Environmental

Summer
2025/2026

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Water Quality Parameters

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7.3
2019

Water Quality

بحكم حسب الهدف المستخدم نسبي

قذر

Q: When is dirty water?

يعتمد بالطبع على ما نعنيه بكلمة قذر

Answer: of course depends on what we mean by dirty.

يشير إلى أن تقييم جودة المياه قد يكون ذاتيا ويعتمد على السياق والمعايير المستخدمة.

معالم جودة المياه

Water Quality Parameters

- أي عوالق بتعطي طعم ولون ورائحة **Physical** → turbidity
- مواد كيميائية **Chemical**
- مواد من مصدر حيوي **Biological**
- اشياء مشعة **Radiological**

* هذه التصنيفات تستخدم لتقييم سلامة المياه للاستهلاك البشري، زراعة أو صناعة بناءً على خصائصها المختلفة

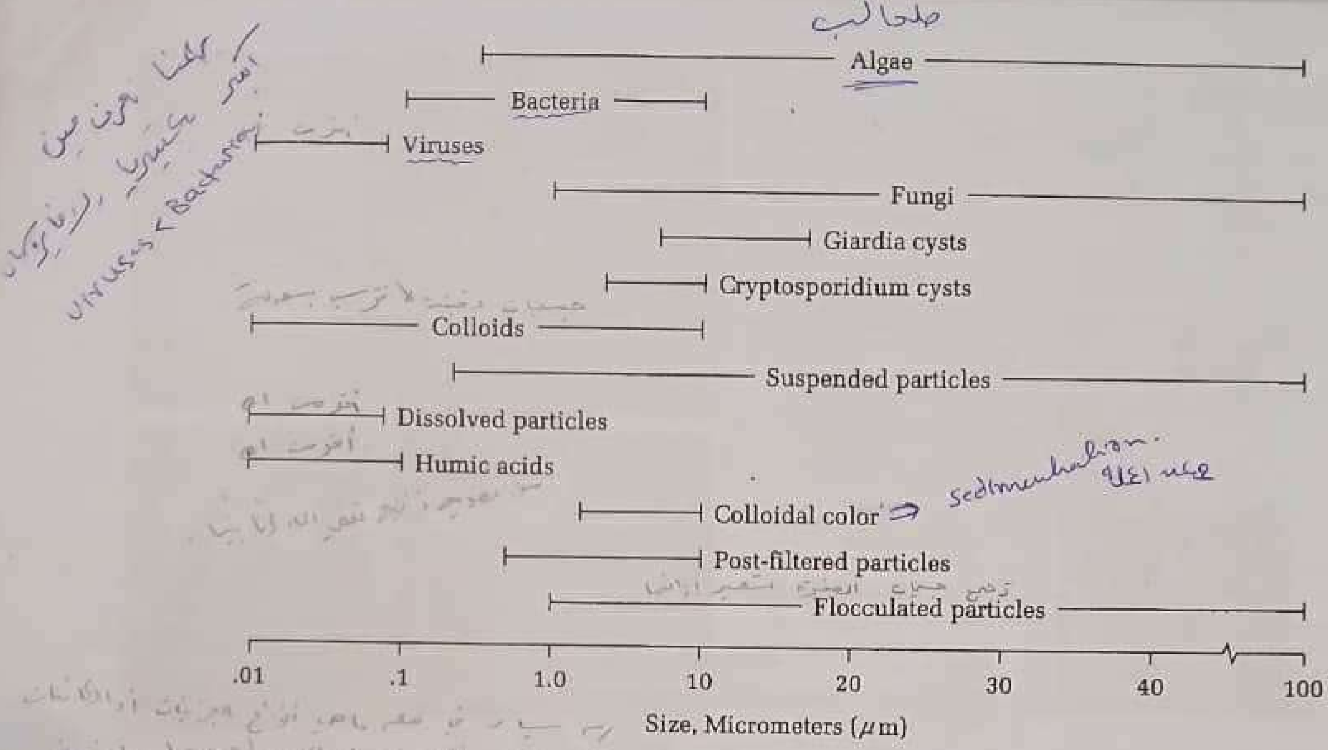
* هذه المعايير تستخدم لتحليل الخصائص الفيزيائية للمياه ... تحديد مدى صلاحيتها للاستخدام الآدمي أو الصناعي

Physical Parameters

are the first step in water quality assessment before chemical/biological analyses.

1. بتقدر تشوفهم **Suspended solids (big particles)** that remain undissolved in water
2. ما بتقدر تشوفهم **Turbidity (tiny particles)** تسبب العكر — Causing cloudiness affecting water clarity
3. **Odor and Taste** Indicators of chemical/organic contamination
4. **Color** يدل على وجود شوائب أو مواد عضوية — May signal impurities or organic matter
5. **Temperature** Influences oxygen solubility and microbial growth

Sizes of Particles in Water



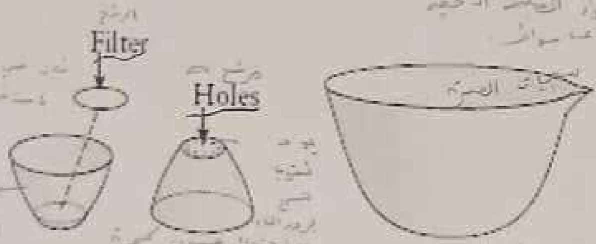
Solids by Size

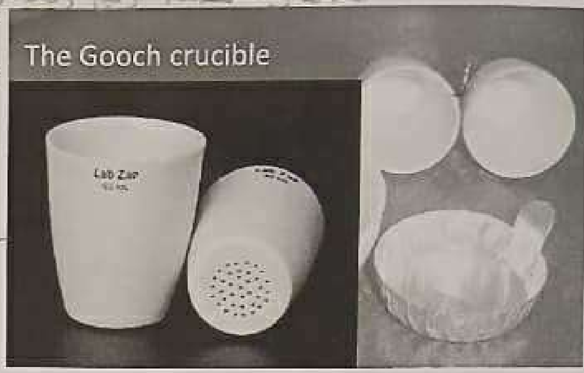
مش مهم الارقام، بس مهم نعرف ترتيبهم

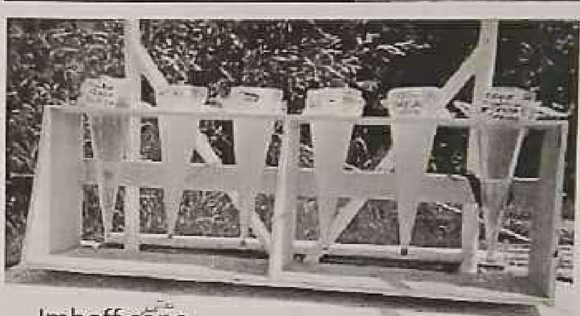
Classification	Diameter (mm)
مذاب — Dissolved	< 0.000 001
عوالق مذاب — Colloidal	0.000 001 – 0.001
عوالق — Suspended	0.001 -0.1
Particulate	> 0.1

SS Separation from Water

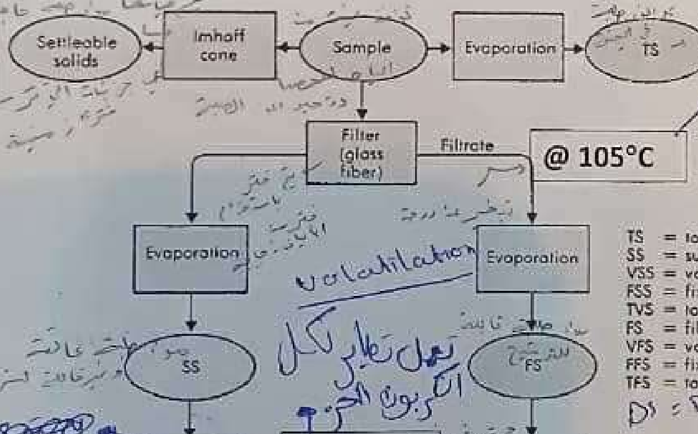
① Filtration
② distillation







Imhoff cone



TS = total solids
SS = suspended solids
VSS = volatile suspended solids
FSS = fixed suspended solids
TVS = total volatile solids
FS = filtrable solids
VFS = volatile filtrable solids
FFS = fixed filtrable solids
TFS = total fixed solids
DS = Dissolve Solids

TS + TDS = TSS

Suspension
dissolve

Volatile → Fixed

volatilation

Fixed carbon

1000

1100

Volatile Suspended
Total Volatile Solids
Total Fixed Solid

TS = TSS + TFS

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.

TS & SS

$$TS = \frac{W_{ds} - W_d}{V} \times 10^6$$

where,

TS = total solids, mg/L
W_{ds} = weight of dish plus the dry solids after evaporation, g
W_d = weight of the clean dish, g
V = volume of sample, mL

$$SS = \frac{W_{df} - W_d}{V} \times 10^6$$

where,

SS = suspended solids, mg/L
W_{df} = weight of dish plus dry filtered solids, g
W_d = weight of clean crucible and filter, g
V = volume of sample, mL

TS DS SS

➤ Total solids = ***dissolved solids*** + ***suspended solids***.

