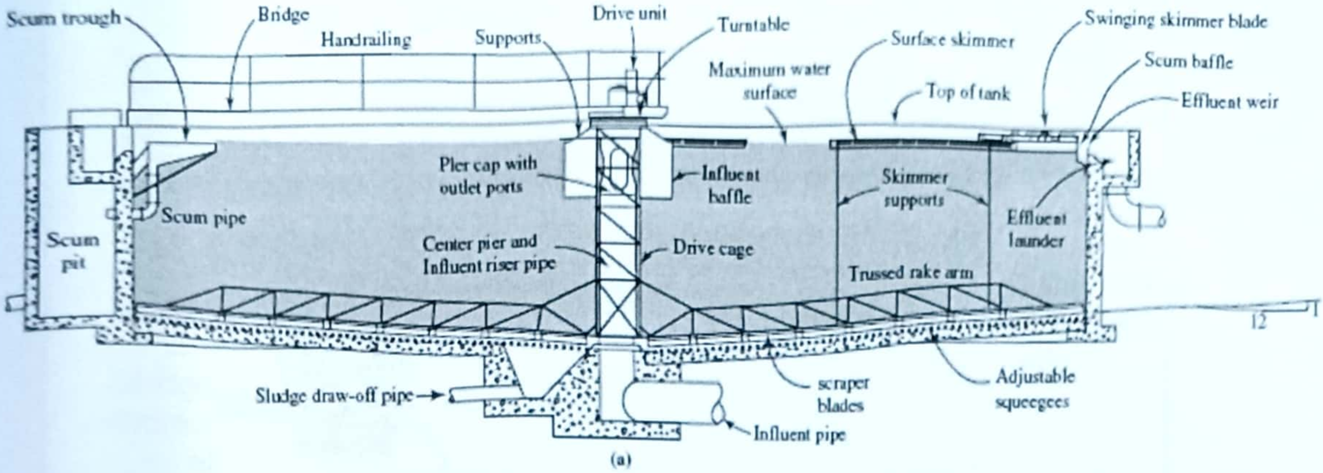
معظم ال → clarifier حاليًا بتكون cylindrical لأن ال rec فيه مشاكل، الأداء بصير عندي dead zones وبنشفان لبعض ال sludge على الحيطان بتحتا ال rec dead zone بالتالي بقلل ال volume avail. جوا ال tank وبقلل ال retention time وهاد بيؤثر على ال quality وال eff ال removal

Sedimentation tanks and clarifiers

- The settling tank that follows preliminary treatment, such as screening and grit removal, is known as the *primary clarifier*.
- Primary treatment, in addition to removing about 60% of the solids, removes about 30% of the demand for oxygen and perhaps 20% of the phosphorus (both as a consequence of the removal of raw sludge).



تترسب جوا ال tank عن طريق الجاذبية أو من خلال الجزام.. وبصير الكشط



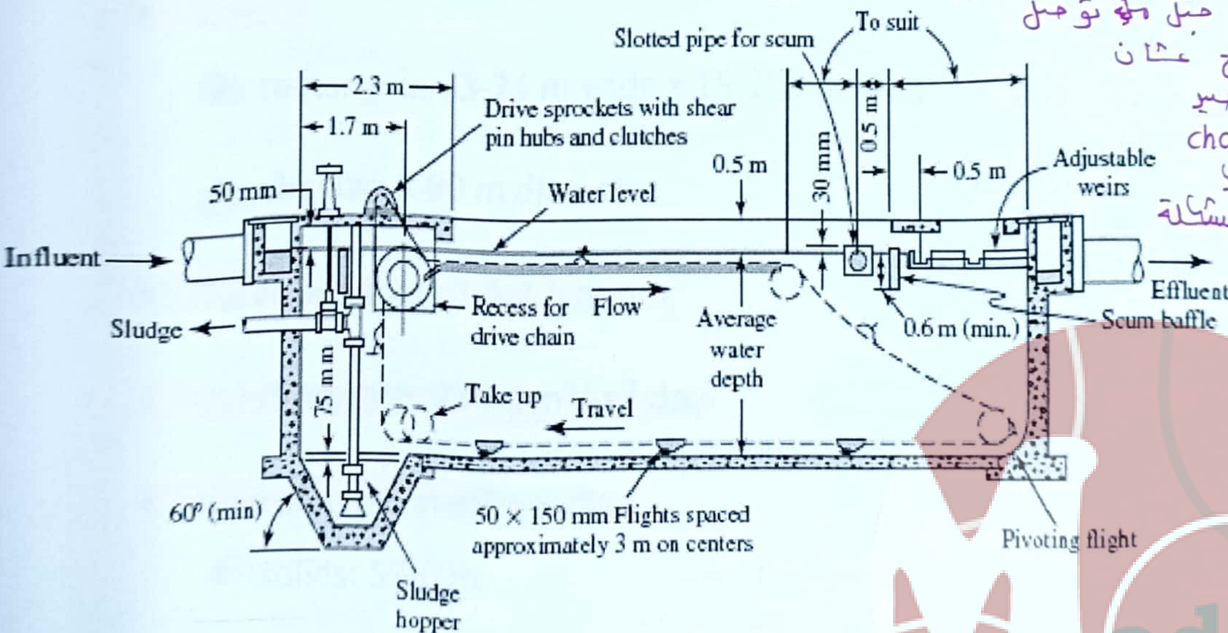
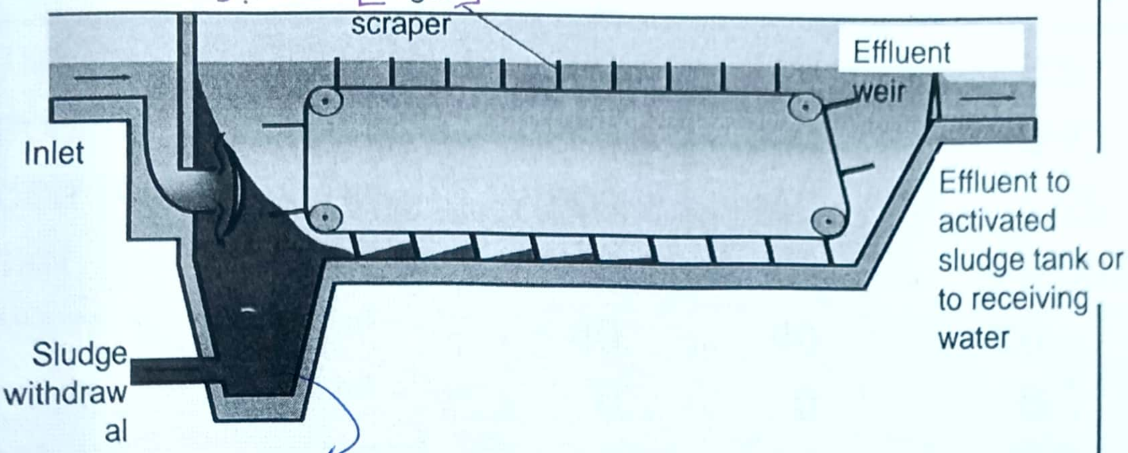


FIGURE 21-3
Rectangular primary settling tank. (*Source:* Davis and Cornwell, 2008.)

Primary / secondary clarifier



حواجز ← Flight

العمق هون مدروس عشان ال time مايكون غير كافي وكيف على رواسب

13 Umweltbereich Wasser

Primary Settling Tank Design

- Size:
  - rectangular: 3-24 m wide x 15-100 m long
  - circular: 3-90 m diameter
- Detention time: 1.5-2.5 hours
- Overflow rate: 25-60 $m^3/m^2 \cdot day$
- Typical removal efficiencies:
  - solids: 50-60%
  - BOD_5: 30-35%

في بعض المحطات ممكن ال primary tank نلاقيه على شكل غرف مثلا 4 clarifier حسب بعض يعني بنقسم ال flow على 4 clarifier لهيك بيكون في standard ل diam. و dimensions لكل clarifier

→ النسبة الأكبر لي بنشال هي ال solid لهيك هاي المرحلة physical

Effects of primary clarifier on wastewater

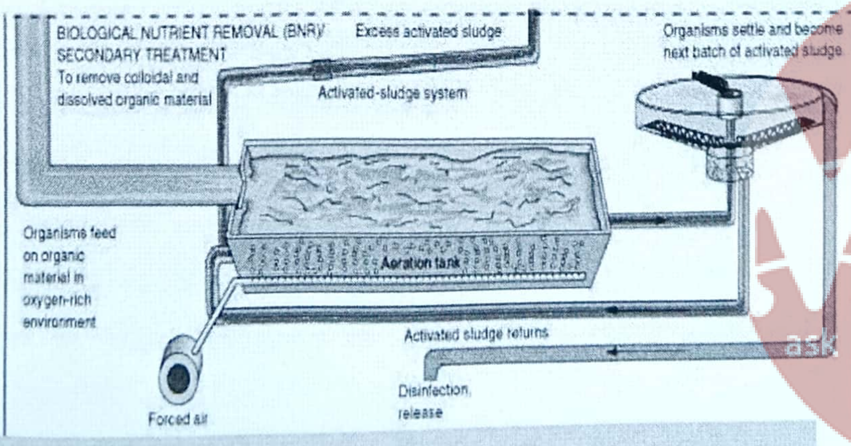
Compound	Unit	Inlet	Outlet*	$\eta = \frac{C_{in} - C_{out}}{C_{in}}$
TSS	g TSS / m^3	360	180	0.5
BOD_5	g O_2 / m^3	300	230	0.23
COD	g O_2 / m^3	600	450	0.25
TKN	g N / m^3	60	56	0.067
NH_4-N	g N / m^3	40	40	0
NO_2-N	g N / m^3	0	0	0
NO_3-N	g N / m^3	1	1	0
P_{tot}	g P / m^3	10	9	0.1
Alkalinity	mol HCO_3^- / m^3	= f(Drinking water) + NH_4-N		

* Short residence time

Secondary Treatment

- A Biological Process
- The objective of secondary treatment is to remove/reduce BOD using microbial action from soluble to suspended solids.

Organic Matter + Bacteria + O_2 → New Cells (Biomass) + H_2O, CO_2, NH_3



Biological wastewater treatment

Classification of biological Wastewater methods

Suspended and attached

Suspended growth process is a biological w.w.t in which microorganisms are maintained in suspension while converting organic matter to gases and cell tissue (Activated sludge).

Attached growth is a biological w.w.t in which microorganisms responsible for the conversion of organic matter to gases and cell tissue are attached to some material such as rocks, sand, or plastic (Trickling filter).

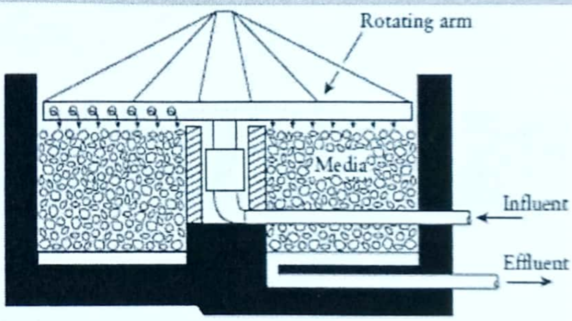
Aerobic and anaerobic

Aerobic: biological treatment is a process in which the pollutants in the waste water (organic matter) are stabilized by microorganisms in the presence of molecular oxygen

Anaerobic: biological treatment is a process in which the pollutants in the waste water (organic matter) are stabilized by microorganisms in the absence of molecular oxygen

Secondary Treatment Method

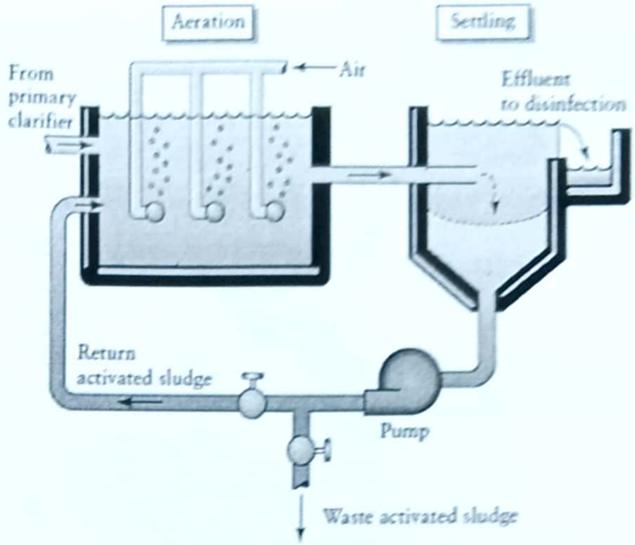
The Trickling filter



- It does not "filter" the water
- It consists of a bed of media (such as fist-sized rocks or various plastic shapes) over which the waste is trickled
- An active biological growth forms on the media, and the organisms obtain their food from the waste stream dripping over the bed.
- Air is either forced through the media
- Wastewater is sprayed and runs over a plastic media and organisms clinging to the media remove organic matter from the wastewater.

Activated sludge system

- Air is bubbled into this tank (called the *aeration tank*)
- The microorganisms use the energy and carbon by decomposing this material to CO_2 and H_2O.
- The microorganisms are separated from the liquid in a settling tank, called a *secondary* or *final clarifier*



- The separated microorganisms exist on the bottom of the final clarifier without additional food and become hungry waiting for more dissolved organic matter. These microorganisms are said to be ***activated.***

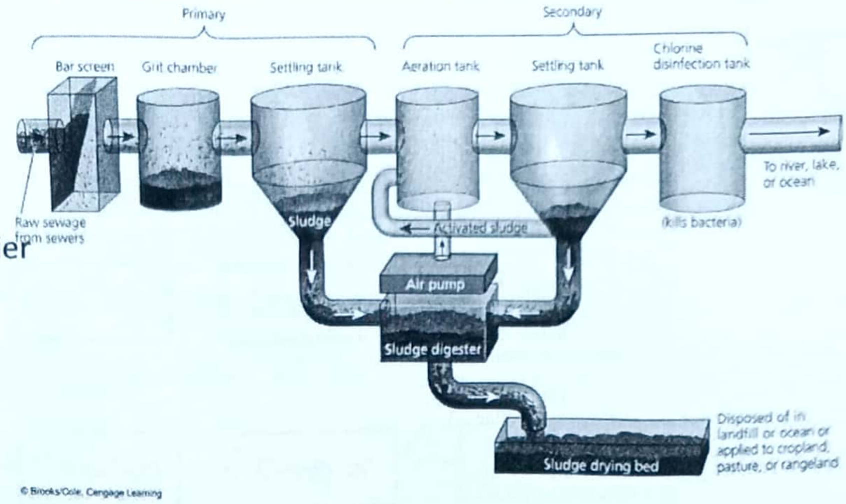
Final Clarifier

- The activated sludge process is a continuous operation
- one of the end products of this process is excess microorganisms. If the microorganisms are not removed, their concentration eventually increases to the point where the system is clogged with solids.