▪ A ***Gooch crucible*** is used to separate suspended solids from dissolved solids

Solids: FS & VS

$$FS = \frac{W_{du} - W_d}{V} \times 10^6$$

Where,

FS = fixed solids, mg/L
W_{du} = weight of dish plus unburned solids, g
W_d = weight of clean crucible and filter, g
V = volume of sample, mL.

$$VS = TS - FS$$

Where,

VS = volatile solids, mg/L.

Although volatile solids are considered to be organic, some of the inorganics are decomposed and volatilized as well at the 550°C - 600°C used for the test. However, this is not considered a serious drawback.

Turbidity

Ting partical

- It is the muddy or cloudy appearance of clay or such other particles that presents hindrance to the path of light .

- The turbidity is measured by a turbidity rod or a turbidity meter with physical observations and is expressed as the suspended matter in mg/l or ppm (part per million).

- Colloids, clay, silt, tiny fragments of organic matter and microscopic organisms (bacteria, algae) are some of the substances that cause turbidity.

Units of turbidity

- The standard unit of turbidity is that which is produced by 1 mg of finely divided silica in one liter of distilled water

- The interference in the passage of light caused by a suspension of 1 mg/l of silica is equivalent to one **turbidity units** (TU).

in 1 L distilled water

NTU

Measurement methods:

- Nephelometers (NTU)
- Jackson candle turbidimeter (JTU)

beaker

Taste and Odor

- A physical characteristics of drinking wa[…] aesthetic reasons.
- The dissolved inorganic salts or organic […] gases may impart taste and odor to the […]
- Inorganics (e.g. soil components) are u[…] only be responsible for taste.
- T & O are most commonly caused by: algae, decomposed organic matter, and dissolved gases.
- Oxidants (Chlorine, potassium permanganate) are used to oxidize the materials causing the taste and odor. Or Activated carbon filters can be used.

T & O measurement

- The extent of taste or odor is measured by a term called **odor intensity** which is related with threshold odor, which represents the dilution ratio at which the odor is hardly detectible.

➤ The water to be tested is gradually diluted with odor free water and the mixture at which the detection of taste and odor is *just lost* is determined.

➤ The odor is measured (by human nose) and expressed in terms of a **threshold odor number** (TON)= (Vt+Vd)/Vt.

Vt: volume tested, Vd: volume added.

TON=1 is the lowest value possible.

Example: 50 ml is diluted to vol. of 200 ml. The dilution no. equals 200/50 = 4 = TON

50 + 150 = 200

200/50 = 4 TON

diluted with (50+200)/50

Color

- It is a physical characteristic of drinking water that are important for aesthetic reasons.
- It may be caused by dissolved (*true color*) or suspended colloidal particles (*apparent color*) or by dissolved organic matters from decaying vegetation.
- It is measured in the labs by Nessler's tubes by comparing the sample with the known color intensities. More precisely tintometer measures it.
- One color unit is equivalent to the color produced by a 1 mg/l solution of platinum.

True Color	apparent color
dissolved matter	suspended dissolved and organic

M. Saidan

Temperature

- Warm water tastes flat.
- Cooling water suppresses odors and tastes and makes it more palatable.
- Temperature also affects the chlorination and purification of water.
- Disinfection takes longer when water is colder, and purification capacity is reduced with reverse osmosis treatment equipment.
- An average temperature of 15°C is generally suitable.

1. Total dissolved solids: 6

- Hardness
- Alkalinity
- Fluoride
- Metal ions
- Organics
- Nutrients

عسر المياه

Hardness

علية بسيطة كثيرة بالاقتران

[2+ or more]

- **Hardness** is caused by multivalent cations (or minerals)—such as calcium, magnesium and iron—that dissolve from soil and rocks (particularly limestone).

تربة

خاصة الحجر الجيري. لا تسبب مشاكل صحية

➢ While hardness does not cause health problems, it does reduce the effectiveness of soaps, and cause scale formation especially in heat transfer equipment.

طبقة كلسية

- **Total hardness (TH)** is defined as the sum of the multivalent cations in the water. Mainly, Calcium (Ca^{2+}) and Magnesium (Mg^{2+}).

$$TH = \sum(\text{Multivalent cations}) \cong Ca^{2+} + Mg^{2+}$$

➢ ~~Typical~~ units for hardness are mg/L as $CaCO_3$ and meq/L

50

milli equivalent

Hardness Classification

كيف نفحص

Hardness

qualitative نوعي

→ Quantativity كمي ونفحص بالمختبر ونشوف

→ qualitative نوعي نحط عليه قطرة كاشفة للون ونعرف اذا Hard or soft وصار شغلنا بالمصانع

هدول بالمصانع

- Soft < 50 mg/L
- Moderate = 50 -150 mg/L
- Hard = 150 -300 mg/L
- Very Hard > 300 mg/L

ما يترك للمستهلك

حل

➤ Treatment usually left to consumer (domestic, industrial, etc.) depending on needs.

Hardness Classification

Classification	Hardness meq/L	Hardness mg/L as $CaCO_3$
Extremely soft to soft	0–0.9	0–45
Soft to moderately hard	0.9–1.8	46–90
Moderately hard to hard	1.8–2.6	91–130
Hard to very hard	2.6–3.4	131–170
Very hard to excessively hard	3.4–5	171–250
Too hard for ordinary domestic use	>5	>250

لازم اشوف unit هيك

Source: L.A. Lipe and M. D. Curry, "Ion Exchange Water Softening," a discussion for water treatment plant operators, 1974–75 seminar series sponsored by Illinois Environmental Protection Agency.

Hardness Calculations

فهم جدا ١٣ هاد القانون

شان حول

mg/L → Concent ✓ $C_q = \frac{C}{EW}$ → (mg/L)

meq/L

نستخدم هاي المعادلة

where C_q = concentration in meq/L
C = concentration in mg/L
EW = equivalent weight in g/eq or mg/meq → molecular weight - atomic weight

$$\boxed{C_q = \frac{C}{EW}}$$

$$\boxed{EW = \frac{\text{AW or MW}}{n}}$$

n → cation charge

where, atomic weight (AW) and molecular weight (MW), valence or ionic charge (n, which is always positive):

Ca mg → +2
iron → (+3)

$C_q \times 50$

To convert to the standard unit mg/L as $CaCO_3$, the meq/L concentration is multiplied by the equivalent weight of $CaCO_3$, which is 50.0 mg/meq (100 g/mol/ 2 eq/mol):

$$C_{CaCO3} = C_q \times \boxed{50.0}$$

→ EW $\frac{40 + 12 + 16 \times 3}{2}$ → $\boxed{Ca^{2+}}$

where C_{CaCO3} = concentration in mg/L as CaCO3
C_q = concentration in meq/L

Example 10.4

Problem The concentration of calcium in a water sample is 100 mg/L. What is the concentration in (a) meq/L and (b) mg/L as $CaCO_3$?

Solution The valence or ionic charge of calcium is +2, so n is 2 eq/mol. Calcium's atomic weight is 40.1 g/mol. Therefore, its equivalent weight is (Equation 10.5):

$$EW = \frac{AW}{n} = \frac{40.1 \text{ g/mol}}{2 \text{ eq/mol}} = 20.0 \text{ g/eq} = 20.0 \text{ mg/meq}$$

a. The concentration in meq/L is then simply obtained through unit conversion (Equation 10.4):

$$C_q = \frac{C}{EW} = \frac{100 \text{ mg/L}}{20.0 \text{ mg/meq}} = 5.0 \text{ meq/L}$$

b. Again, the concentration in mg/L as $CaCO_3$ is simply obtained through unit conversion (Equation 10.6):

$$\begin{aligned} C_{CaCO_3} &= C_q \times 50 \\ &= (5.0 \text{ meq/L})(50 \text{ mg/meq}) \\ &= 250 \text{ mg/L as } CaCO_3 \end{aligned}$$

Note that the *correct* unit includes "as $CaCO_3$."

قلوية المياه =

Alkalinity

- **Alkalinity** is a measure of the buffering capacity of water (or the capacity of the water to neutralize acid, or H^+).
- It is not the same as pH; water does not have to be basic to have high alkalinity.
- The natural sources of alkalinity in water are the **atmosphere** and **limestone**.

$CO_2 + H_2O \rightarrow H_2CO_3$

> Atmospheric carbon dioxide dissolved in water forms carbonic acid (H_2CO_3), which can dissociate into bicarbonate (HCO_3^-) and carbonate (CO_3^{-2}).

> Limestone formations ($CaCO_3$) can also dissolve in water and produce HCO_3^- and CO_3^{-2}. Both HCO_3^- and CO_3^{-2} can "grab" (or neutralize) H^+ that is added to the water. Notice that carbonate can grab two H^+ while bicarbonate can grab only one.

Alkalinity Calculations (mol/L)

$$\text{Alkalinity (mol/L)} = \left(\frac{\text{mol } HCO_3^-}{\text{L}}\right)\left(\frac{\text{1 mol ALK}}{\text{mol } HCO_3^-}\right) + \left(\frac{\text{mol } CO_3^{2-}}{\text{L}}\right)\left(\frac{\text{2 mol ALK}}{\text{mol } CO_3^{2-}}\right) + \left(\frac{\text{mol } OH^-}{\text{L}}\right)\left(\frac{\text{1 mol ALK}}{\text{mol } OH^-}\right) - \left(\frac{\text{mol } H^+}{\text{L}}\right)\left(\frac{\text{1 mol ALK}}{\text{mol } H^+}\right)$$

or simply

$$\boxed{\text{Alkalinity (mol/L)} = [HCO_3^-] + 2[CO_3^{2-}] + [OH^-] - [H^+]}$$

(1 H) 2 H لأنه تنقص Alkalinity

mol/L

Alkalinity Calculations (meq/L)

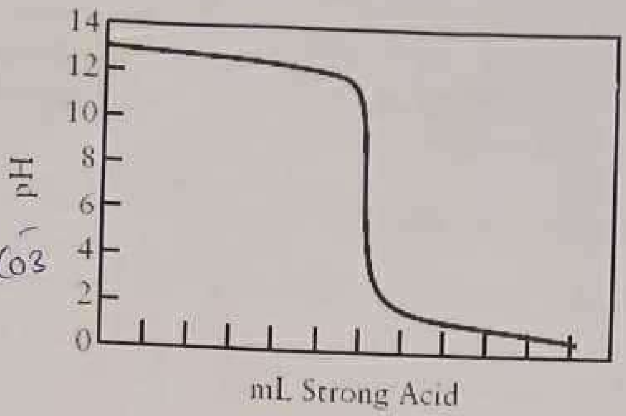
2H لازم نضرب ب $CO_3^{2-}\ (\text{eq/L}) = \left(\frac{\text{mol } CO_3^{2-}}{\text{L}}\right)\left(\frac{\text{2 eq}}{\text{mol}}\right)$

$$\text{Alkalinity (meq/L)} = \left(\frac{\text{1 meq } HCO_3^-}{\text{L}}\right)\left(\frac{\text{1 meq ALK}}{\text{meq } HCO_3^-}\right) + \left(\frac{\text{1 meq } CO_3^{2-}}{\text{L}}\right)\left(\frac{\text{1 meq ALK}}{\text{meq } CO_3^{2-}}\right) + \left(\frac{\text{1 meq } OH^-}{\text{L}}\right)\left(\frac{\text{1 meq ALK}}{\text{meq } OH^-}\right) - \left(\frac{\text{1 meq } H^+}{\text{L}}\right)\left(\frac{\text{1 meq ALK}}{\text{meq } H^+}\right)$$

or simply

$$\text{Alkalinity (meq/L)} = (HCO_3^-) + (CO_3^{2-}) + (OH^-) - (H^+)$$

Alkalinity: Titration curve



pH = 7.3 so Alkalinity ≅ HCO_3^-

At pH less than 7.3, the carbonate concentration is much less than the bicarbonate concentration, and around neutral pH, [H+] ≈ [OH−]. Therefore, for most potable water sources:

$$\text{Alkalinity} \cong (HCO_3^-)$$

Carbonate hardness & Noncarbonate hardness

Total hardness

TH = carbonate hardness (**CH**) + noncarbonate hardness (**NCH**)

Ca / Mg 2^+

- Carbonate hardness is the component of total hardness associated with the anions carbonate (CO_3^{-2}) and bicarbonate (HCO_3^-);
- Carbonate hardness (total alkalinity) is a temporary hardness that is removed by heat;
- Noncarbonate hardness is equal to the difference between total hardness and carbonate hardness;
- If the alkalinity is equal to or greater than the total hardness, then the noncarbonate hardness is zero;

NCH = TH − CH

Example

10.6

Problem From the following water analysis, determine the total hardness, carbonate hardness, and noncarbonate hardness in (a) milliequivalents per liter (meq/L) and (b) milligrams per liter (mg/L) as $CaCO_3$.

Component	Concentration (mg/L)
CO_2	6.0
Ca^{2+}	50.0
Mg^{2+}	20.0
Na^+	5.0
Alkalinity	120 as $CaCO_3$
SO_4^{2-}	94.0
pH	7.3

$= HCO_3^-$

$\frac{50}{20}$ $\frac{20}{12.2}$ $\frac{120}{50.0}$

Component	EW (mg/meq)	Concentration mg/L	meq/L	mg/L as $CaCO_3$
Ca^{2+}	20.0	50	2.5	125
Mg^{2+}	12.2	20	1.6	82
Alkalinity	50.0	120	2.4	120

EW = AW / z

→ 50 × 2.5
→ 50 × 1.6
→ 50 × G
50 × 2.4

24.31

$CO_2 + H_2O \rightarrow H^+ + CO_3^-$

CH or Temporary

$\underline{TH} = (2.5\ meq/L) + (1.6\ meq/L) = 4.1\ meq/L$

or TH = (125 mg/L as $CaCO_3$) + (82 mg/L as $CaCO_3$) = 207 mg/L as $CaCO_3$

TH − CH = non carbonate

207 >> Alkalinity

2.82

Examples

- Ex 10.4 ✓
- Ex 10.5 ✓
- Ex10.6

INTRODUCTION TO ENVIRONMENTAL ENGINEERING
THIRD EDITION
P. AARNE VESILIND Bucknell University
SUSAN M. MORGAN Southern Illinois University Edwardsville
LAUREN G. HEINE Clean Production Action

WATER AND WASTEWATER ENGINEERING
Design Principles and Practice
Mackenzie L. Davis, Ph.D., P.E., BCEE
Michigan State University

7.2
7.3

- All Examples in Chapter 7

287
8 except 321

Microorganisms:

- Bacteria
- الأوليات Protozoa
- الديدان الطفيلية Parasitic Worms
- Viruses
- طحالب Algae
- فطريات Fungi
- مؤشرات التلوث **Pollution indicators:** Coliform bacteria

Microorganisms

البحث عن مسببات الأمراض في المياه السطحية يشبه البحث عن إبرة في كومة قش (لا يوجد)

✓ Looking for pathogens in most surface waters is a perfect example of the proverbial needle in a haystack!

لذلك نستخدم كائنات [illegible]

تم استخدام بكتيريا الإشريكية القولونية كمؤشر على جودة المياه

➢ E. coli used as an indicator of water quality: normal inhabitant of intestines of many animals تعيش طبيعيا في أمعاء العديد من الحيوانات والبشر

[illegible]

➢ *Indicator organisms*: the indicator most often used is a group of microbes called coliforms (which includes the 150 strains of *E. coli*).

هذه المجموعة تشمل حوالي 150 نوع مختلف من E. coli

اختبار القولونيات

Coliform test:

ترشيح الغشاء ثم تحضين العينات لمدة 24 أو 48 ساعة نتائج تم تسجيلها بوحدة MPN (العدد الأكثر احتمالا) لكل 100 مل

جوها رطب [illegible] حاضنات

- Membrane filtration and 24 or 48 hours of incubation.
- Results reported as Most Probable Number (MPN) per 100 mL
- Incubation at moderate temperature (35°C) for 48 hr

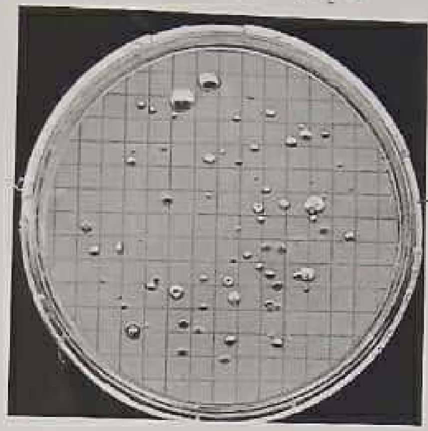
تحضين في درجة حرارة معتدلة حوالي 35°C لمدة 48 ساعة

[illegible] E. coli [illegible]

[illegible]

A fecal coliform bacteria test is used to indicate the likely presence of disease-causing bacteria in water.

لفحص تعدد شي تركيز البكتيريا



- ✓ a high coliform count is suspicious, and although the water may in fact be perfectly safe to drink, it should not be consumed.
- ✓ The opposite is also true!

Radiological Parameters

Radioactive substances

	Disinfection By-Products (interim)		Primary MCLs
Total trihalomethanes	0.10		
	Radionuclides		
Radium 226	20 pCi/L	Beta particle and photon radioactivity	4 mrem/yr
Radium 228	20 pCi/L	Radon	300 pCi/L
Gross alpha particle activity	15 pCi/L	Uranium	20 μg/L

تستقبل الاشعة

- The *rem*, or roentgen equivalent man, takes into account the biological effect of absorbed nuclear radiation, so it measures the extent of biological injury.
- One Sv is numerically equal to 100 rem. غاز تتطاير في الهواء
- pCi/L (pico Curies of radon per liter of air)

Water Quality Management

Dr. Motasem Saidan

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Water Quality Management

- Water quality management is the science that predicts how much waste is too much for a body of water
  - Assimilated-amount of waste that can be tolerated by a body of water
  - Determined by knowing the type of pollutants discharged and their effect on water quality

Measures of Water Quality

What are some parameters that determine water quality?