Sludge Sources

Sources of sludge

- Primary sedimentation tank
- Aeration basin or secondary clarifier
- Screening and grinder
- Filter backwash water



Sludge must be treated because:

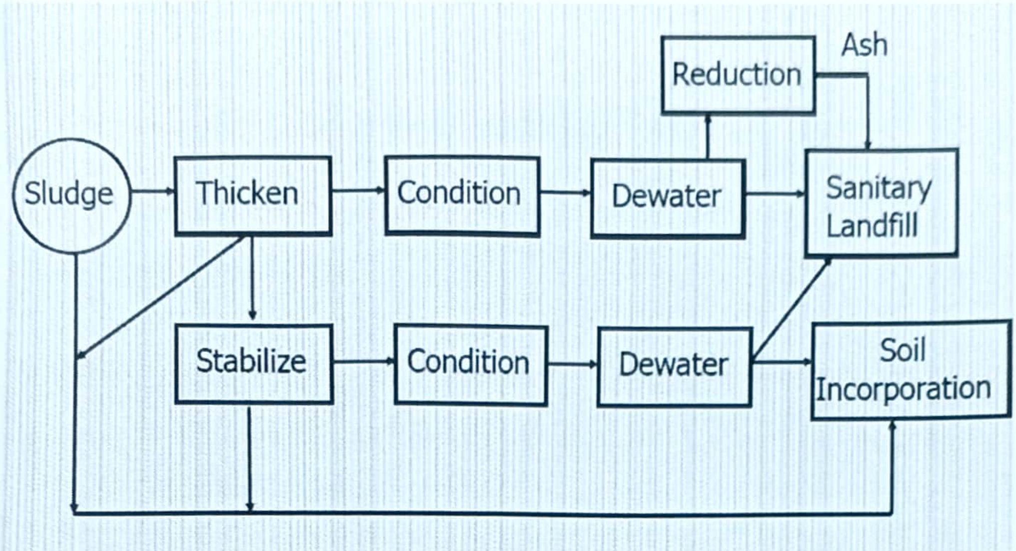
- they are aesthetically displeasing,
- they are potentially harmful,
- and they contain too much water.

Sludge Types

- No two wastewater sludges are alike in all respects.
- Sludge characteristics change with time.
- There is no "average sludge."

- **Primary sludge**
  - 3 to 8% solids
  - About 70% organic material
- **Secondary sludge**
  - Consists of wasted microorganisms and inert materials
  - About 90% organic material
  - Trickling filter sludge: 2-5% solids
- **Tertiary sludge**
  - If secondary clarifier is used to remove phosphate, this sludge will also contain chemical precipitates (more difficult to treat)
  - De-nitrification sludges -similar to WAS sludge

Sludge Treatment



Wastewater Treatment:

Sedimentation

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Introduction

- Sedimentation is the physical operation that separates solid particles with a density higher than that of the surrounding liquid.
- In a tank in which the water flow velocity is very low, the particles tend to go to the bottom under the influence of gravity. As a result, the supernatant liquid becomes clarified, while the particles at the bottom form a sludge layer, and are then subsequently removed with the sludge.
- Sedimentation is a unit operation of high importance in various wastewater treatment systems.
- The main objective in most of the applications is to produce *a clarified effluent*, that is, with a low suspended solids concentration. However, at the same time it is also frequently desired to obtain *a thickened sludge* to help its subsequent treatment

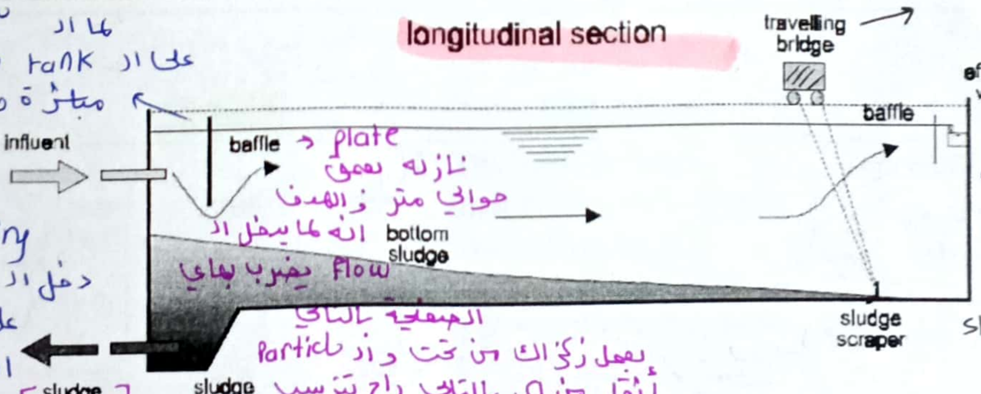
#جبت 2 slurry واحد ال Particle منه أكبر من الثاني
وحطيتهم مع بعض يلي الحجم والها أكبر راح ينزل تحت أسرع ويلي
أقل بدها وقت وأنا بعطي ال time بال design في ال
design ww .sed بنعمله على ال time الأطول لل .part يعني الأبطأ
يلي إلها ص و حجم أقل ما بروح على ال fast .

Sedimentation Applications in WWT

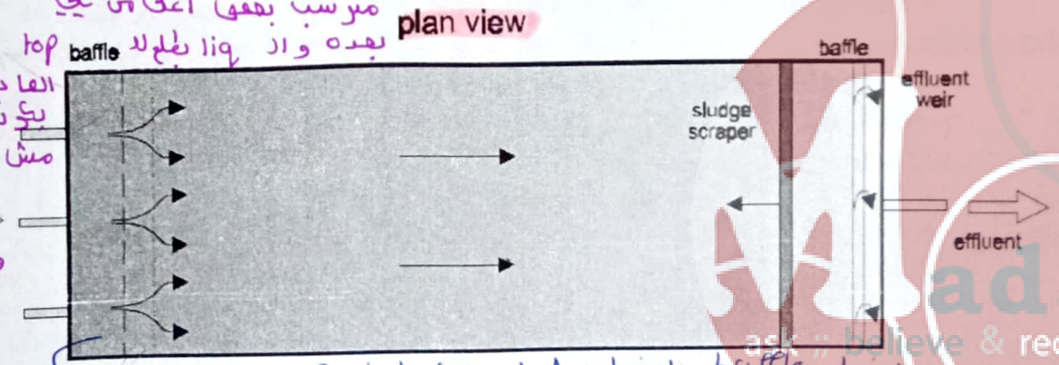
- **Preliminary treatment.**
  - Grit removal (sedimentation of inorganic particles of large dimensions)
  - Grit chamber
- **Primary treatment.**
  - Primary sedimentation (sedimentation of suspended solids from the raw sewage)
  - Conventional primary clarifiers, with frequent sludge removal
  - Septic tanks
- **Secondary treatment.**
  - Secondary sedimentation (removal of mainly biological solids)
  - Final sedimentation tanks in activated sludge systems
  - Final sedimentation tanks in trickling filter systems
  - Sedimentation compartments in anaerobic sludge blanket reactors
  - Sedimentation ponds, after complete-mix aerated lagoons
- **Sludge treatment.**
  - Thickening (settling and thickening of primary sludge and/or excess biological sludge)
  - Gravity thickeners
- **Physical–chemical treatment.**
  - Settling after chemical precipitation
  - Physical–chemical treatment (chemical coagulation)
  - Chemical nutrient removal

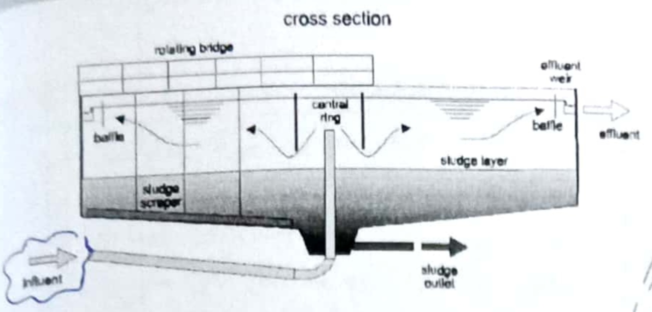
Sedimentation process schematics

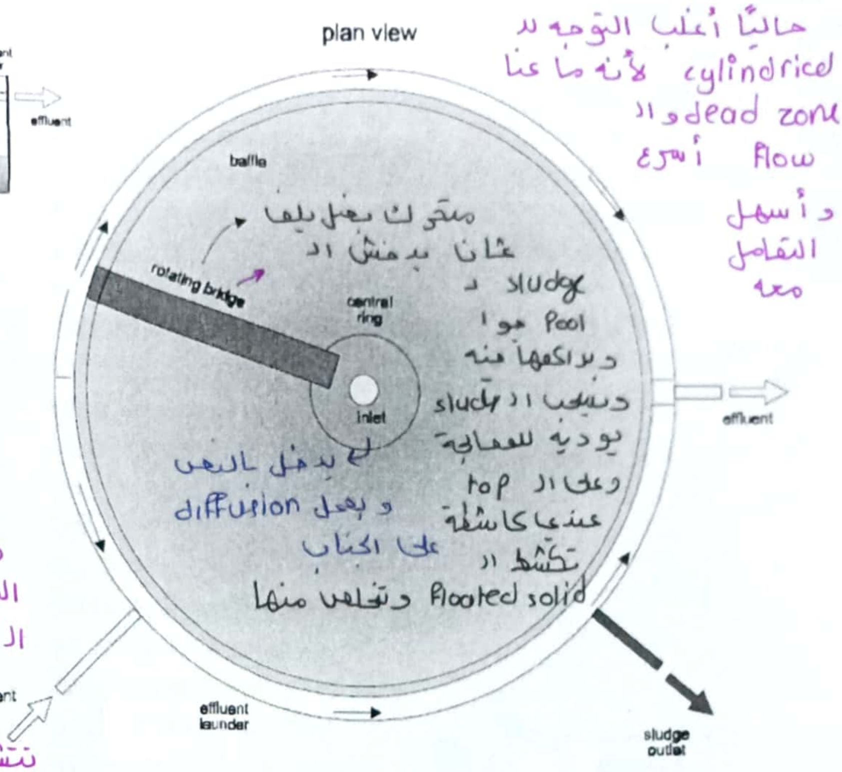
longitudinal section



plan view





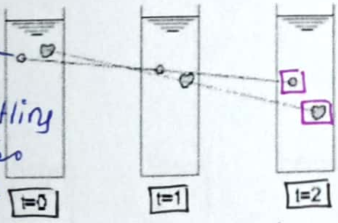
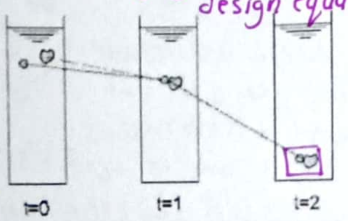


حاليًا أغلب التوجه لـ cylindrical لأنه ما عنا dead zone والـ flow أسرع وأسهل التعامل معه

أخذوا عينات من الـ Prim والـ sec وحطوهم بـ tubes على time معين وشافوا كيف الـ settling بصير وجدوا إنه مش بس variation بـ behavior of Part. بالترسيب عشان لما تركيز الـ Part. يكون عالي بصير تحتك ببعضها حتى ما توصل الـ bottom ممكن تلتصق بالجدران ممكن يصير صدام بحيث تتشتت مرة ثانية والـ Part. لما كانت fine ممكن تحمل مع الـ top هاد كله خلانا نوصل إنه الـ settling له أنواع :

لما إنه الـ sed بتكون أكثر من process بالتالي كل مرة عندي الـ Particle size بتغير وتركيز الـ Particle وعددها وكميتها بحيث بتغير هدول الـ process بأثر على كيفية ترسيب الـ Particle من السطح لـ bottom

Types of settling

Type	Scheme	Description	Example of application/ Occurrence
Discrete		The particles settle, maintaining their identity, that is, they do not coalesce. Hence, their physical properties such as shape, size and density are preserved.	• Grit chambers
Flocculent		The particles coalesce while settling. Their characteristics are changed, with an increase in size (floc formation) and, as a result, in the settling velocity.	• Primary sedimentation tanks • Upper part of secondary sedimentation tanks • Chemical flocs in physical-chemical treatment

كل Particle بتضل زي ما هي يعني ما بصير أو الـ Particle تختلف وتتماسك مع إشي ثاني فش Friction ولا colision والـ floc والحجم بتكبر

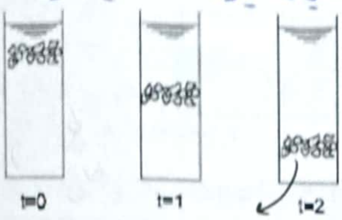
الي الها حجم متغير بتاخذ وقت أكثر ليصير settling مقارنة بالـ Particle الكبيرة

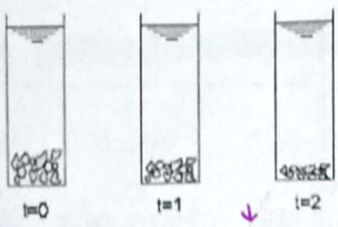
الـ Particle الي الها D أكبر راح تنزل لـ bottom بشكل أسرع لهيك لما أصمم لازم آخذ بعين الاعتبار الـ D والـ v لـ يكون مناسب لـ Particle

لهيك الي الها v و D أقل هي الي بأخذها بعين الاعتبار بالـ design لأنه تدها وقت أطول لتوصل للـ bottom فبأخذه هو بالـ design equa.