- ➢ The parameters that have been covered in the previous lectures
- ➢ Biochemical Oxygen Demand Bod
- ➢ Chemical Oxygen Demand COD
- ➢ Dissolved oxygen DO

min 5 days

water quality

Biochemical Oxygen Demand (BOD)

- **BOD**
  - ➢ Measurement of the rate at which microbes degrading organic matter use oxygen
    - One can calculate the theoretical oxygen demand
    - If you know the chemical formula – for example 1.67×10^{-3} M glucose

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

$$6 \times 1.67 \text{moles/L} \times 32 \text{ g/mole} \times 1000 \text{ mg/g} = 321 \text{ mg/L}$$

BOD

    - BOD is used because wastewater isn't one organic molecule

experimental procedure

Five-day BOD

BOD_5 is the amount of dissolved oxygen consumed by microorganisms during the biochemical oxidation of organic matter to carbon dioxide in 5-day standard test at 20°C.

of living organism

Glucose

- A very low rate of use would indicate

التلوث غائب

1) contamination is absent,
2) the available microorganisms are uninterested in consuming the available organics, or
3) the microorganisms are dead or dying.

or unavailable. unactive.

The standard BOD test

5 days

oxygen

The standard BOD test is run:

- in the dark at 20 °C for five days
- At specified temperature because the rate of oxygen consumption is temperature dependent.
- In a reaction that must occur in the dark because algae may be present.
- universally using a standard BOD bottle (about 300mL volume),
- In a special nonreactive glass and supplied with a ground-glass stopper

glass stopper

oxygen

BOD test procedures:

1. A special 300 mL BOD bottle is filled with a sample of water that has been appropriately diluted and inoculated with microorganisms
2. Blank samples containing only the dilution water are also placed in BOD bottles and sealed
3. The sealed BOD bottles containing diluted samples and blanks are incubated in the dark at 20°C for the desired number of days
4. After five days has elapsed, the samples and blanks are removed from the incubator and the dissolved oxygen concentration in each bottle is measured.

initial

Fresh Water at 1 atm*

	...ed (mg/L)	Temperature (°C)	Dissolved Oxygen (mg/L)
0	14.60	$\boxed{23}$	8.56
1	14.19	24	8.40
2	13.81	25	8.24
3	13.44	26	8.09
4	13.09	27	7.95
5	12.75	28	7.81
6	12.43	29	7.67
7	12.12	30	7.54
8	11.83	31	7.41
9	11.55	32	7.28
10	11.27	33	7.16
11	11.01	34	7.05
12	10.76	35	6.93
13	10.52	36	6.82
14	10.29	37	6.71
15	10.07	38	6.61
16	9.85	39	6.51
17	9.65	40	6.41
18	9.45	41	6.31
19	9.26	42	6.22
20	9.07	43	6.13
21	8.90	44	6.04
22	8.72	$\boxed{45}$	5.95

m.croorganisms

DO

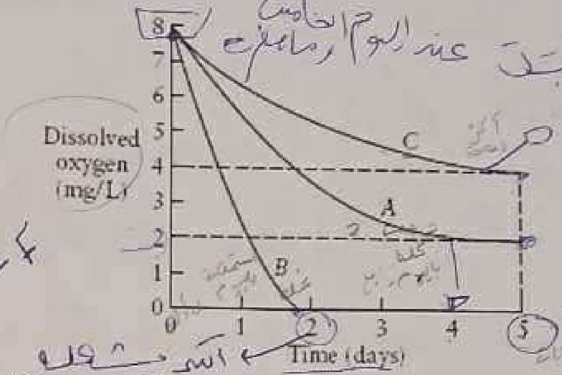
Source: *For atmospheric pressures of less than 1 atm, the dissolved oxygen concentration has to be reduced because there is less pressure to push the oxygen into the water. Published correction factors are available.

- **Ultimate BOD (BOD_u, or L)**: which is the O_2 demand after a very long time—when the microorganisms have oxidized as much of the organics as they can. The ultimate BOD is usually run for 30 days.

$BOD = I - F$

Where;

- I = initial DO, mg/L
- F = final DO, mg/L



$BOD = I - F$

Dilution

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.

BOD = (I – F)D

where, D = dilution factor.

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

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

300 ml

$\frac{300}{300-}$

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

Dilution = D factor = Total / sample

$BOD_5 = (I - F)D$

$D = \frac{300}{15}$

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

9.4	sample	Dilution water	
1	3 ml	297	$D_1 = 99$
2	1.5	298.5	$D_2 = 199$
3	0.75	299.25	$D_3 = 399$

BOD = (I - F) D

How much dilution?

not a fact — it's just a Rule. not necessary

- The BOD of the sample is seldom known before the BOD test is conducted, so the dilution must be estimated.
- The test is not very precise if the drop in DO during the five days of incubation is less than about 2 mg/L or if the DO remaining in the bottle is less than 2 mg/L.
- Generally, a final BOD is estimated from previous tests or similar waste and at least two dilutions used, with one expected to have at least 2 mg/L DO remaining and one expected to use at least 2 mg/L of DO.

The dilution is then calculated as

$$D = \frac{\text{expected BOD}}{\Delta DO}$$

initial - final

DO < 2

F < 2

initial - final = 2

2 Cases — very important

سؤال امتحان

room Temp

Example: The five-day BOD of an influent ~~to an~~ industrial wastewater treatment plant is expected to be about 800 mg/L based on similar wastewaters. What dilutions should be used in a five-day BOD test?

$D = \frac{\text{expected}}{(I - f)} = \frac{800}{(10 - f)}$

= expected od

$I = 10$

Bod = I - f

assume $DO \geq 2$

$F \geq 2$

two dilution must set

case 2 = $\frac{800}{8} = 100$

case 1 = $\frac{800}{2} = 400$

$2 = 10 - f$

$f =$

$\sqrt{800}$

$100 < D < 400$

rate

العينة بدها dilution وبدها بكتيريا

Seeding: The addition of active microorganisms that take up oxygen

- May be required in samples that do not have their own
- If seeding is necessary, any BOD that is contributed by the seed must be subtracted

seeded dilution water

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

Total volume 300 mL

seeding

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 Dilution factor.

seeding.

300 mL

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.

$$BOD_5 = \left[(9.2-2)-(9.2-8)\left(\frac{290}{300}\right)\right]30$$

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

$X = \text{total } V - \frac{\text{total } V}{D}$

BOD Kinetics → rate

Thus the mass balance is:

Rate of DO Accum. = Rate of DO consumed

$$dz/dt = -r$$

$z = Do$

z = dissolved oxygen, mg/L

Assume that it is a first-order reaction

$$\frac{dz}{dt} = -k_1 z \Rightarrow \frac{dz}{z} = -k_1 dt \Rightarrow \boxed{z = z_0 e^{-k_1 t}}$$

$$\int_{z_0}^{z} \frac{dz}{z} = \int_0^t -k\,dt$$

$$\ln \frac{z}{z_0} = -kt$$

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.

$$BOD_5 = \left[(9.2-2)-(9.2-8)\left(\frac{290}{300}\right)\right]30$$

$= 181$ mg/L

300 ← 10 → 300

Total / D

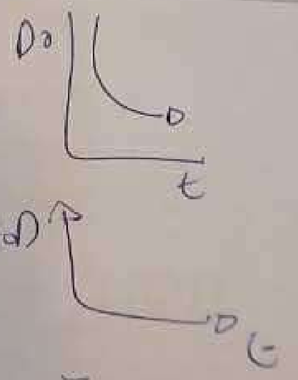
$X = \text{total } V - \frac{\text{total } V}{D}$

$\frac{300}{30}$

BOD Kinetics

→ rate

Thus the mass balance is:



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$$\int_{z_0}^{z} \frac{dz}{z} = \int_0^t -k\,dt$$

$$\ln\frac{z}{z_0} = -kt$$

BOD_5 = consumption

z ← potential

still to be used — available to be consumed

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

$y = BOD_5$

DO

$z = L - y$

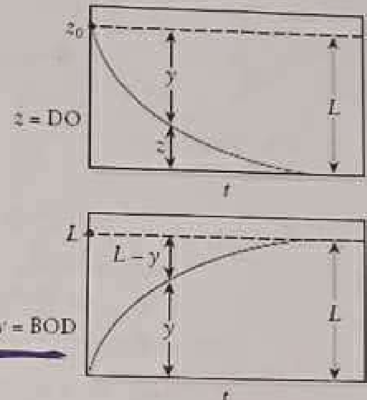
$L = y + z$ @ t=0 , y=0 , $L = z_{t=0}$

Where, **L**= ultimate demand

$$z = L - y$$

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

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



Where;

y = BOD at any time t

L = ultimate BOD

k_1 = deoxygenation constant, day^{-1}

BOD ultimate

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

Average *k*

k_1

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

rate constant

Numerical value of the rate constant k depends on:

- Nature of waste
- Ability of organisms in the system to use the waste
- Temperature

organic

Temperature Effect on k

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

Correction for Temp

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

"C" celcius

- 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)

1.135 domestic

1.024 reaeration

1.135 1.024

time BOD = y

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

ultimate BOD5

$y = z +$

$y = L - Le^{-k(t)}$

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

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

$$= \cancel{50 \text{ mg/L}}$$

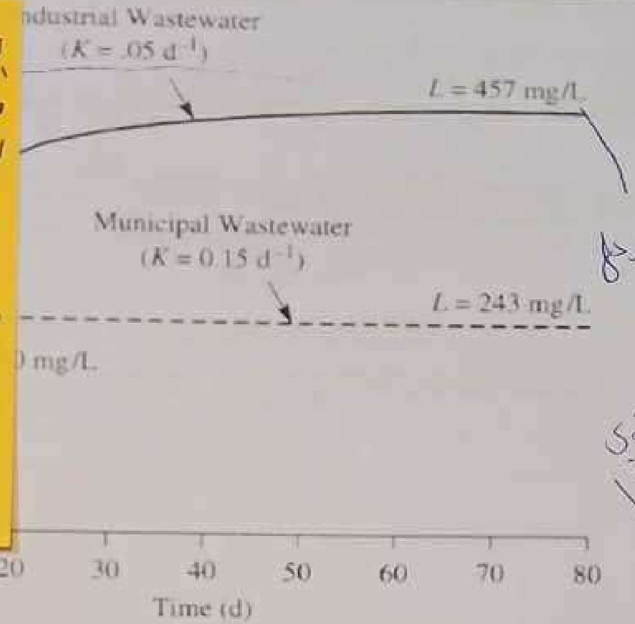
$y = 232.5$ mg/L

✓ Example 9.8 9.9

الهدف منه نفهم انه العينة تشابه فيها BOD5 مش شرط تتشابه . Ultimate (نوعية المياه . المحتوى العضوي الكربوني) .