أسرع لأن لما تأثر الاتجاذبية عليها أعلى

منها الـ chem خربطت الـ surface وخلت الـ Particle تتغير يصير تجاذب والـ Part. تلتصق وبيكبر حجمها بالتالي ترسيبها أسرع.

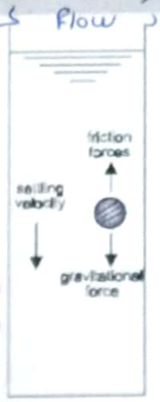
Type	Scheme	Description	Example of application/ Occurrence
Hindered (or zone)		When there is a high concentration of solids, a sludge blanket is formed, which settles as a single mass (the particles tend to stay in a fixed position with relation to the neighbouring particles). A clear separation interface can be observed between the solid phase and the liquid phase. The interface level moves downwards as a result of the settling of the sludge blanket. In this case, it is the settling velocity of the interface that is used in the design of the settling tanks.	• Secondary sedimentation tanks • Sludge gravity thickeners

Type	Scheme	Description	Example of application/ Occurrence
Compression		If the solids concentration is even higher, the settling could occur only by compression of the particles' structure. The compression occurs due to the weight of the particles, constantly added because of the sedimentation of the particles situated in the supernatant liquid. With the compression, part of the water is removed from the floc matrix, reducing its volume	• Bottom of secondary sedimentation tanks • Sludge gravity thickeners

Source: adapted from Tchobanoglous and Schroeder (1985), Metcalf and Eddy (1991)

Discrete Settling velocity

- The sedimentation of discrete particles can be analyzed through the classic laws of Newton and Stokes. According to these laws, the final velocity of a particle under sedimentation in a liquid is constant, that is, the frictional force is equal to the gravitational force.



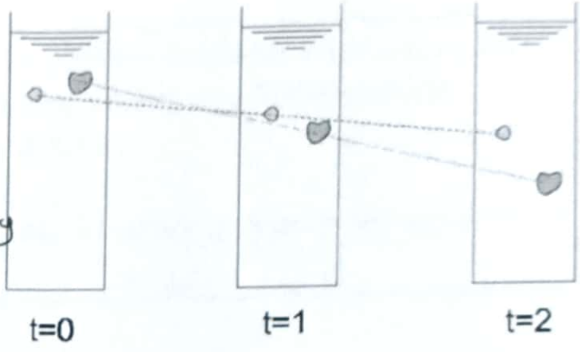
- This terminal velocity is reached in the liquid medium in fractions of a second.

$$v_s = \frac{1}{18} \cdot \frac{g}{\upsilon} \cdot \frac{\rho_s - \rho_l}{\rho_l} \cdot d^2$$

where:

v_s = settling velocity of the particle (m/s)
g = acceleration due to gravity (m/s^2)
υ = kinematic viscosity of the liquid (m^2/s)

ρ_s = particle density (kg/m^3)
ρ_l = liquid density (kg/m^3)
d = particle diameter (m)



Discrete settling, showing constant settling velocity of the particles

- The kinematic viscosity v and the density of water ρ_l are functions of the temperature T.

- However, the variation in the density of the water within the usual temperature ranges in wastewater treatment can be neglected (999.8 kg/m^3 and 992.2 kg/m^3 for temperatures of 0°C and 40°C, respectively) and a value of 1000 kg/m^3 can be adopted.

Kinematic viscosity of the water as a function of temperature

T (°C)	0	5	10	15	20
υ (m^2/s)	1.79×10^{-6}	1.52×10^{-6}	1.31×10^{-6}	1.15×10^{-6}	1.01×10^{-6}
T (°C)	25	30	35	40	
υ (m^2/s)	0.90×10^{-6}	0.80×10^{-6}	0.73×10^{-6}	0.66×10^{-6}	

In the range of T = 10 to 30°C, von Sperling (1999) proposes the following equation for the viscosity as a function of the temperature ($R^2 = 0.986$):

$$\upsilon = 3.76 \times 10^{-6} \times T^{-0,450}$$

$$V_s = \frac{1}{18} \cdot \frac{g}{\upsilon} \cdot \frac{\rho_s - \rho_l}{\rho_l} . d^2$$

- v_s *is proportional to* $(\rho_s - \rho_l)/\rho_l$
- v_s *is proportional to* d^2

- The fact that v_s is proportional to the square of the particle diameter emphasizes the importance of the increase in the size of the particles, aiming at a faster particle removal, and, consequently, smaller sedimentation tanks.

- As an example, when the particle diameter doubles, the settling velocity increases four times.

Example

Calculate the settling velocity of a sand grain using the following data:

- Grain diameter: d = 0.7 mm
- Sand density: $\rho_s = 2650$ kg/m^3
- Liquid density: $\rho_l = 1000$ kg/m^3
- Liquid temperature: T = 25°C

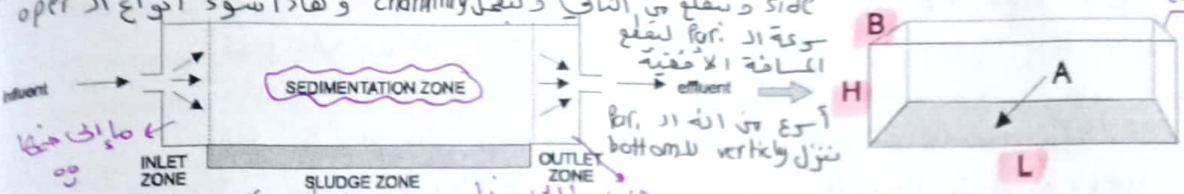
Solution:

From Table 4.2 for the temperature of 25°C, the kinematic viscosity of the water υ is 0.90×10^{-6} m^2/s. The diameter of the particle is 0.7×10^{-3} m. From Equation 4.1, assuming laminar flow:

$$V_s = \frac{1}{18} \cdot \frac{g}{\upsilon} \cdot \frac{\rho_s - \rho_l}{\rho_l} . d^2 = \frac{1}{18} \cdot \frac{9.81}{0.90 \times 10^{-6}} \cdot \frac{2650 - 1000}{1000} . (0.7 \times 10^{-3})^2$$

$$= 0.49 \text{ m/s}$$

Sedimentation tank with horizontal flow



- The discrete settling of a particle can be analyzed in a settling column without flow as well as in a rectangular horizontal-flow tank with constant horizontal velocity (v_h).
- The theoretical considerations apply to the zone where settling effectively occurs (sedimentation zone).

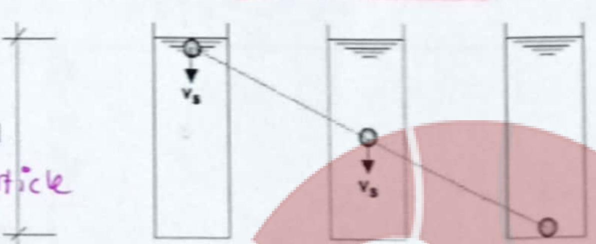
For the theoretical analysis of sedimentation, it is necessary to assume that:

- ✓ the particles are uniformly distributed in the inlet zone;
- ✓ the particles that touch the sludge zone are considered removed;
- ✓ the particles that reach the outlet zone are not removed by sedimentation.

The main dimensions of the sedimentation zone

- In an ideal sedimentation tank with constant horizontal velocity, the discrete settling of a particle occurs as in a sedimentation column.
- The time taken for a particle to reach the bottom is given by:

SETTLING COLUMN



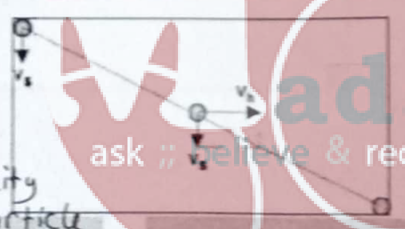
- *sedimentation column*: time = distance/velocity

$$t = \frac{H}{V_S}$$

- *horizontal flow tank*: time = volume/flow

$$t = \frac{V}{Q} = \frac{H.A}{Q}$$

HORIZONTAL-FLOW TANK



Combining Equations

$$V_s = \frac{Q}{A}$$

※ المدخل والمخرج برة ال sed stage لأنه بكون عندي مؤثرات لا flow بتأثر على حركة ال particles بالتالي باستبعدها وما باخذها بحسابي لما بعمل ال design لل sed. zone، لما تدخل ال fluid جوا ال tank عند المدخل بكون عندي تأثير ال turbulance وهذا ممكن يشيل ال particle لفوق ممكن يعملها على شكل eddie فبالتالي sed stage جوا ال tank إلها dimension مختلفة عن ال dimension تبع ال tank بالتالي دايمًا أول متر أفقي من ال tank وآخر متر أفقي من ال tank عند المدخل وعند المخرج هدول لا بعتبرو sed zone ما بصير فيهم عمليات الترسيب فبنحطهم برة الحسبة تبعتنا.

⇐ ال rectang. فيه زوايا حادة وهاي دايمًا فيها dead zone وهناك دايمًا بكون عنا مشاكل وهاي ال zones بتلاقي فيها تكتل من ال particle وعامل scum يلي هي زي رغوة صلبة حتى لما بدك تشيلها بتلاقيها viscous قديمة صرلها فترة زمنية موجودة هناك وعملت طبقة على هذا ال volume وهاي مشكلة.

← أي particle بتدخل في إلها مؤثرات ك forces بتاخذ ال particle ويسحبها أفقيًا يا عموديًا يا التنين مع بعض بالتالي عندي vectors وعندي Resultant نهاية المطاف وبين ال force الأكبر يلي بسحب ال particle في particle أول ما تدخل تنزل نازلة تحت مباشرة ممكن تمشي على شكل زكزاك عشانها نازلة على درج أو بشكل مايل وبغض النظر نزلت بأي طريقة من هدول لازم تضل بال sed zone لتطلع من ال bottom إذا مسابات مع ليك حتى نعبر عن هاد الحكي بمعادلاتنا عنا 2times مهمين جدًا الأول معني بال settling velocity والثاني له علاقة بال sed, flowrate ال particle وهي داخلة إلها اما ال 2forces ال flow بدو يسحبها shearing وتطلع من ال side الثاني وأما ال gravity تسحبها لتحت بالتالي بتأثر بال 2forces حتى أنساب لتحت بال bottom وأضل بال sed zone وأطلع.

- This below equation is very important in the design of sedimentation tanks. If it is desired to remove particles with settling velocities equal to or greater than V_S, and knowing the wastewater flow to be treated Q, the required surface area can be obtained from:

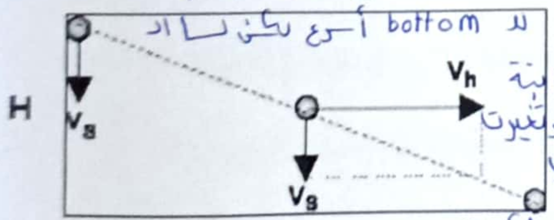
$$A = \frac{Q}{V_S}$$

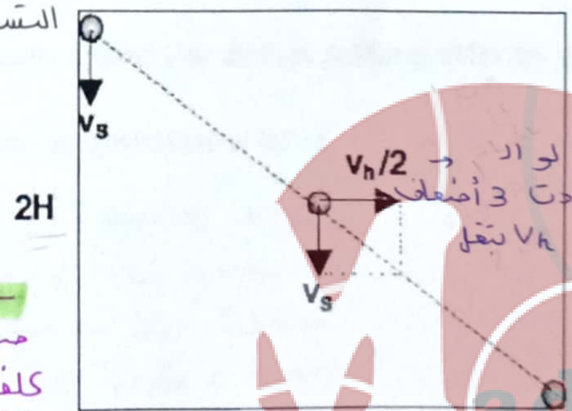
- The settling velocity to be adopted for design (v_s, or v_o) is also called *overflow rate* or hydraulic surface loading rate, and is expressed in units of velocity (m/h), or flow per unit area ($m^3/m^2.h$).

- v_s can be obtained through experiments with the liquid to be treated or from literature values (in a design, v_s is a design parameter),
- the removal of discrete particles depends only on the surface area (A) and not on the height (H) and time (t).

Non-influence of H on the removal of discrete particles

- If A and Q are maintained constant, and if H doubles, the volume V doubles, and so does the time t. The horizontal velocity v_h ($v_h = Q/(B.H)$) is reduced to half.
- Since vs is constant (function only of the particle characteristics), the new trajectory of the particle leads to its removal in the final extremity of the tank, identically to the tank with a lower height



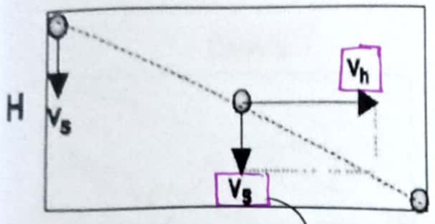


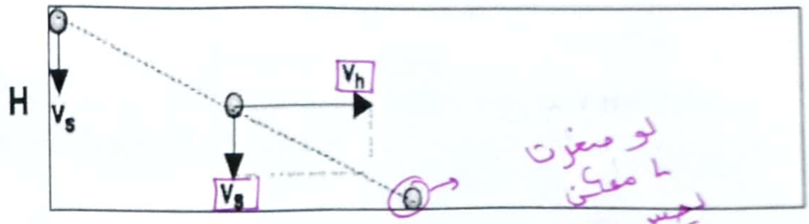
لما أدخل ال flow جوا ال tank ما بدخله بـ pipe عندي wall كامل على side من ال tank هاد ال wall فيه ثقوب عشان هيك سميناه perforated : بدخل ال flow ما قبل هاد ال wall وال flow بدخل على ال tank من خلال هاي الثقوب هاي الثقوب موزعة كأنها منخل بس شوي في مناطق مسكرة من أعلى ال اص للأسفل في Particle بتدخل على ارتفاع متر أو 3 أو 4 فدخول ال Particle على ارتفاع محدد هاد هو ال height لي بهمنا أما ال max height لي هو ارتفاع ال tank الأصلي ما بهمني لأنه احتمال إذا طلعت على ارتفاع أعلى ممكن تنسحب لل side الثاني وما بتلحق تنزل بال zone لي بدي إياها.