كيف BOD5 تختلف باختلاف نوعية العينة

(Nitrogenuous (BOD))
السبب: - هو الاكسجين الذي تستهلكه انواع معينة من البكتيريا (بكتيريا النترجة) لاكسدة المركبات العضوية النيتروجينية (مثل الامونيا) وتحويلها الى نتريت ثم نترات.
التوقيت: - تبدأ بعد استهلاك جزء كبير من المواد العضوية الكربونية بعد اليوم 5
الناتج: - مركبات النترات NO_3 الامونيا NH_3 .



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

L

يعتمد على نوعية المياه
المحتوى العضوي الموجود فيها

(Carbonaceous (BOD))
السبب: هو الاكسجين الذي تستهلكه الكائنات الحية الدقيقة لتحليل وأكسدة المواد العضوية الكربونية الموجودة في الماء.
مثل السكريات، الدهون، البروتينات.
التوقيت: تحدث في بداية BOD تستهلك معظم الاكسجين في فترة من 5 days
الناتج: - ينتج عنها غاز ثاني أكسيد الكربون CO_2 وماء H_2O .

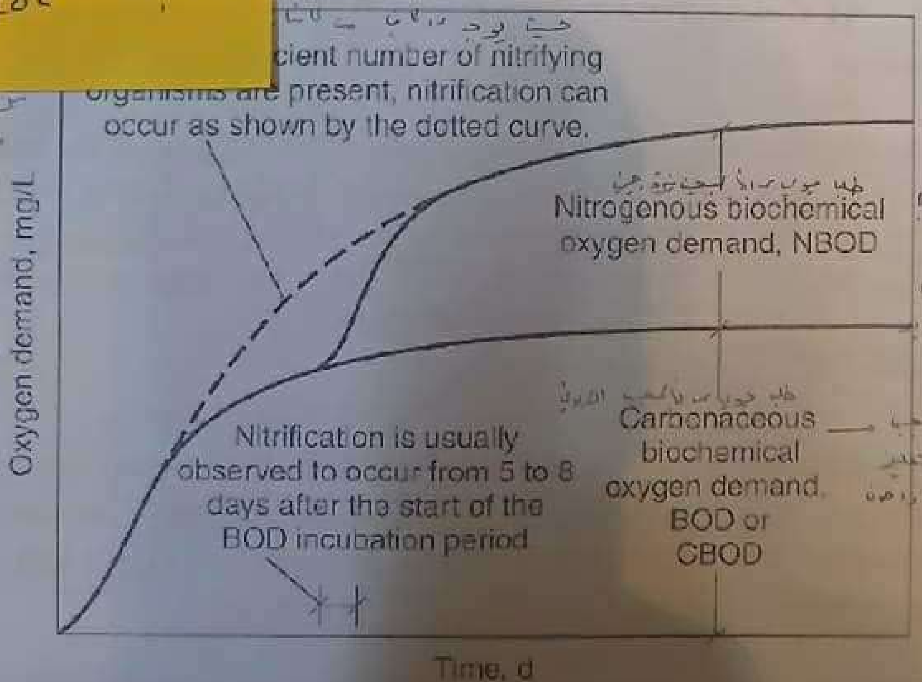
نفس جهاز
same Temp
same K
same BOD

$y = BOD_5$

مو شرط L تساوي

& Nitrogenous Oxygen Demand

كل ما كان Nitrogenous content اعلى كل ما اخذ ultmite اكبر واعلى

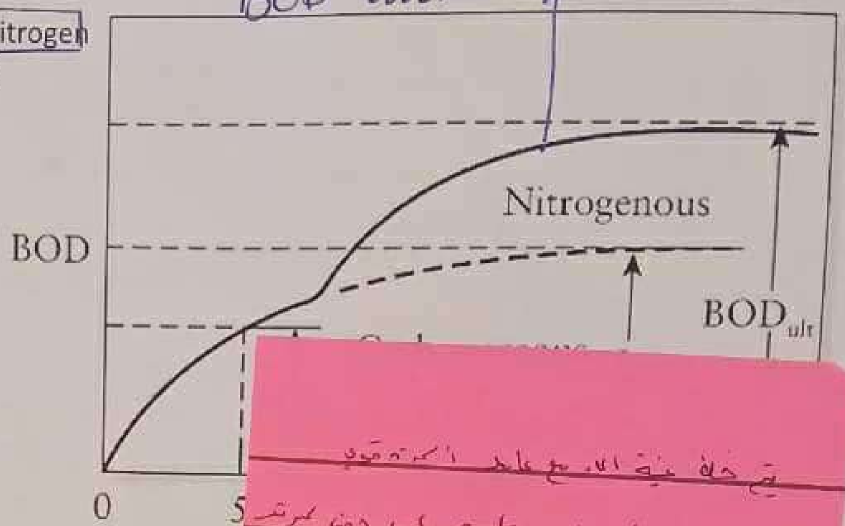


BOD Ultimate

$$BOD_{ultimate} = a(BOD_5) + b(KN)$$

Where, KN Kjeldahl nitrogen
a,b constants

بحتاج المرحلة لانه بأقصى حد
BOD ultimate



يتم خلط عينة الماء مع عامل مؤكسد قوي
إضافة ثنائي كرومات البوتاسيوم + حمض مركز
ثم تحديد قيمة COD من خلال
استهلاك المادة العضوية سواء كانت قابلة
للتحلل بيولوجيا أو غير قابلة للتحلل بيولوجيا.

BOD
Biological — حيوي
COD — كيماوي — محتوى عضوي

أو
كبر من
BOD

Chemical Oxygen Dema

يتم فيه رص ساعة أو ساعة ← maximum

كلوا محلل.

Procedure:

- A sample is mixed with a strong chemical oxidizing agent (potassium dichromate, $K_2Cr_2O_7$) plus a strong acid (sulfuric, H_2SO_4) and then heated. The COD is determined by measuring the consumption of $K_2Cr_2O_7$. The chemicals oxidize all the organic matter—biodegradable and non-biodegradable.

oxidizing

غير قابلة للتحلل — قابلة للتحلل الحيوي

إذا العينة — فيها فقط — BOD — تحتاها COD قريب من BOD.

إذا العينة فيها BOD + chemical — COD >> BOD مثل DDT

BOD = COD — محتوى عضوي بس

- **The COD for a sample will be greater than the BOD** unless the sample contains primarily easily biodegradable wastes. For example, DDT, a refractory organic, would yield a high COD but a zero BOD.

محتوى أكثر

noway have COD
COD << BOD

So why is COD used?

- COD can be obtained in about 3 hr, while BOD takes 5 days at least.
- It also provides more consistent results because it is chemically, rather than biologically based.
- Sometimes the COD is also used to estimate BOD_u and to indicate the presence of biologically resistant organics.

HW

9.1

9.4

9.7

9.16

9.18

9.21

exmp 9.9.

exm 9.4

← بعرفا مصدره
← مصانع ذات منشآت ثابتة
← مستمرة ما دام المصدر شغال

Sources of Water Pollutants

▪ **Point source:**

- Point source pollution comes mainly from industrial facilities and municipal wastewater treatment plants.
- The range of pollutants is vast, depending only on what gets "thrown down the drain."
- collected by a network of pipes or channels and conveyed to a single point of discharge in receiving water.
- Point sources are the easiest to identify and control
- Point source pollution can be controlled by waste minimization and proper wastewater treatment

ease to control

* ← اي اشي طبيعي مرتبط بمصادر غير مسيطر عليه.