Influence of A on the removal of discrete particles

- However, if the surface area A doubles, for example through the duplication of the length L, v_h, and v_s remain constant. The trajectory of the particle is not altered, but the particle is removed in half of the tank length.

- Hence, this new tank is able to receive particles with settling velocities lower than v_s.





ال Vs وصل ال max لأنها بتعتمد على ال physical prop ما إلها دخل بال L ، Vs هي free fall سقوط حر لهيك ما بتتغير بالبداية بتسارع بعدين التسارع بصير صفر لأن السرعة تثبت

2L ← زدت ال length لكن السرعة نفس ال Particle وهي نازلة ما تأثرت ومتى لو ضاعفت H نفس المبدأ

لو صغرت L ممكن يصير مشاكل

* دائماً إذا بدك تغير على sys انتبه لل A ، إذا صغرتها فقدت ال sys لازم يكون عندي optimum A أو تزيد عنها بال safety factor

← ال height وال depth بتأثر على ال volum ما بتأثر على ال A

In summary, for the ideal discrete settling, the surface area A is of fundamental importance, while H and t do not play any role.

- The particles to be removed in a sedimentation tank depend on the:
  - ✓ Settling velocity of the particle (compared with the design settling velocity v_s)
  - ✓ Height at which the particle enters the sedimentation zone

كل ما ال Particle دخلت بال H يلي أنا مصمم عليه أو أقل منه ما عندي مشكلة لكن هنا بعض ال Particle بدخلوها على H أعلى من ال optimum بالتالي بدها تنزل تقل السيولة لكن للأسف ممكن توصل ل side الثاني وتطلع قبل ما اسحبها بال zone تبع ال settling

لما يكون عندي شتاء مشكلة العطات لأحل مشكلة العطات بالشتاء

عندي 2 options ، إما تكون مصمم ال tank على surface area أكبر بالتالي أعطيه زمن أكثر ليترسب لأنه صار يدخل على ال sys وهو diluted بكبره ال surface area بزيادة ال length عن طريق إنهم بفتحوا تانكين على بعض بالتالي بحقق هاد ال settling أو بودي ال Flowrate على برك بخزنها وثاني يوم ثالث يوم بسحبها مع ال Flow rate الداخل جديد على ال sys ليحقق إنه كلاشي تمام :: ، غير هيك

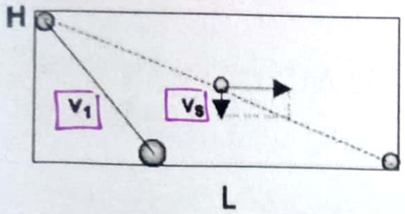
نورمنا على ال tank بعد يوم شتاء بتلاقي ال Particls كلها كونت رغوة على ال surface وصارت تعمل Fluding للجناب لأنها ما ترسبت صارت تعمل overflowrate تطلع channling من side لـ side مع الرغوة صارت تمسك بال Pupple وتقل Ploxs وثبت لأنه الهواء بحملها ص أقل فصلت طافية على السطح وركبت على الفقاعات وعلت scum يلي هي الرغوة :: .

Discrete particles to be removed in a horizontal flow tank

مهم

Case	Particles removed or not removed

CASE 1



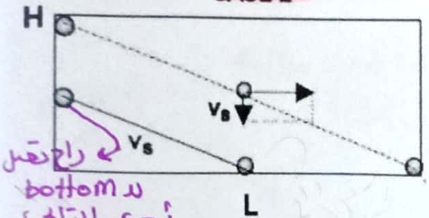
Particles removed:

- particles with a settling velocity equal to v_s that enter the tank at a height H
- particles with a settling velocity $v_1 > v_s$ that enter the tank at a height H

بدها أقل time لتترسب وهاد منيح ← ال particle will be removed بالتالي

ال floc. وال coag. بحسنو من عملية ال settling

CASE 2



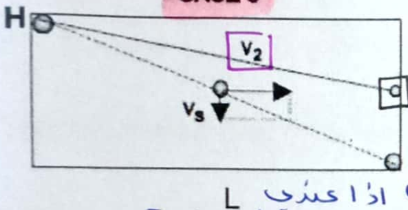
راح تقعد ب ال bottom أسرع بالتالي will be removed

Particles removed:

- particles with a settling velocity equal to v_s that enter the tank at a height lower than H → ال tank مصمم مثلاً على 3m بس دخلت ع 2m

ال Particle دخلت على مترين يعني هي أقرب لل bottom
مشكلة إذا ال Particle دخلت على ال tank ب H أعلى من ال design H

CASE 3



إذا عندي دوامات تعلو مرة بدل ما تنزل وهاي مشكلة آخر sed.

Particles not removed:

- particles with a settling velocity $v_2 < v_s$ that enter the tank at a height H

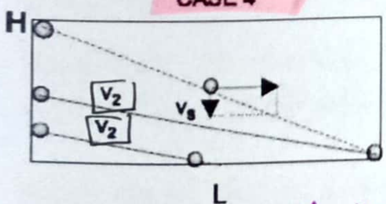
كأنها عملت channeling دخلت من مكان وطلعت من مكان بدون ما تدخل لل sys يعني بدها time أطول لتوصل لل bottom وممكن تنسحب للجهة الثانية قبل ما توصل بالتالي ال Particle ما بتتحرك.

مرات بال sys بيصير ال Particle غصب عنها تمشي بزكزاك بحطوا baffle منشان ال Profil يعني بيمشي بطريقة معينة هاد إذا بدك حل ل sys أعطاك مبني وفي مشاكل.

$v_2 < v_s$ بس قليلة شوي مثلاً slightly, small, ... تحكيلنا ← أقرب ل to be removed

Particles that can be removed:

CASE 4

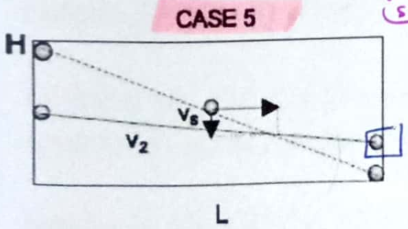


- particles with a settling velocity $v_2 < v_s$ that enter the tank at a height lower than H → دخلت ب H أقل فهي أقرب لل bottom ال channeling ما راح يقدر يسحبها من ال side الثاني

ال Profil بيتحكم فيها يعني أنا ومقيش حسب ال V وين تتحرك

Particles that may be not removed:

CASE 5



- particles with a settling velocity $v_2 < v_s$ that enter the tank at a height lower than H

هون ال V_2 أقل بكثير من V_s تحكيلي

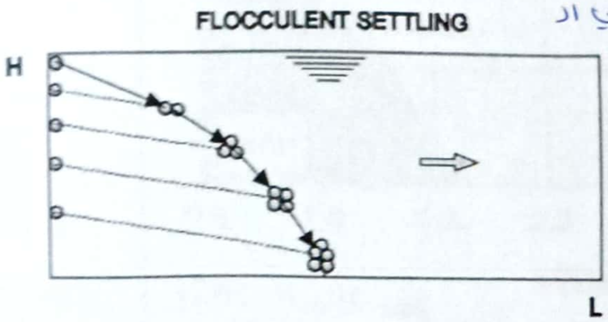
بيعتمد على ال Particle نفسها داخل ال sys هل هو conc. أو diluted

..., signif, cleary, large حسب السؤال أو الكلمات بميز بين ال case 4 & case 5 أو انه تحدد رقم ومنه بتعرف انه كثير قليل مقارنة ب V_s ولا قليل شوي وهكذا.

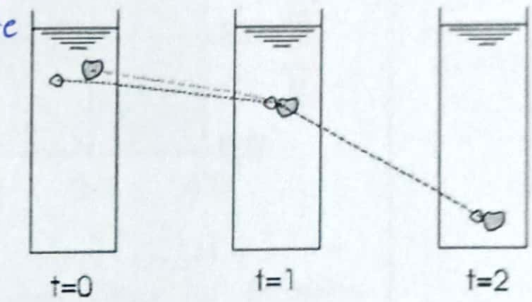
✱ بالامتحان تجيب للغة ال time مثلاً يعني بدل $V_1 > V_s$ تحكيلك الو الزمن أقل وهكذا حتى أعرف وأعرف هل بس قريب على V_s داخل ب H نفسها ولا أقل...

Flocculent Settling

- In flocculent settling, the particles agglomerate themselves and form flocs that tend to grow in size while settling.
- With the increase in the size of the particles (flocs), there is an increase in the settling velocity.
- Therefore, in flocculent settling the velocity is not constant as in discrete settling, but tends to increase.



Flocculent settling in a horizontal flow tank

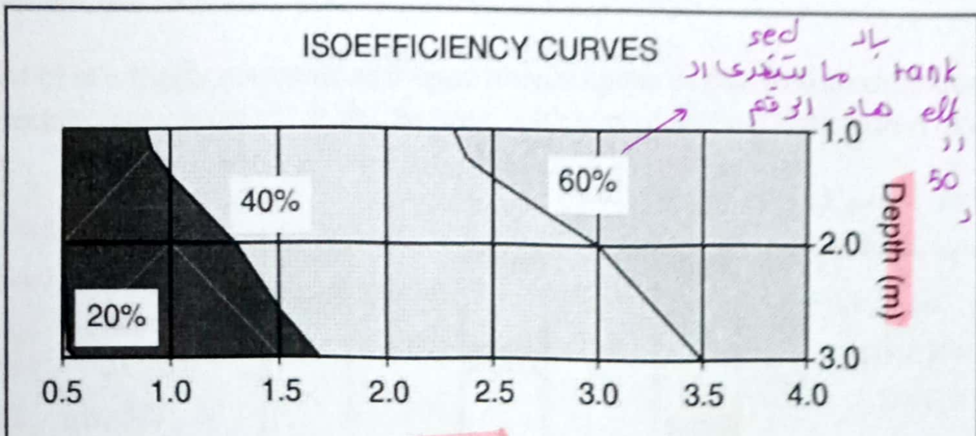


Flocculent settling in a settling column

Discrete → function of surface area.
flocculent → function of depth & time.

- Since the flocculation occurs while the particles go to the bottom, the greater the chance of contact they have, the greater will be the floc formation.
- As a result, the removal efficiency in flocculent settling is increased with an increase in the depth H and in the time t (differently from discrete settling).
- Similarly to discrete settling, flocculent settling in an ideal horizontal flow tank can be compared with settling in a column without flow.
- In the case of flocculent settling, the settling velocity of the individual particles is not analyzed, as in the case of discrete settling.
- Settling column tests are also useful here to permit the selection of the ideal overflow rate V_o

- In the flocculent settling test, the results are presented in the form of curves or a grid, showing the particle removal percentages at certain depths and times

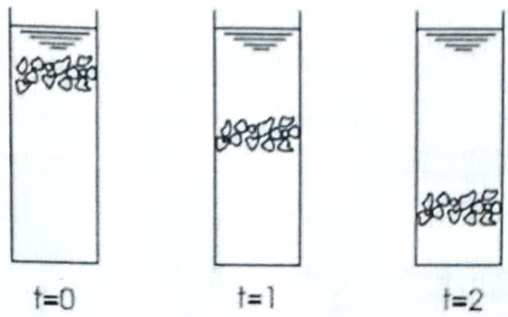


Zone Settling

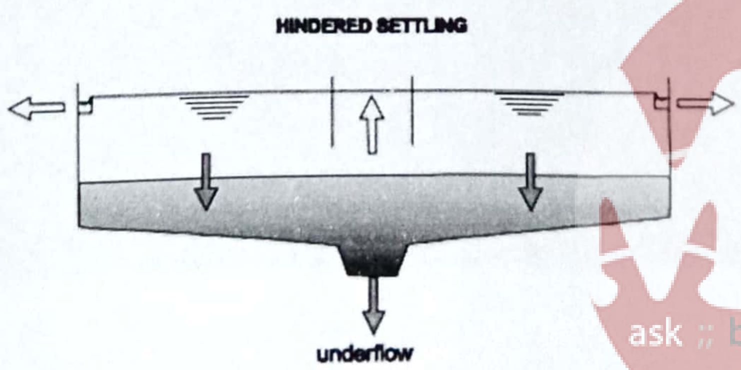
Settling in a column

- When there is a high solids concentration, a blanket tends to form.
- This blanket settles as a single mass of particles (the particles tend to remain in a fixed position with relation to the neighboring particles).
- A clear separation interface can be observed between the solid phase and the liquid phase, and the level of the interface moves downwards as a result of the sedimentation of the sludge blanket.
- For the blanket to move downwards, the liquid situated underneath tends to move upwards.
- In the zone settling, it is the settling velocity of the interface that is used in the design of sedimentation tanks. Zone settling is also called hindered settling.

- In a settling column completely homogenized with a high concentration of suspended solids, under quiescent conditions and after a short time, a clear interface is formed.
- While the interface moves downwards, the supernatant liquid becomes clarified, and a layer with a higher concentration is formed at the bottom.
- The level of this highly concentrated layer moves upwards due to the continuous increase of the accumulated material at the bottom, which cannot leave the column from its bottom.

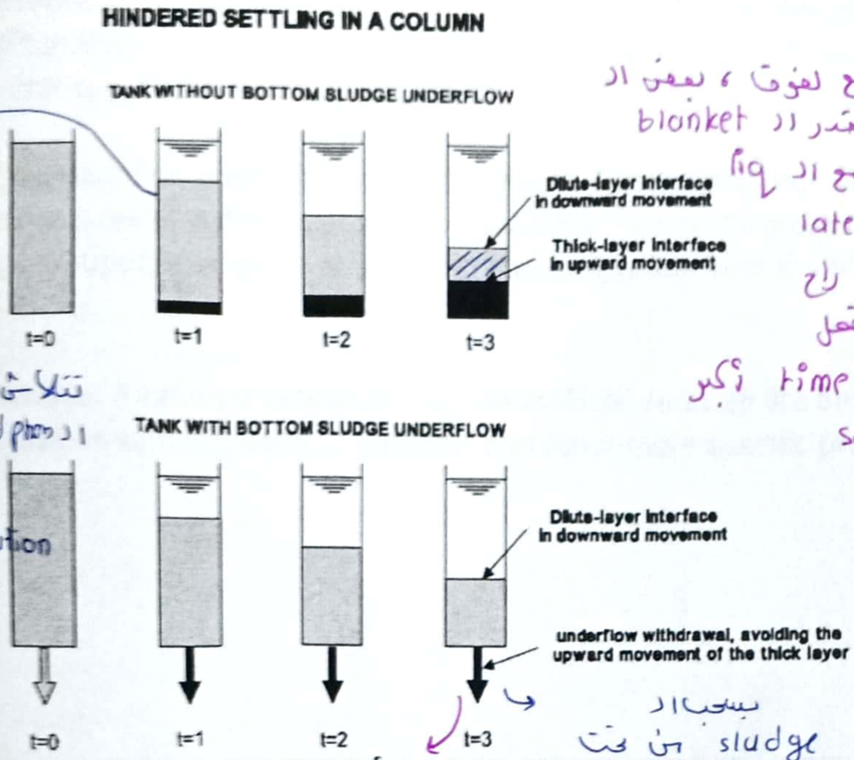


- In a sedimentation tank with continuous withdrawal of the settled sludge from the bottom, the more concentrated layer does not propagate upwards.
- The reason is that the underflow velocity of the sludge (downward, from the bottom) counterbalances the expansion velocity (upwards).
- This situation occurs in tanks with continuous sludge removal from the bottom, such as secondary sedimentation tanks in the activated sludge process.



عملية إزالة ال sludge من ال bottom
ما لازم تكون fast ولا slow لازم تكون optimize
جماعة التشغيل هم الأكثر معرفة بهاي الأمور.

Schematics present the behavior of the layers created in these two distinct conditions (without and with sludge removal from the bottom):



عشان another layer تتشكل بين ال solid وال liq هاي ال layer راح تتلاشى لأنها راح يكبر ال solid phase ويصير ال thick متع ال clear solution

ال liq بطلع لفوق ، بعض ال fine particles يلي ما قدر ال blanket يمسكهم راح يطلع مع ال liq فوق لكن later on هاي ال particle راح ترجع مرة ثانية تعمل settled down على time أكبر فبكبر ال solid phase thick

بسحب ال sludge من تحت بس فوق لا

لما أسحب ال solid تحت ما راح يعمل build up

Aeration Systems

Prof. Motasem Saidan

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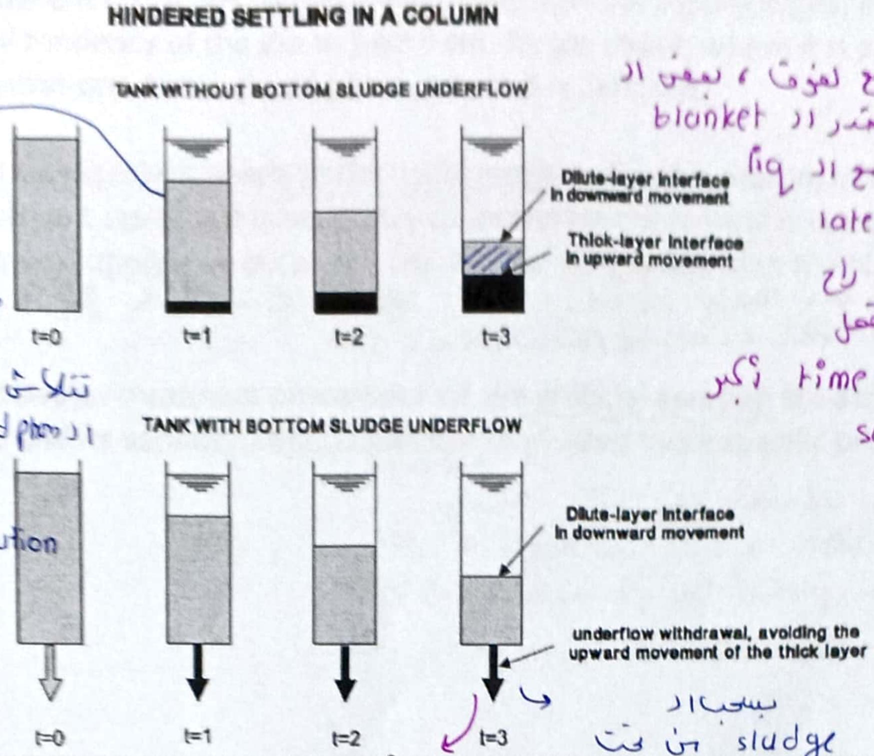
Schematics present the behavior of the layers created in these two distinct conditions (without and with sludge removal from the bottom):



Aeration Systems

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Introduction

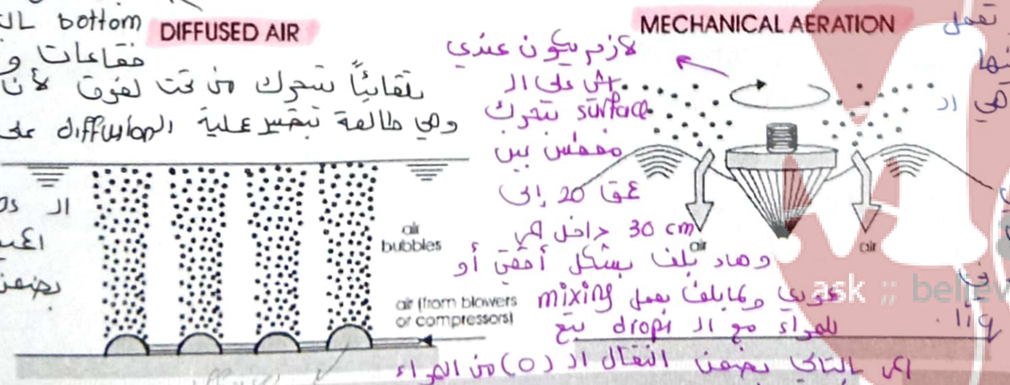
- Aeration is a unit operation of fundamental importance in a large number of aerobic wastewater treatment processes. When a liquid is deficient in a gas (oxygen, in this case), there is a natural tendency of the gas to pass from the gas phase, where it is present in sufficient concentrations, to the liquid phase, where it is deficient.

- Oxygen is a gas that dissolves poorly in the liquid medium. For this reason, in various wastewater treatment systems it is necessary to accelerate the natural process, in such a way that the oxygen supply may occur at a higher rate, compatible with the biomass utilization rate.

- Among the wastewater treatment processes that use artificial aeration are aerated lagoons, activated sludge and its variants, aerated biofilters and other more specific processes.

Artificial aeration

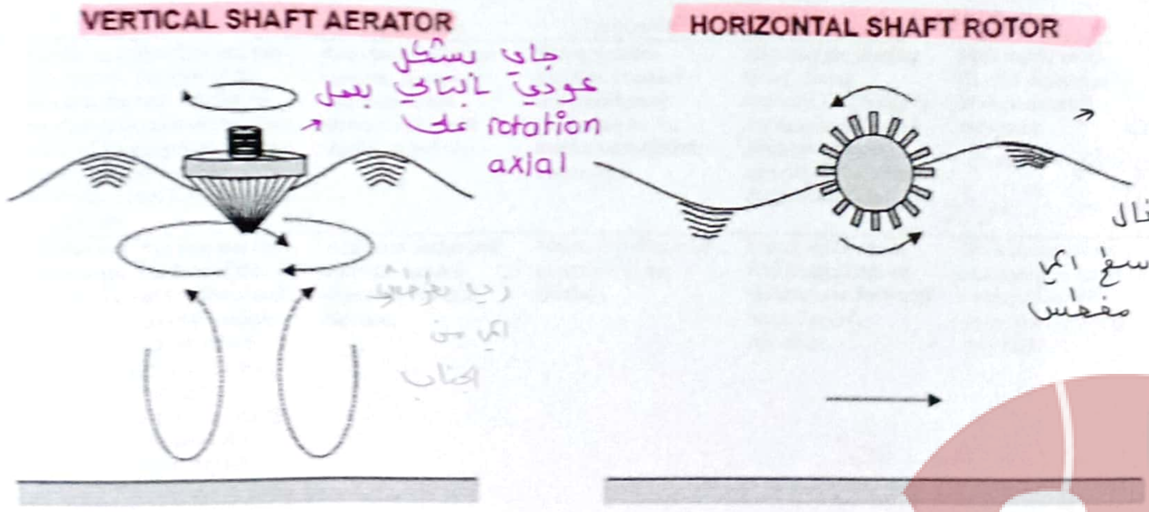
- In terms of sludge treatment, aerobic digesters also use artificial aeration.
- There are two main forms of producing artificial aeration:
  1. ➤ introduce air or oxygen into the liquid (diffused air aeration)
  2. ➤ cause a large turbulence, exposing the liquid, in the form of droplets, into the air, and also permitting the entrance of atmospheric air into the liquid medium (surface or mechanical aeration)
- Within these two types, which are presented below: aeration by diffused air and mechanical aeration



Mechanical aeration systems

- The main mechanisms of oxygen transfer by mechanical surface aerators are:
  - Atmospheric oxygen transfer to the droplets and the fine films of liquid sprayed in the air.
  - Oxygen transfer at the air-liquid interface, where the falling drops enter into contact with the liquid in the reactor.
  - Oxygen transfer by air bubbles transported from the surface to the bulk of the liquid medium.

- The more commonly used mechanical aerators can be grouped according to:
  - ❑ Classification as a function of the rotation shaft:
    - *vertical shaft aerators*
      - ✓ low speed, radial flow
      - ✓ high speed, axial flow
    - *horizontal shaft aerators*
      - ✓ low speed
  - ❑ Classification as a function of the supporting:
    - *fixed aerators*
    - *floating aerators*



- The power of mechanical aerators usually varies between 5 HP and 100 HP.

- In mechanical aerators, the submergence of the impellers in relation to the water level is a very important aspect in terms of oxygen transfer and energy consumption.
- The following situations can occur:
  1. Adequate submergence. The performance is optimal. There is good turbulence and absorption of air with relation to the oxygen consumption.
  2. Submergence above the optimal. The unit tends to function more as a mixer than as an aerator. The energy consumption increases without being accompanied by a substantial increase in the oxygen transfer rate.
  3. Submergence below the optimal. Only a surface spray is formed in the vicinity of the aerator, without creating an effective turbulence. The energy consumption and the oxygen transfer rate decrease.

Characteristics of the main mechanical aeration systems

Type of aerator	Characteristics	Application	Components	Advantages	Disadvantages	Standard oxygenation efficiency (kgO_2/kWh)
Low speed, radial flow	Similar to a high flow and low head pump. The flow of the liquid in the tank is radial in relation to the axis of the motor. Most of the oxygen absorption results from an induced hydraulic jump. Rotation speed 20–60 rpm.	Activated sludge and variants. Aerobic digesters. Large aeration units with depths up to 5 m.	Motor, reducer, impeller. Fixation units (bridges or platforms) for the fixed aerators (more common).	High oxygen transfer. Good mixing capacity. Flexibility in the design of the tank. High pumping capacity. Easy access for maintenance.	High initial costs. Careful maintenance of the reducers is necessary.	1.4 – 2.0
High speed, axial flow	Similar to a high flow and low head pump. The flow of the liquid pumped is upwards and follows the axis of the motor, passing through the volute before reaching a diffuser, where it is dispersed perpendicularly to the axis of the motor in the form of a spray. Most of the oxygen absorption occurs due to spray and turbulence. Rotation speed: 900 – 1400 rpm.	Activated sludge and variants. Aerobic digesters. Aerated lagoons.	Motor, impeller, float (a reducer is not needed).	Lower initial costs. Easily adjustable to variations in the water level. Flexible operation.	Difficult access for maintenance. Lower mixing capacity. Oxygen transfer not very high.	1.0 – 1.4
Horizontal shaft	The rotation is around the horizontal shaft. When rotor is rotating, a large number of fins perpendicular to the shaft cause aeration by spray and incorporation of air, besides providing the horizontal movement of the liquid in the reactor. Rotation speed: 20 – 60 rpm.	Activated sludge oxidation ditches (depth less than 2.5 m)	Motor, reducer, rotor.	Moderate initial cost. Easy to fabricate locally. Easy access for maintenance.	Limited shape of the tank. Low depth requirement. Possible problems with long shaft rotors. Oxygen transfer not very high.	1.2 – 2.0

Source: Arceivala (1981), Qasim (1985), Metcalf & Eddy (2002), Malina (1992), WEF & ASCE (1992)

Diffused air aeration system

The diffused air aeration system is composed of diffusers submerged in the liquid, air distribution piping, air transport piping, blowers, and other units through which the air passes.

The air is introduced close to the bottom of the tank and the oxygen is transferred to the liquid medium while the bubble rises to the surface.

The main diffused air systems can be classified according to the porosity of the diffuser and the size of the bubble produced:

- porous diffuser (fine and medium bubbles): plate, disc, dome, tube (ceramic, plastic, flexible membrane).
- non-porous diffuser (coarse bubbles): nozzles or orifices.
- other systems: jet aerator, aspirating aerator, U-tube aerator.

- Aspirating devices have an impeller at the lower end (immersed in the liquid), which, when rotating, create a negative pressure, sucking in atmospheric air through a slot situated at the upper end (outside the liquid).

- Air is diffused into the liquid medium in the form of small bubbles, which are responsible for the oxygenation and mixing of the liquid mass.

- The aspirating aerators are presented in some texts as mechanical aerators, since they have motors that rotate outside the liquid, and in other texts as diffused air aerators, because they generate air bubbles in the liquid medium.

الـ aspirating aerators لأنه في مروحة اشي بلف في ناس بصنفوا ك diffused
aerators وفي ناس بتصنفه ك mechanical aer. ، ما بفرق معنا بهمنا يعمل aeration
يلي بدو شو يسميه متدايش عن الـ impeller جوا الـ liq ، اذا وصلنا للعمق
بنفضل نصنفه ك diffused ، واذا كان الـ impeller أو الـ tube المغطس جاي على السطح
أو أقرب للـ surface فأنا بصنفه mech. aerators .