الناجم عن ~~الفيضانات~~ ← الامطار اللي بتعمل سيول
الفيضانات ← وكثير غير منتظم

▪ ***Non-Point* source:**

- Urban and agricultural runoff that are characterized by overland discharge
- This type of pollution occurs during rainstorms and spring snowmelt

Non-point Source

- The term non-point source encompasses a large range of sources such as:
  - when rain or snow moves through the ground and picks up pollutants as it moves towards a major body of water
  - the runoff of fertilizers from farm animals and crop land
  - air pollutants getting washed or deposited to earth
  - storm water drainage from lawns, parking lots, and streets

Runoff → الجريان السطحي

للمعرفة فقط

Sediment
Soil particles transported from their source

Biochemical Oxygen Demand (BOD)
- Oxygen depleting material
  - Leaves
  - Organic material

Toxics
- Pesticides
  - Herbicides
  - Fungicides
  - Insecticides
- Metals (naturally occurring in soil, automotive emissions/ tires)
  - Lead
  - Zinc
  - Mercury
- Petroleum Hydrocarbons (automotive exhaust and fuel/oil)

Nutrients
- Various types of materials that become dissolved and suspended in water (commonly found in fertilizer and plant material):
  - Nitrogen (N)
  - Phosphorus (P)

Bacteria/ Pathogens
Originating from:
- Pets
- Waterfowl
- Failing septic systems

Thermal Stress
Heated runoff, removal of streamside vegetation

Debris
Litter and illegal dumping

Pollutants Found in Runoff

Water quality management in rivers

- Main goal is to control the discharge of pollutants so that water quality is not degraded above the natural background level

assimilation capacity

➢ Controlling waste involves:

centian fraction from x, t.

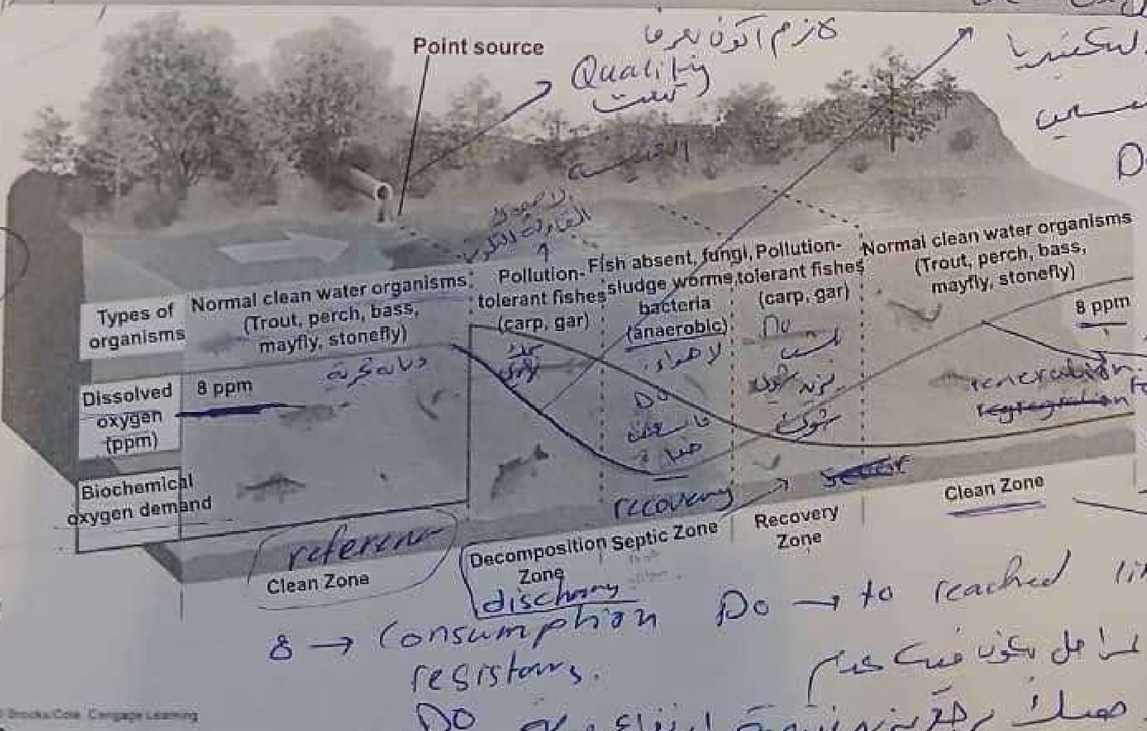
1. Measuring pollutants levels (x, z, t)
2. Predicting their effect on the water quality
3. Determining background water quality that would be present without human intervention
4. Evaluate the levels acceptable for intended uses of the water

flow → demonant and convections

Trout → سمك السالمون
perch → جثم

distance → 20 - 40 km

de-oxygenation



septic

reference

recovery

regeneration

discharge

8 → consumption resistors.

DO → to reached limit.

4 → still servive

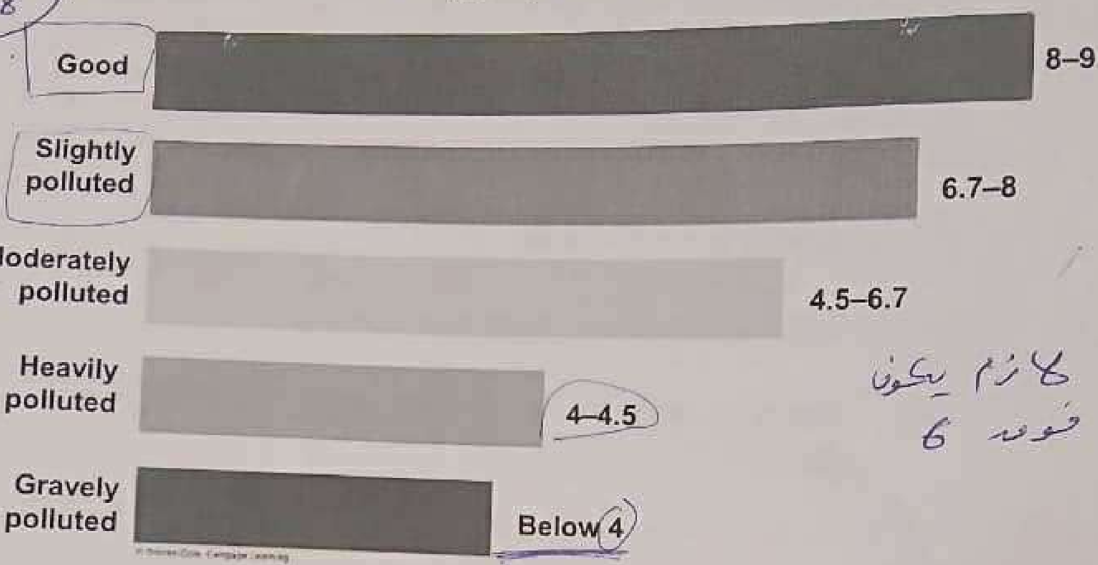
<4 → البكتيريا بتموت

BOD →

heater → DO كافة / soln + s20
الحرارة ← DO تتبدد . ثاني تبط بالحوض السريع

المخلفات ← 4
بتعلق بين البحار
لانه تحت تسحب
DO .

DO (ppm) at 20° C



ساقادرين تتعامل مع التلوث

لازم يكون فوق 6

below 4

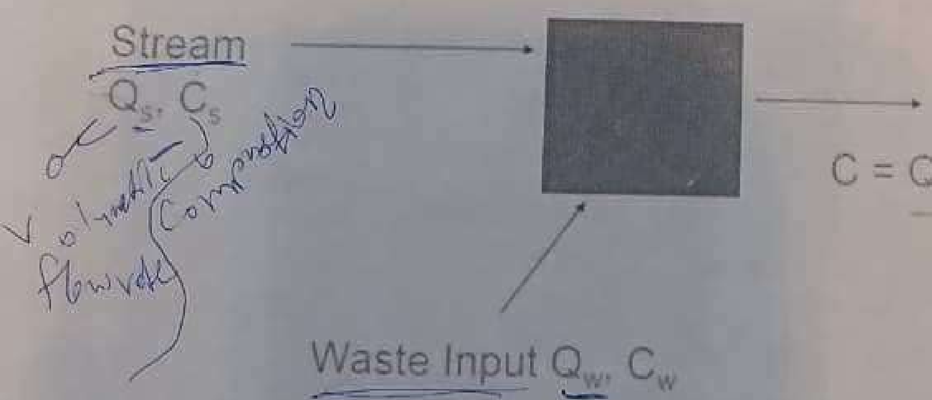
غاز الميثان بيلش يزيد
anaerobic

معدل الاضمحلال

Input rate - Output rate - decay rate = Accumulation rate

k

Steady state conservative system



$$C = \frac{Q_w C_w + Q_s C_s}{Q_s + Q_w}$$

- **Transport characteristics that affect concentration**
    - Velocity
    - Dilution (mixing)
    - Dispersion
    - Degradation (mass loss)
    - Adsorption (to soils)
    - Sedimentation (to bottom)
    - Aquatic Life (attached)

Dissolved Oxygen

- If the discharge of oxygen-demanding wastes is within the self-purification capacity, the DO is high
- If the amount of waste increases, it can result in detrimental changes in plant and animal life
- Objective of water quality management is to assess the capability of a stream to absorb waste
- Oxygen use speeds up as the temperature increases and slows down as the temperature decreases

ينخفض التركيز عندما تتأكسد المواد التي تحتاج إلى الأكسجين
ثم يرتفع عندما يتم تجديد الأكسجين من الغلاف الجوي والتمثيل الضوئي

Do Sag Curve

- DO concentration dips as oxygen-demanding materials are oxidized and then rises as oxygen is replenished from atmosphere and photosynthesis ← التمثيل الضوئي