The diameters of the bubbles considered in the classification of the aeration type are:

- ✓ fine bubble: diameter less than 3 mm
- ✓ medium bubble: diameter between 3 and 6 mm
- ✓ coarse bubble: diameter greater than 6 mm

In general, the smaller the size of the air bubbles, the greater the surface area available for gas transfer, that is, the greater the oxygenation efficiency. For this reason, aeration systems with fine bubbles are the most efficient in the transfer of oxygen.

The oxygen transfer efficiency of the porous diffusers decreases with the use due to the internal or external clogging. The internal clogging is due to impurities in the air that are not removed by the filter. The external clogging is due to bacteria growth on the surface, or the precipitation of inorganic compounds.

The oxygen transfer rate can be changed to adjust itself to the oxygen consumption through the control of the blowers and the air distribution system, thus allowing energy savings.

aracteristics of the main diffused air systems

ion	Characteristics	Application	Advantages	Disadvantages	Average standard oxygen transfer efficiency (%)	Standard oxygenation efficiency (kgO_2/kWh)
les	The bubbles are produced in plates, discs, tubes or domes, made of a ceramic, glass or resin medium	Activated sludge	High oxygen transfer. Good mixing capacity. High operational flexibility through the variation of the airflow.	High initial and maintenance costs. Possibility of clogging of the diffusers. Air filters are necessary.	10–30	1.2–2.0
um les	The bubbles are produced in perforated membranes or perforated tubes (coated stainless steel or plastic)	Activated sludge	Good mixing capacity. Reduced maintenance costs.	High initial costs. Air filters could be necessary.	6–15	1.0–1.6
se les	The bubbles are produced in orifices, nozzles, or injectors.	Activated sludge	No clogging. Low maintenance costs. Competitive initial costs. Air filters are not necessary.	Low oxygen transfer. High-energy requirements.	4–8	0.6–1.2
rating tors	The bubbles are produced by a propeller rotating at high speed at the bottom of a tube, which sucks in atmospheric air through the orifice at the upper end of the tube.	Aerated lagoons, activated sludge	No clogging. Air filters are not necessary. Conceptual simplicity. Maintenance relatively simple.	Lower oxygenation efficiency compared to mechanical aeration or fine bubble systems.	–	0.6–1.2

ce: Qasim (1985), Metcalf & Eddy (1991), Malina (1992), WEF & ASCE (1992)

شرح نقطة 3 □ سلايد 10 😊

الـ Porous بيفي في مخبات الـ diffuser يلي جاي باد الـ bottom تبع الـ tank وهاد عادة بصير منه مشاكل الـ eff. بتقل والسبب هو الـ clogging يلي بصير يا إما داخل فتحات الـ disc أو خارجه (بصير تسكير بالفتحات الـ diffuser إذا التركيز internaly معناته دخل عندي impurities مع الهواء يلي داخل على هذا الـ diffuser وإذا كان التسكير خارجي معناته صار عندي Biomass و bacteria growth على الـ surface تبع هاد الـ Porous diffuser وهو يلي عمل الـ clogging أو مرات بصير عنا ترسيب لأي اشي org. بترسب خارج الـ diffuser فبتسكر عنا الفتحات لهيك الهواء يلي داخل على الـ diffuser لازم يكون قبله فيه فلتر حتى نفلتره من الشوائب وإذا كان عنا عمليات bacterial growth بالـ bottom تبع هاد الـ tank أو ترسيب لمواد غير عضوية داخل هاد الـ tank لازم الـ diffuser نفلعه ونعمله صيانة ونتظف ونرجعه مرة ثانية للـ sys. 😊

Factors influencing the oxygen transfer

a) Temperature

The influence of temperature occurs according to two apparently opposite directions:

- Influence on the saturation concentration (C_s). The increase of the temperature causes a reduction in the saturation concentration C_s, which implies a reduction in the transfer rate dC/dt.
- Influence on the mass transfer coefficient K_La. The increase in the temperature causes an increase in the coefficient K_La, which implies an increase in the transfer rate dC/dt.

$$K_La_{(T)} = K_La_{(20^\circ C)} . \theta^{(T-20)}$$

where:

$K_La_{(T)}$ = coefficient K_La at any temperature T (s^{-1})
$K_La_{(20)}$ = coefficient K_La at a temperature of 20 °C (s^{-1})
θ = temperature coefficient. Usually adopted as 1.024.

b) Atmospheric pressure (altitude)

- The influence of the altitude is manifested in the oxygen saturation concentration (the greater the altitude, the lower the atmospheric pressure and, therefore, the lower the saturation concentration).

$$f_H = \frac{C'_s}{C_s} = \left(1 - \frac{H}{9450}\right)$$

where:

f_H = correction factor for the DO saturation concentration by the altitude (–)
C'_s = saturation concentration at the altitude H (mg/L)
H = altitude (m)

c) Dissolved oxygen concentration

- Under steady-state conditions, the greater the dissolved oxygen concentration (C) maintained in the reactor, the lower the value of $C_s - C$, that is, the lower is the oxygen transfer rate.
- For example, in activated sludge systems, the DO concentration maintained in the reactor is usually in the range of 1.0 to 2.0 mg/L.

سلايد 12

\# إذا بدي أربي أسماك جوا منطقة بالغور لازم أعمل aeration عالي لأنه الـ Temp عالية بالتالي الـ DO equi الذائب أقل مايمكن naturally لهيك لازم أتدخل وأعمل aeration sys عالي الكفاءة لكن لو أنا عملت السمك بمنطقة باردة على الـ atmo. condi بدنا نعمل aeration بكميات قليلة لأن الـ DO الذائب داخل هاد الـ sys أعلى مايمكن.

d) Wastewater and reactor characteristics

- The specific characteristics of the wastewater being treated and the configuration of the reactor, which are different from the test conditions in which the oxygen transfer is measured, also exert an influence on the actual transfer rate in the field, under operating conditions.

- This influence occurs in two ways:

  - ❑ ***Influence on C_{sw}.*** The presence of salts, particulate matter and detergents affect the saturation concentration of the liquid in the reactor. This influence can be quantified through the following correction factor:

$$\beta = \frac{C_{sw}(\text{wastewater})}{C_s(\text{clean water})}$$

The values of β vary from 0.70 to 0.98, but the value of 0.95 is frequently adopted (Metcalf & Eddy, 1991).

  - ❑ ***Influence on K_La.*** The oxygen transfer coefficient is influenced by the characteristics of the wastewater as well as the geometry of the reactor and mixing level.

The correction factor is:

$$\alpha = \frac{K_La\ (\text{wastewater})}{K_La\ (\text{clean water})}$$

Typical values of α vary from 0.6 to 1.2 for mechanical aeration and from 0.4 to 0.8 for diffused air aeration (Metcalf & Eddy, 1991).

Oxygen transfer rate (OTR)

$$OTR_{standard} = \frac{OTR_{field}}{\dfrac{\beta . f_H . C_s - C_L}{C_s(20\,^\circ C)} . \alpha . \theta^{T-20}}$$

where:

$OTR_{standard}$ = Standard Oxygen Transfer Rate – **SOTR** (kgO_2/h)

OTR_{field} = Oxygen Transfer Rate in the field, under operating conditions (kgO_2/h)

C_s = oxygen saturation concentration in clean water, at the operating temperature in the field (g/m^3)

C_L = average concentration of oxygen maintained in the reactor (g/m^3)

$C_s(20\,^\circ C)$ = saturation concentration of oxygen in clean water, under standard conditions (g/m^3)

f_H = correction factor C_s for the altitude (= 1 – altitude/9450)

β = see comments

α = see comments

θ = see comments

T = liquid temperature (°C)

Example

In a wastewater treatment plant the supply of 100 kgO_2/h is necessary under operating conditions, using a mechanical aeration system. Determine the Standard Oxygen Transfer Rate knowing that:

- Liquid temperature: T = 23 °C
- Altitude = 800 m
- DO concentration to be maintained in the liquid: C_L = 1.5 mg/L

Solution:

Adopt the following values for the parameters of Equation 5

C_s (20 °C) = 9.2 mg/L, column 0 m altitude, for T = 20 °C

C_s = 8.7 mg/L, column 0 m altitude, for T = 23 °C

α = 0.90 (see comments for Equation 5.24)

β = 0.95 (see comments for Equation 5.23)

θ = 1.024 (see comments for Equation 5.21)

According to Equation 5.8 the value of f_H is:

$$f_H = 1 - \frac{\text{altitude}}{9450} = 1 - \frac{800}{9450} = 0.92$$

$$OTR_{standard} = \frac{OTR_{field}}{\frac{\beta . f_H . C_s - C_L}{C_s(20\,°C)} . \alpha . \theta^{T-20}}$$

$$= \frac{100}{\frac{0.95 \times 0.92 \times .8.7 - 1.5}{9.2} . 0.9 \times 1.024^{23-20}} = \frac{100}{0.62}$$

$$= 161 kgO_2/h$$

The final results are:

$OTR_{field} = 100\ kgO_2/h$ (given in the problem)
$OTR_{standard} = 161\ kgO_2/h$
Ratio $OTR_{field}/OTR_{standard} = 100/161 = 0.62 = 62\%$

كلما زادت القيمة كلما كان
ال sys شغال صح اذا
ال Ratio أقل من 50%
معناتها you need to
install another aerators لحتى
تحقق ال eff أعلى ما
يمكن

*Therefore, it can be seen that in the field the aeration system is capable of supplying only 62% of the capacity under standard conditions. For this reason, to obtain the value of $100\ kgO_2/h$ in the field, a system that supplies $161\ kgO_2/h$ under standard conditions must be specified.

Sludge Management: Calculations

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ال sludge هو biosolids ، بسميه sludge لأنه by product بدي أتخلص منه
وبسميه biosolid لما أكون بدي أنتشله على application ، جملة الزراعة بحكي انه ال biosolid
مفيد للتربة لأن فيه nutrients بالتالي ممكن يستخدم كسماد أو محسن للتربة

ال Pollution يلي بحصر بالمي وبحولها ww هو 0.1% هذا مع الوقت لما نعمل treatment
بصير تنقي المي وعنا دائماً من ال bottom عنا drain هذا منه بي و solid مع الوقت ال
conc. لل solid بزيد هذا يلي أخذته من ال bottom كـ grain
وال sludge هو by product بطلع من ال ww treatment

Introduction

- The term '***sludge***' has been used to designate the solid by-products from wastewater treatment.

طالع من ال sec وكله بكتيريا

- In the biological treatment processes, part of the organic matter is absorbed and converted into microbial biomass, generically called biological or secondary sludge. This is mainly composed of biological solids, and for this reason it is also called a ***biosolid***.

معنى أستخدم ال biosolid في UK

- The utilization of this term still requires that the chemical and biological characteristics of the sludge are compatible with productive use, for example, in agriculture.

معين لكن لازم تكون خواصه الكيماوية والبيولوجية متوافقة مع هاد ال application

كأنه بجعل ال sludge الصياد أي ممكن نستغله

- The term '***biosolids***' is a way of emphasizing its beneficial aspects, giving more value to productive uses, in comparison with the mere non-productive final disposal by means of landfills or incineration.

→ بدفنه أو بحرقه لنطلع كهرباء أو heat

ما بنفع أوجه sludge لأهداف زراعية وهو مليان جوانه heavy metals أو مفضلات

- Although the sludge represents only 1% to 2% of the treated wastewater volume, its management is highly complex and has a cost usually ranging from 20% to 60% of the total operating costs of the wastewater treatment plant.

وإذا بدي أنقله لا على شان هيك بتعدى ال 80% عشان تكاليف النقل عالية

- Besides its economic importance, the final sludge destination is a complex operation, because it is frequently undertaken outside the boundaries of the treatment plant.

لـ كميات كبيرة لهيك انت مضطر تنقله خارج حدود محطة المياه العادمة وهاد مكلف اقتصادياً

- The amount of sludge produced in wastewater treatment plants, and that should be directed to the sludge processing units, can be expressed in terms of mass (g of total solids per day, *dry basis*) and volume (m3 of sludge per day, *wet basis*).

ال sludge يا بنسميه dry sludge أو wet sludge
اذا dry بنحكي عن مادة ناشفة صلبة وحدتها اد g
أو kg أو ton واذا حكينا عن wet معناها بنحكي عن
m³ ، وهاد بعتمد قديش عملته conditioning
و drying في محطة معالجة المياه العادمة.

Example

مكان فيه 100 000 مواطن

For a 100,000-inhabitant conventional activated sludge plant compute the amount of sludge in each stage of the sludge treatment.

Wastewater treatment system	Sludge removed from the liquid phase: Sludge mass (gSS/inhabitant·d)	Dry solids conc. (%)
Conventional activated sludge		
Primary sludge	35–45	2–6
Secondary sludge	25–35	0.6–1
Mixed sludge	60–80	1–2

قديش كل واحد منا باليوم بيعطي g من ss

Solution:
Sludge removed from the activated sludge system, to be directed to the sludge treatment stage:

The activated sludge system produces primary and secondary sludge.
Sludge mass production:

- Primary sludge: 35 to 45 gSS/inhabitant·d
- Secondary sludge: 25 to 35 gSS/inhabitant·d
- Mixed sludge (total production): 60 to 80 gSS/inhabitant·d

Sludge mass production:

- Primary sludge: 100,000 inhabitants × 40 gSS/inhabitant·d = 4,000,000 gSS/d = 4,000 kgSS/d
- Secondary sludge: 100,000 inhabitants × 30 gSS/inhabitant·d = 3,000,000 gSS/d = 3,000 kgSS/d
- Mixed sludge (production total): 4,000 + 3,000 = 7,000 kgSS/.d

Sludge volume production:

- Primary sludge: 100,000 inhabitants × 1.5 L/inhabitant·d = 150,000 L/d = 150 m^3/d
- Secondary sludge: 100,000 inhabitants × 4.5 L/inhabitant·d = 450,000 L/d = 450 m^3/d
- Mixed sludge (production total): 150 + 450 = 600 m^3/d

Design data

Density, specific gravity, VS/TS ratio and percentage of dry solids for various sludge types

Types of sludge	VS/TS Ratio	% dry solids	Specific gravity of solids	Specific gravity of sludge	Density of sludge (kg/m^3)
Primary sludge	0.75–0.80	2–6	1.14–1.18	1.003–1.01	1003–1010
Secondary anaerobic sludge	0.55–0.60	3–6	1.32–1.37	1.01–1.02	1010–1020
Secondary aerobic sludge (conv. AS)	0.75–0.80	0.6–1.0	1.14–1.18	1.001	1001
Secondary aerobic sludge (ext. aer.)	0.65–0.70	0.8–1.2	1.22–1.27	1.002	1002
Stabilisation pond sludge	0.35–0.55	5–20	1.37–1.64	1.02–1.07	1020–1070
Primary thickened sludge	0.75–0.80	4–8	1.14–1.18	1.006–1.01	1006–1010
Second thickened sludge (conv. AS)	0.75–0.80	2–7	1.14–1.18	1.003–1.01	1003–1010
Second thickened sludge (ext. aer.)	0.65–0.70	2–6	1.22–1.27	1.004–1.01	1004–1010
Thickened mixed sludge	0.75–0.80	3–8	1.14–1.18	1.004–1.01	1004–1010
Digested mixed sludge	0.60–0.65	3–6	1.27–1.32	1.007–1.02	1007–1020
Dewatered sludge	0.60–0.65	20–40	1.27–1.32	1.05–1.1	1050–1100

Anaerobic digestion

- The word ***digestion*** in wastewater treatment is applied to the stabilization of the organic matter through the action of bacteria in contact with the sludge, in conditions that are favorable for their growth and reproduction.
- The anaerobic digestion process, characterized by the stabilization of organic matter in an oxygen-free environment, has been known by sanitary engineers since the late 19th century.