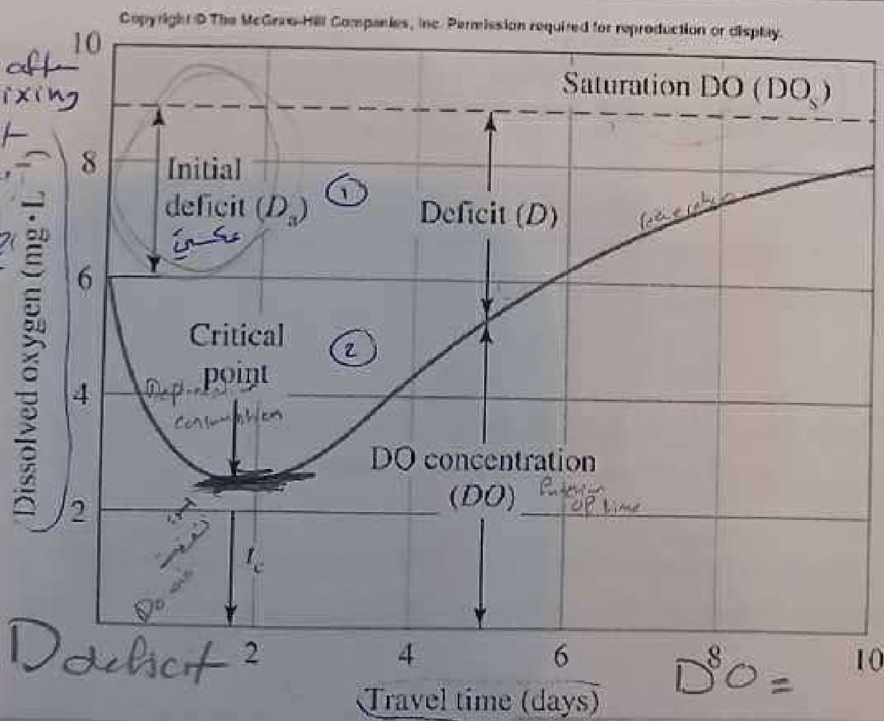
  recharged

- Major sources of oxygen:
  - Reaeration from the atmosphere
  - Photosynthesis of aquatic plants
- Factors of oxygen depletion: → استنفاد
  - BOD of waste discharge
  - DO in waste discharge is less than that in the river
  - Nonpoint source pollution
  - Respiration of organisms and aquatic plants التنفس

Do satu − Do after mixing = initial deficit

critical point

$\boxed{(x, t, v)}$



$DO = Satu - D_{deficit}$

$DO = DOs - D$

$DO_c = Sat - D_c$

$DO_c = DO_s - D_c$

← ما قبل mixing ← لازم أكون عارف Quality of water.

Steps in Developing the DO Sag Curve

← تناقص يومي للأكسجين بالنسبة إلها BOD

1. Determine the initial conditions
2. Determine the reaeration rate from stream geometry
3. Determine the de-oxygenation rate from BOD test and stream geometry

بسحب الأكسجين

تزود الأكسجين

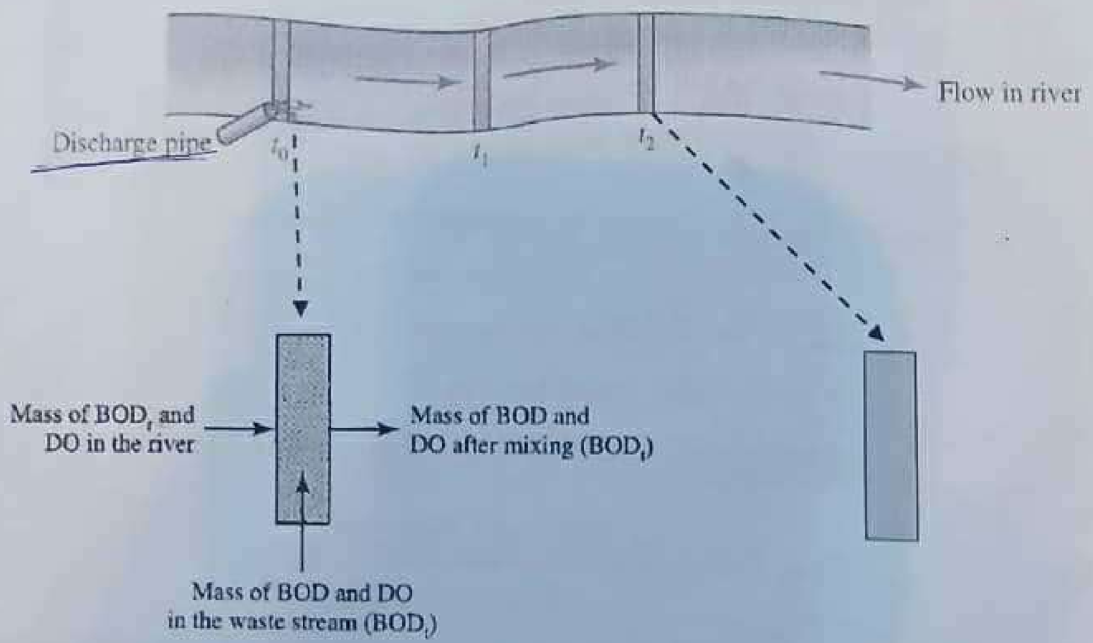
أهم الاشياء

two value. 4. Calculate the DO deficit as a function of time
5. Calculate the time and deficit at the *critical point*

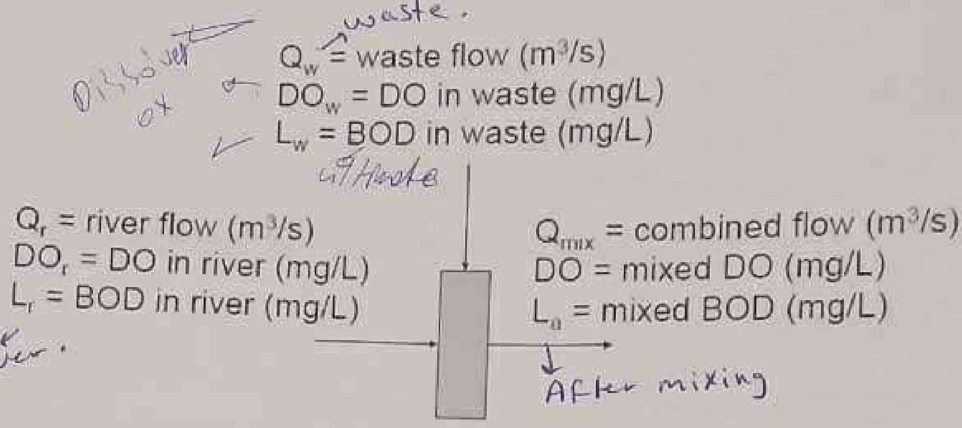
at critical

Measurement − saturation = deficit

Selecting System Boundaries



Initial Mixing



Unit

DO

1. Determine Initial Conditions

A. Initial dissolved oxygen concentration

$$DO_a = \frac{Q_w DO_w + Q_r DO_r}{Q_w + Q_r}$$

table

B. Initial dissolved oxygen deficit

$$D = DO_s - DO$$

where D = DO deficit (mg/L)

saturation, critical point [illegible]

DO_s = saturation DO conc. (mg/L)

$$D_a = DO_s - \frac{Q_w DO_w + Q_r DO_r}{Q_{mix}}$$

After mixing.

DO → [illegible]

Theoritical [illegible]

table [illegible]

$\boxed{Do_{sat}}$ is a function of temperature. Values can be found tabulated in books.

C. Initial *ultimate* BOD concentration

$$L_0 = \frac{Q_w L_w + Q_r L_r}{Q_w + Q_r}$$

مهم ⇒ Reaeration → function of geometry and flow

- Reaeration → DO بطلع
- de-oxygenation → DO بنزل

DO

2. Determine Reaeration Rate

A. O'Connor-Dobbins correlation:

mixing

depth & kr علاقة عكسية

$$k_r = \frac{3.9u^{1/2}}{h^{3/2}}$$

recovery the element

Atmosphere

geometry system

where k_r = reaeration coefficient @ 20°C (d^{-1})

u = average stream velocity (m/s)

h = average stream depth (m) → limited, have certain rang

B. Correct rate coefficient for stream temperature

$$k_r = k_{r,20}\Theta^{T-20}$$

where Θ = 1.024

Table 4-1. Reaeration Constants

Type of watercourse	k_2' at 20°C[a] (days^{-1})
Small ponds or backwaters	0.10–0.23
Sluggish streams	0.23–0.35
Large streams, low velocity	0.35–0.46
Large streams, normal velocity	0.46–0.69
Swift streams	0.69–1.15
Rapids	>1.15

[a] For temperatures other than 20°C, $k_2'(T) = k_2'(20°C)(1.024)^{T-20}$.

$$k_2' = \frac{3.9v^{1/2}\sqrt{(1.037)^{(T-20)}}}{H^{3/2}},$$

element rule here play the (بيتغير) ~~kientic~~ test. kientic rate.