Comparison between raw sludge and anaerobically digested sludge

Raw sludge	Digested sludge
Unstable organic matter	Stabilised organic matter
High biodegradable fraction in organic matter	Low fraction of biodegradable organic matter
High potential for generation of odours	Low potential for generation of odours
High concentration of pathogens	Concentration of pathogens lower than in raw sludge

- It is desirable to have solids concentrations in the raw sludge fed to digestion in the order of 4% to 8%. Higher solids concentrations can be used, as long as the feeding and mixing units are able to handle the solids increase. Solids concentrations lower than 2.5% are not recommended, as excess water has a negative effect on the digestion process.
- Anaerobic bacteria are sensitive to several substances that, depending upon their concentrations, are capable to completely stop the digestion process. The main inhibiting agents are hydrocarbons, organochlorinated compounds, non-biodegradable anionic detergent, oxidizing agents and inorganic cations.
- In a conventional activated sludge WWTP, mixed primary sludge and excess activated sludge are biologically stabilized under anaerobic conditions and converted into methane (CH_4) and carbon dioxide (CO_2).
- The process is accomplished in closed biological reactors known as anaerobic sludge digesters. Digester tanks are fed with sludge either continuously or in batches, and the sludge is kept inside the tank for a certain period of time previously determined during the design phase.
- The sludge and the solids have the same detention time in the digester.

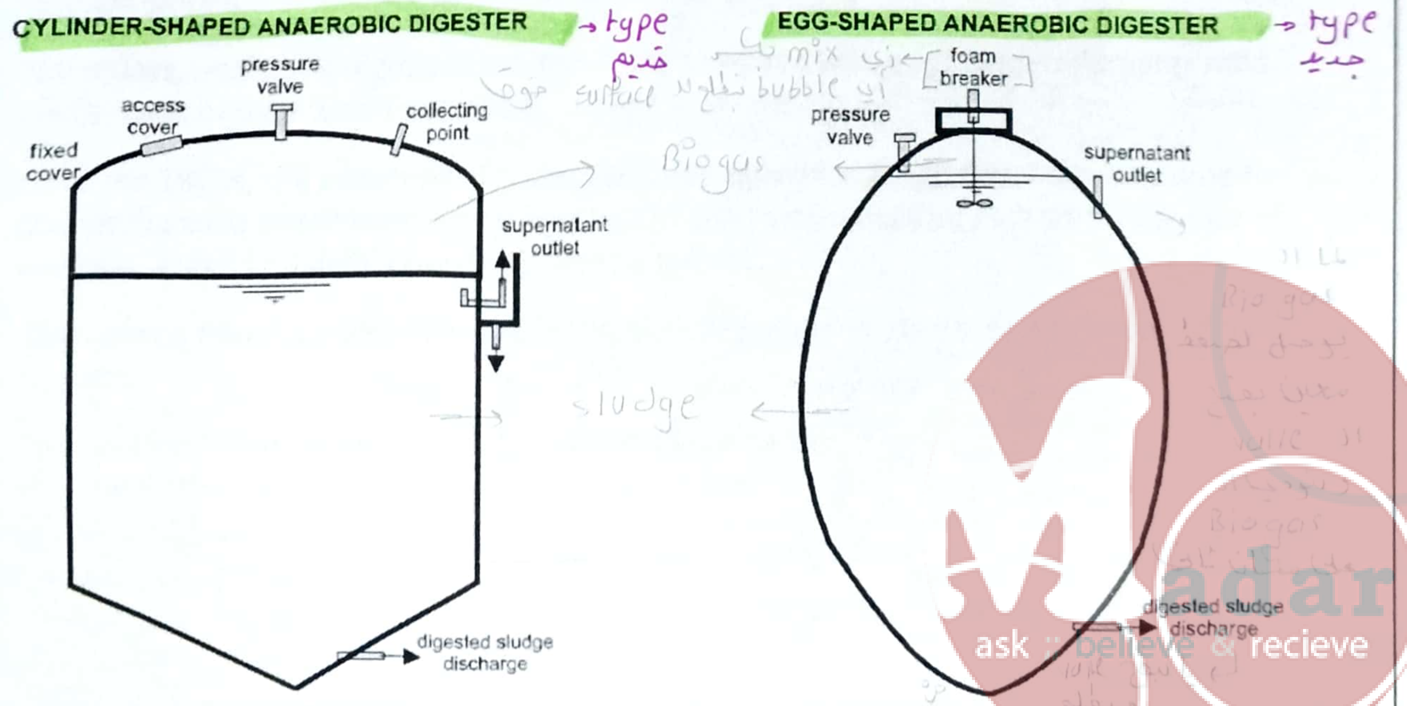
Design of anaerobic digesters

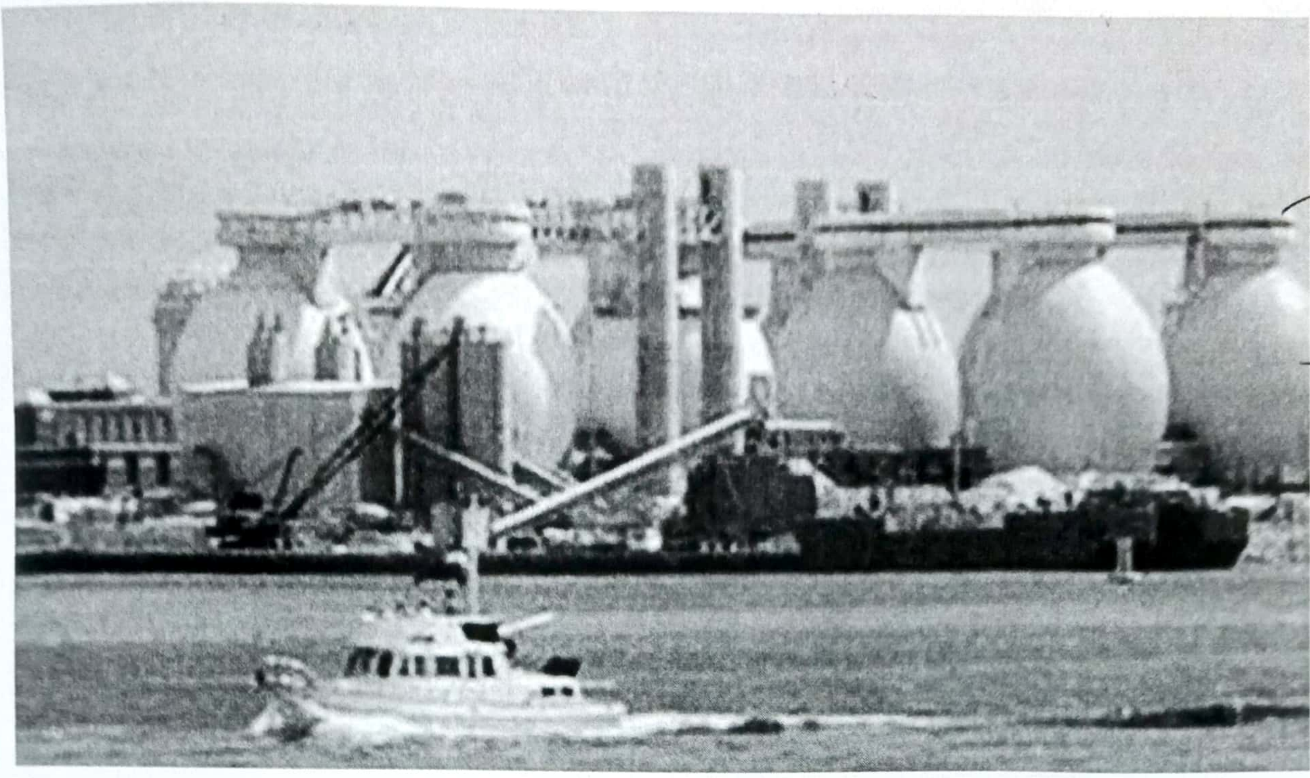
Typical design parameters for anaerobic sludge digesters

Parameters	Typical values
Detention time (θ_c) (d)	18–25
Volumetric organic load (kgVS/m^3·d)	0.8–1,6
Total solids volumetric load (kgSS/m^3·d)	1.0–2.0
Influent raw sludge solids concentration (%)	3–8
Volatile solids fraction in raw sludge (%)	70–80
Efficiency in total solids reduction (% TS)	30–35
Efficiency in volatile solids reduction (% VS)	40–55
Gas production (m^3/kgVS destroyed)	0.8–1.1
Calorific value of gas (MJ/m^3)	23.3
Digested sludge production (gTS/inhabitant·day)	38–50
Gas production (L/inhabitant·day)	20–30
Raw sludge heating power (MJ/kgTS)	15–25
Digested sludge heating power (MJ/kgTS)	8–15

Source: Adapted from CIWEM (1996)

Typical formats of anaerobic digesters (adapted from WEF, 1996)





Design of anaerobic digesters

- Most cylinder-shaped sludge digesters have less than 25 m diameter.
- Traditional design has a height-to-diameter ratio ranging from 1:2 to 1:3, and up to 33% bottom slopes.
- Nowadays, anaerobic digesters are also being designed with a 1:1 height:diameter ratio and a small or even zero floor slope.
- Until the 1970s, the anaerobic digesters were designed for 25–30 day detention time to counterbalance possible volume losses due to sand accumulation, high water content of the raw sludge and deficiency of the mixing system.
- Nowadays, there is a trend to reduce the detention time to 18–25 days in warm-climate regions.
- The required volume for the sludge digesters is given by:

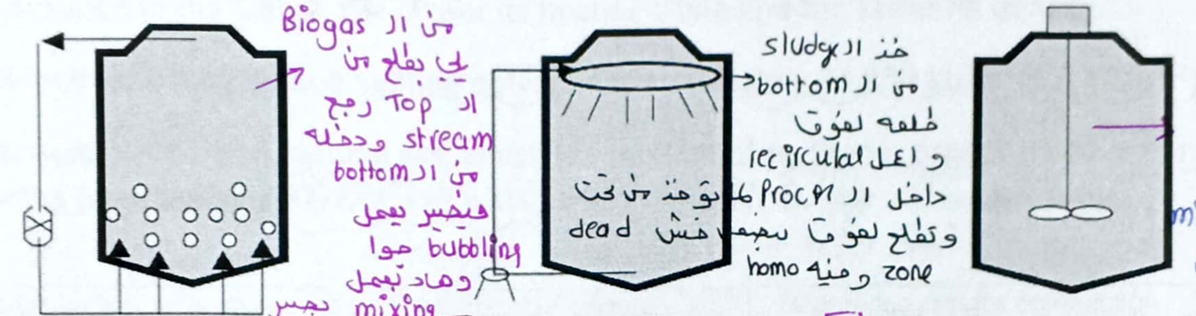
$$V = \frac{\text{Influent VS load (kgVS/d)}}{\text{Volumetric organic loading (kgVS/m}^3\text{-d)}}$$

تكملة نقطة 3 سلايد 12 ..

← بصير عندي مشاكل إنه مع ال sludge الداخل من ال Primary أو ال sec وحكينا ال primary معظمه مش كربون عندك SS من أصل تراب أو أي شيء مش free carbon فهاد لما يتراكم هوا ال tank بقلل ال volume ، وداًيما ال water content very high عادة من (80-94)% بكون بال tank مي وما بتبقى هو كربون solid Particle يلي هو sludge.

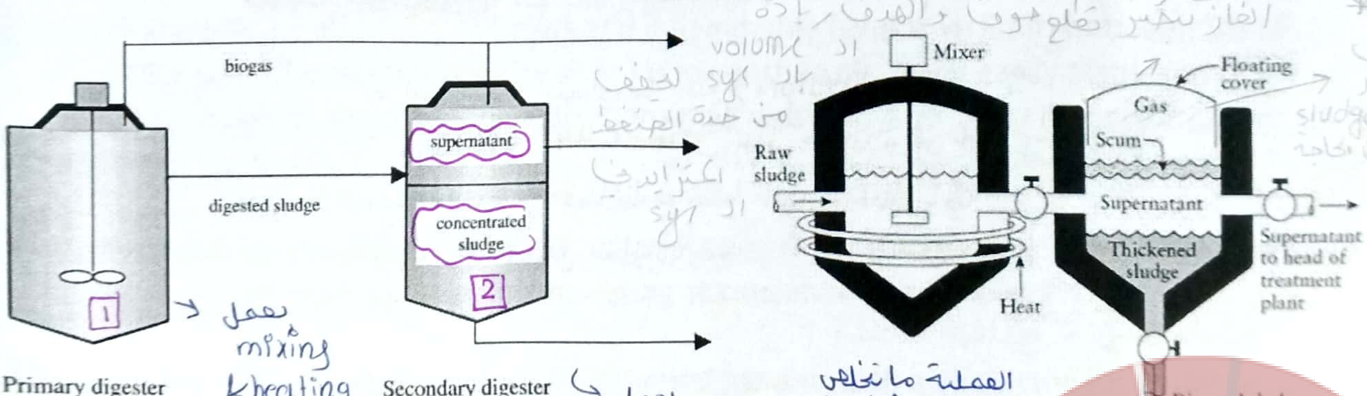
Mixing in anaerobic sludge digesters

- The maintenance of a homogeneous sludge medium within the digester is a fundamental requirement for its good performance.
- Keeping homogeneity is assured through sludge mixing devices, aiming to:
  - ✓ assure the internal medium uniformity from the physical, chemical and biological points of view,
  - ✓ quickly disperse the raw sludge when it enters the tank,
  - ✓ minimize thermal stratification, avoiding temperature gradients,
  - ✓ minimize foam formation and inert material (mainly sand) accumulation,
  - ✓ maximize the useful volume of the digester, minimizing hydraulic short circuits and the occurrence of dead zones,
  - ✓ dilute the concentration of occasional inhibiting agents throughout the digester volume



(a) Mixing through recirculation of pressurised biogas (b) Mixing through pumped recirculation of sludge (c) Mixing through mechanical mixer

Two-stage anaerobic sludge digestion system



Primary digester (complete mix) Secondary digester

- ➤ ***The primary digester*** is a complete-mix reactor responsible for fast stabilization of the organic matter,
- ➤ In ***the secondary digester*** the separation of solid/liquid phases prevails. Secondary digesters usually do not have mixing or heating systems, except when designed to replace the primary digester during maintenance periods.

Biogas

- Anaerobic digestion processes produce biogas, which is basically a mixture of methane (CH_4), carbon dioxide (CO_2), small concentrations of nitrogen, oxygen, hydrogen sulphide (H_2S) and traces of volatile hydrocarbons.
- Biogas production in anaerobic digesters is directly associated with the raw sludge feeding. Maximum biogas production in anaerobic digesters fed at regular intervals along the day normally occurs 2 hours after each feeding.
- The production rate of biogas may be estimated as 0.8 m^3/kg volatile solids destroyed, which is equivalent to approximately 25 L/inhabitant·day.
- Biogas density and thermal capacity vary with the composition. The higher the methane concentration in the biogas, the higher its heating value and the lower its density.
- A 70%-methane biogas has a heating power of approximately 23,380 kJ/m^3 (6.5 kW/m^3).
- As a simple comparison, natural gas, which is a mixture of methane, propane and butane, has a heating power of 37,300 kJ/m^3 (10.4 kW/m^3).

Poor mixture for combustion	Inflammable mixture	Mixture too rich for combustion
LEL = 5%	UEL = 15%	

The main characteristics of the biogas components

- Methane (CH_4) – odorless, colorless and inflammable (explosive limit) between 5% LEL and 15% UEL. The relative density (0.55) is lower than air, being easily dispersed. It is not toxic, although at very high concentrations may reduce the air oxygen concentrations to asphyxiating levels.
- Carbon dioxide gas (CO_2) – odorless, colorless and non-inflammable. The relative density (1.53) is higher than air, being asphyxiating at concentrations above 2%.
- Hydrogen sulphide (H_2S) – colorless, inflammable and with a characteristic rotten-egg smell. It has a relative density (1.19) nearly equal to air and 4.3% LEL and 43.5% UEL. It is irritant and asphyxiating. Concentrations higher than 1% leads to unconsciousness.

Gas	% (volume/volume)
Methane	62–70
Carbon dioxide	30–38
Hydrogen sulphide	50–3,000 ppm
Nitrogen	0.05–1.0
Oxygen	0.022
Hydrogen	<0.01
Water vapour	Saturation

Biogas ← CH_4 (كغاز قابل للاشتعال)
+
CO_2

هدول الـ domenant بالـ mix

→ دايمًا CH_4 أعلى من CO_2 في حال الـ sys كان شغال eff
CH_4 ← 55%
CO_2 ← 45%
أعلى اشي بيوصل إله الـ CO_2

* CH_4 → (50 – 70)% → حسب انت وين شغال

* CO_2 → تكملة لل 100% → (30 – 50)%

* other gases بحدود 1% بيسمو هاد بكون بشكل خاص المسيطر هو الـ H_2S

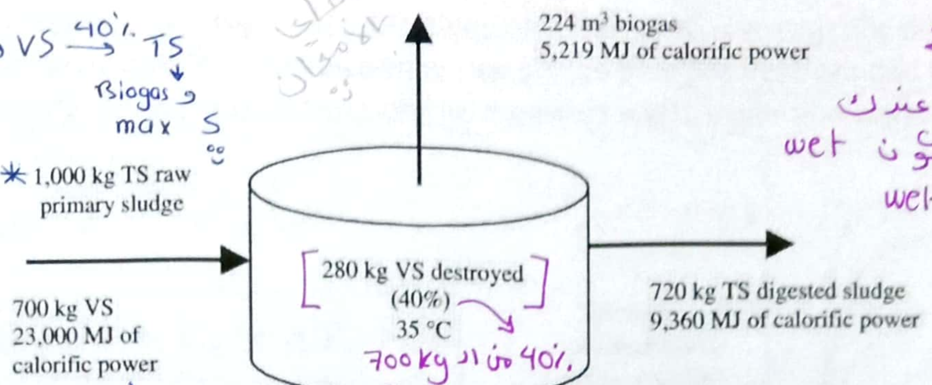
← مثلًا مخيم الزعتري فيه 100000 مواطن كم الـ Biogas بطلع :-

25 * (100 000) * 70%
↓
بضرب فيه لأن مش اشي 100% فعال هاد الـ Preestimated اشي مش دقيق بس الواحد يعرف وين رايح

natural gas ← methan, propane, butane

لـ الغاز يلي بنستخدمه للطبخ propane & butane :
ضفنا عليه CH_4 صار غاز طبيعي وهو يلي بنشغل عليه محطاتنا لإنتاج الطاقة الكهربائية وهو من أفضل الغازات بعد الـ H كاحتراق كلي .

Typical mass and heat balance of anaerobic sludge digestion



- raw sludge heating power: 23 MJ/kgTS × 1,000 kgTS = 23,000 MJ
- amount of volatile solids destroyed: 700 kgTS × 0.4 = 280 kg VS
- amount of digested sludge: 1000 – 280 = 720 kgTS
- digested sludge heating power: 13 MJ/kgTS × 720 kgTS = 9,360 MJ
- biogas production: 0.8 m³/kg VS destroyed
- biogas volume produced: 280 kgVS × 0.8 = 224 m³
- biogas heating power: 23.3 MJ/m³ × 224 m³ = 5,219 MJ

- The raw sludge heating power ranges from 11 to 23 MJ/kgTS on a dry weight basis, depending upon the type of sludge and the concentration of volatile solids.
- The digested sludge has a lower heating power, which ranges from 6 to 13 MJ/kgTS due to the smaller concentration of volatile solids.
- Heating is necessary in cold weather climates to compensate for heat losses through the digesters outer surface and to raise the temperature of the raw sludge fed daily.
- Biogas can be used as a heat source for digester heating.
- Biogas is used to feed the furnace and heat the boiler, with the sludge heating indirectly accomplished by heat exchange units.
- In most cases, the system is self-sufficient and no further complementary external heating source is required, except during winter in very cold regions.
- An external heating source (e.g., fuel oil) is necessary only for the unit start-up.

هنا اشي اسمه upper heat value واشي lower heat value ، كلما كان ال water content بال fuel حقيقة معناه ال calorific value في ال higher heat value وكلما كان ال water content بال fuel أكبر جزء من ال heat راح يروح لتبخير بالتالي راح أخسره وهاد اسمه lower heat value .

← 720 kg TS راح يطلعوا من ال bottom لل digister وهو digested يعني البكتيريا اشتغلت عليه بس الكربون يلي فيه ماتحول لـ Biogas .

← ال anaerobic مش complete process إذا بدك نقله complete بدل ما تستنى 18-25 يوم ممكن استنى 3 أشهر ليصير ال distruction لـ 90٪ وهاد موات بنحكي ما بدنا لأنه عيات ال sludge يلي بتجي الحطة عالية بالتالي بقلل بـ 40٪ بدل ما يتراع ال sludge و احقد استنى أيام أطول لأعمل complete rxn لهيك ال anaerobic هو partial conversion process وعادة بعدها مغرومين نرجع كمان مرة عليه aerobic لأحول ال sludge لـ soil conditioner مواد للزريعة ∴ مش تراب هدفه يحسن التربة .

← الحجم بال 18000 و ال 9360 نخمه تقريبًا لهيك مش غلط نستعمله بمصانع الاسمنت لنتخلص منه وما يظل متراكم بالطبيعة فال Row sluge سواء digested ولا محولة لـ Biogas بنقدر نستخدمه كـ ulternativ fuel وقود بديل من fuel

← ال 0.224 هي فعليًا 0.7 من ال vs مضروبة بـ 0.4 مضروبة بـ 0.8 احنا safty factors بنحكي خليها 0.2 فبانت احسب ال TS يوميًا حط ال load الكلي حسب ال m^3 الداخل على المحطة يوميًا بطلع معك ال total TS يلي دخل على كل المحطة وطلع كـ sludge من ال Primary أو ال sec أو ال total فاضربه بـ 0.2 بطلع ع m^3 متوقع يطلع معاك من هاد ال sludge بعد 18 يوم .

0.4 ← هو ال distruction لل vs وهاد ال 0.4
80٪ منه بتحول لـ Biogas (من هون اجو ال 0.8 ، 0.4)
ال 0.7 ال vs content maintinance ∴

سلايد 18

← النشاط التجاري يلي بصير بالمدينة بنعكس على ال sludge روح على مناطق زي الغور عندها نشاط زراعي بالتالي ال Bio content يلي بيجي من ال ww فيها C عالي من أصل حيوي روح على مناطق فيها مصانع ألبان نفس الاشي في إحدى المناطق هنا مصنع مشروبات غازية وجود هاد المصنع كان رفع ال BOD لـ 3 أضعاف الطبيعي وبالتالي هاد راح يعطيني Bio content عالي لهيك دائمًا بنحكي وجود عينات مرافقة

تابع لسلايد 17 ⇐

* إذا بدنا نستعمل ال table كل أسئلة
وما أعطانا رقم معين لاخذ اعلى رقم

Row sludge .. 15 - 25
↓
بناخذ 25

[1] Raw → 23 × 1000
احنا بالامتحان إذا ما في
رقم بناخذها 25
من ال Range

الامتحان بس رح يعطي
ال TS وال VS والباقي
بنحسبه بالاعتماد على الجدول
يلي بسلايد 9+15

[2] ال VS مش كله → 40 - 55 → eff
لو ما أعطى قيمة بتحرر الهيك بنضرب ال 700
بناخدها 55% بال eff يلي بالجدول

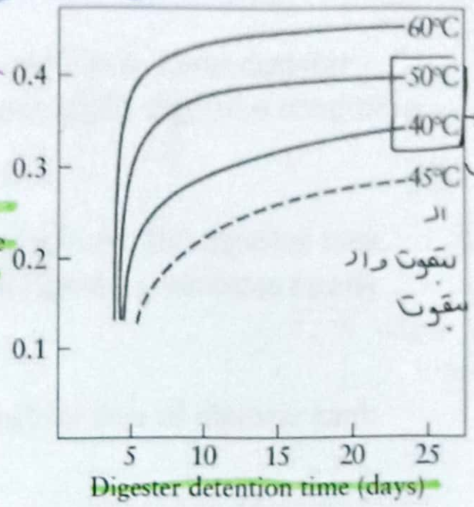
[3] 1000 - 280 → TS
700 - 280 → VS

Needed heat

- The heat needed to keep anaerobic digesters near 35 °C – mesophilic digestion – is the heat needed to heat the incoming raw sludge plus the heat needed to compensate for heat losses through the digesters walls, cover and bottom.

- Thus:

$$Q = M_f \times C_p \times \Delta T_1 + H$$



where:

Q = sludge digester daily energy demand (kJ/d)
M_f = raw sludge mass fed to the digester (kg/d)
C_p = specific heat of water (kJ/kg·°C)
ΔT_1 = difference between the raw sludge temperature and the digester temperature (°C)
H = heat loss through the digester walls (kJ/d)

- The daily heat loss through all the digester surface can be determined by:

$$H = U \times A \times \Delta T_2 \times 86.4$$

where:

U = heat transfer coefficient (J/s·m²·°C)
A = digester outer surface area (m²)
ΔT_2 = difference between the digester inner temperature and the outer temperature (°C).

- Raw sludge mass fed to digester – Mf: thermodynamically, a raw sludge up to 6% solids content may be considered water, with a density of 1 kg/L and specific heat (Cp) of 4.20 kJ/kg·◦C.

- Temperature difference – ΔT: varies with the site climatic conditions. Inner digester temperature must remain between 35◦C ± 3◦C to assure mesophilic digestion conditions.

- Heat transfer coefficient – U: depends on the material used to build the digester tank. Literature gives U values of 2–3 J/s·m².◦C for well-insulated digesters, whereas poorly insulated digesters may have U values of 3–5 J/s.m².◦C.

- Digester surface area – A: includes side walls, cover and bottom area of digester tank.

HW

Design a primary anaerobic digester using data.

Input data:

- Population: 67,000 inhabitants
- Average influent flow: Q = 9,820 m³/d
- Influent SS load: 3,720 kg/d
- Influent SS concentration: SS = 379 mg/L
- SS removal efficiency in the primary clarifier: 60% (assumed
- Mixed sludge load to digester: 3,307 kgTS/d
- Influent sludge flow: Q = 64.2 m³/d
- VS/TS ratio = 0.77

Requirements:

(a) Digester volume
(b) Hydraulic detention time
(c) Primary digester effluent sludge (influent sludge to secondary digester)
(d) Heat balance in digester