3. Determine De-oxygenation Rate

نفس BOD test

a. Rate of de-oxygenation = $\boxed{k_d L_t}$ → by BOD test calculate تراكيز بتغير من زمن

where k_d = deoxygenation rate coefficient (d^{-1})

L_t = ultimate BOD remaining at time (of travel downdstream) t.

b. If k_d(stream) = k(BOD test)

order of reaction. zero order very fast.

and

$$L_t = L_0 e^{-k_d t}$$

2

$$\text{rate of deoxygentation} = k_d L_0 e^{-k_d t}$$

c. However, $k = k_d$ only for deep, slow moving streams. For others,

geometry play rule here also.

BoD test.

$$k_d = k + \frac{u}{h}\eta$$

where η = bed activity coefficient (0.1 – 0.6)

Soil

d. Correct for temperature

$$k_r = k_{r,20}\Theta^{T-20}$$

where Θ = 1.135 (from 4 to 20 °C) or

1.056 (from 20 to 30 °C)

we have two mechanism

→ de-oxygenation.

– rearation.

4. DO as function of time

- Mass balance on moving element

oxygenation. rearation

$$\frac{dD}{dt} = k_d L_t - k_r D$$

- Solution of differential equation is

Numerical soln.

$$\boxed{D_t = \frac{k_d L_a}{k_r - k_d}\left(e^{-k_d t} - e^{-k_r t}\right) + D_a\left(e^{-k_r t}\right)}$$

Deficit

dificiht value After.

بهم بما يعده الرسمة او عند الـ الفه رليتين

5. Calculate Critical time and Deficit

كبيرة

$$\boxed{t_c} = \frac{1}{k_r - k_d}\ln\left[\frac{k_r}{k_d}\left(1 - D_a\frac{k_r - k_d}{k_d L_a}\right)\right]$$

time بصير عنده 0 deficit.

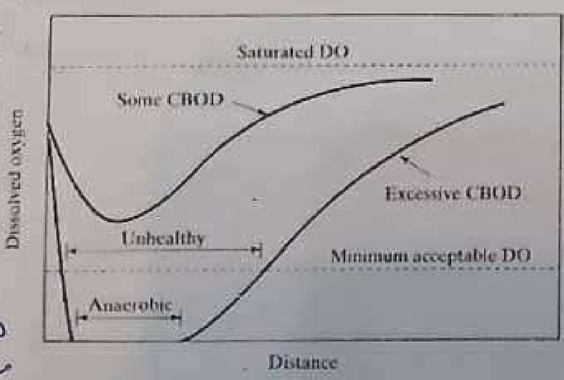
$$D_c = \frac{k_d L_a}{k_r - k_a}\left(e^{-k_d t_c} - e^{-k_r t_c}\right) + D_a e^{-k_r t_c}$$

ترجع بعوضه في المعادلات السابقة تم deficit

← لما نوصل minum
← بياخذ وقت طويل حتى يعمل recovery.

More Oxygen Sag Curves

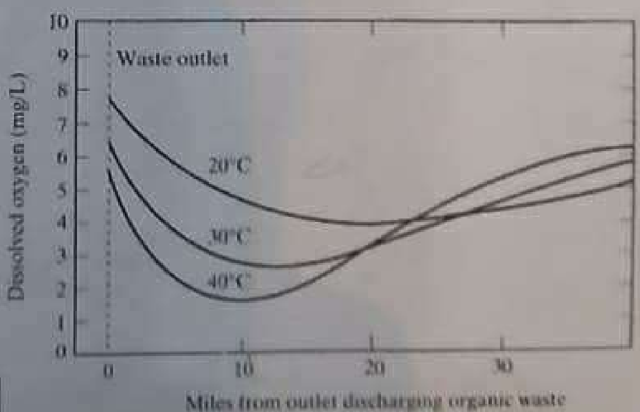
dificit minim موعد تمام مافي مشكلة وبعد ما dificit تحت minimum صار يكون مشكلة كبيرة



Effect of BOD Level:
- sag becomes more severe يصبح التدهور اكثر حدة
- longer distance (or time) at unhealthy DO levels مسافة اطول (او وقت اطول) عند مستويات DO غير الصحية

Effect of temperature:
- sag deepens and shortens
- may cause a portion of river to have unhealthy DO levels

لما الحرارة زادت استهلكت اكسجين اكثر.



فقط النسبة عليهم

التبس السؤال   time , Unit , Temperature

Example

→ سؤال امتحان ←

Calculate the DO at a point 1.609km downstream from a waste discharge point for the following conditions. Report answers to two decimal places. Rate constants are to be temperature adjusted.

velocity + distance = time.

time + distance velocity

Parameters	Stream
K_d (at 20°C)	1.911 d^{-1}
K_r (at 20°C)	4.49 d^{-1}
Flow	2.4 m^3/s.
Speed	0.100 m/s
DO_a(after mixing)	0.00
Temperature (°C)	17
BOD_L (after mixing)	1100 kg/d → mg/L

سؤال امتحان

critical.

$$DO_c = \frac{K_r}{K_d} L_a e^{-k_d t};\ k = k_{20}\theta^{(T-20)};\ \theta = 1.047$$

La

1 mg · 10^{-3} g

$$\frac{2.4}{2.4\ m^3/s} \left| \frac{1100\ kg}{day} \right| \frac{mg}{L} \left| \frac{1000000\ mg}{1\ kg} \right.$$

24×3600

Example

24 hour · 3600 s / 1 hour

a. Calculate travel time   distance / velocity

جواب السؤال على درجة حرارة 20

per day $t = \frac{(1.609\text{km})(1000\text{ m/km})}{(0.100\text{ m/s})(86400\text{ s/d})} = \boxed{0.186\text{d}}$

$$\frac{1.609\ Km}{0.1\ m/s} \left| \frac{1000\ m}{1\ Km} \right| \frac{1s}{1\ day}$$

16090 s | 1 day / 24 × 3600 s

ويكمل السؤال 17 عندنا والتي بدك تحل جواب ثاني

b. Convert kg/d to mg/L   BOD/F

$$L_a = \frac{(1100\text{ kg/d})(10^6\text{ mg/kg})}{(2.40\text{ m}^3\text{/s})(86400\text{ s/d})} = 5.31\text{mg/L}$$

c. Calculate deficit

$Da\, e^{-kt}$

شان احول من kg/d ل mg/L لازم اقسم بـ 2.4 m³/s

$$D = \frac{(1.911)(5.31)}{4.49 - 1.911}\left(e^{-(1.199)(0.186)} - e^{-(4.49)(0.186)}\right) + 0$$

$$D = 3.93(0.7009 - 0.4338) = 1.046\text{ mg/L}$$

0 deficit   ويكمل بدنا علية

Saturation − Do = Deficit.

DOc ⇒ criticle dissolve oxygen :- is the actual amount of oxygen remaining in the water at is lowest point.

Example

DOc → criticle dissolve oxygen → is the actual amount of oxygen remaining in the water at is lowest point

Dc → criticle oxygen deficit → is the amount of oxygen that has been consumed at the same point

$DO = DOs - D$

Appendix at 17 °C find $DO_s = 9.74$ mg/L

046 = 8.69 mg/L

نزل عن 8-9 الوضع آمن safe

إذا حدث / ما حدث

كيف بدي أطلع والسبب

Appendix ??

$DO_c = \frac{k_r}{k_d} L_a e^{-k_d t}$

$= 8.7$ mg/L

HW

The town of ABC has filed a complaint that the City of XYZ is restricting its use of the Alpha River because of the discharge of raw sewage. The water quality criterion for the Alpha River is 5.00 mg/L of DO. The ABC Town is 15.55 km downstream from XYZ City.

a. What is the DO at City ABC?

b. What is the critical DO and

c. Where (at what distance) downstream does the critical DO occur?

d. Is the assimilative capacity of the river restricted?

The following data pertain to the 7-day, 10-day low flow at XYZ.

Parameter	XYZ Wastewater	Alpha River	Units
Flow	0.1507	1.08	m^3/s
BOD_5	128		mg/L
BOD_u		11.4	mg/L
DO	1.00	7.95	mg/L
k at 20°C	0.4375		day^{-1}
Velocity		0.390	m/s
Depth		2.8	m
Temperature	16	16	°C
Bed-activity coeff		0.200	

time ← بطلع ونعوض ب deficit, saturation = 0.

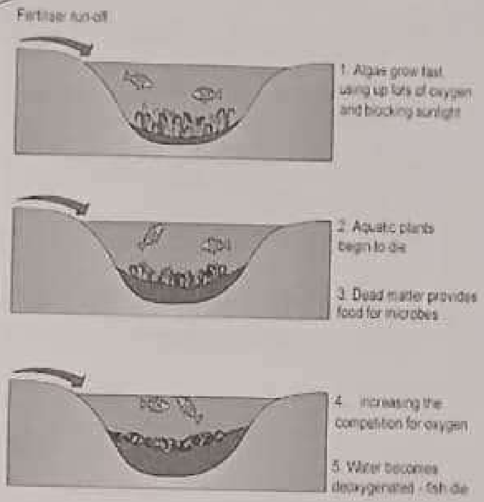
NPK
Nitrogen → potassium
phosphore

← سببه وجود أسمدة فوسفات ونترات

Lake Eutrophication

بحيرة التخثث

- As lakes age, they become more Productive تغذية البحيرة
  - Natural processes: natural Eutrophication
  - Pollutant loading: cultural Eutrophication



زيادة البحيرات بالمغذيات من خلال جريان المغذيات النباتية

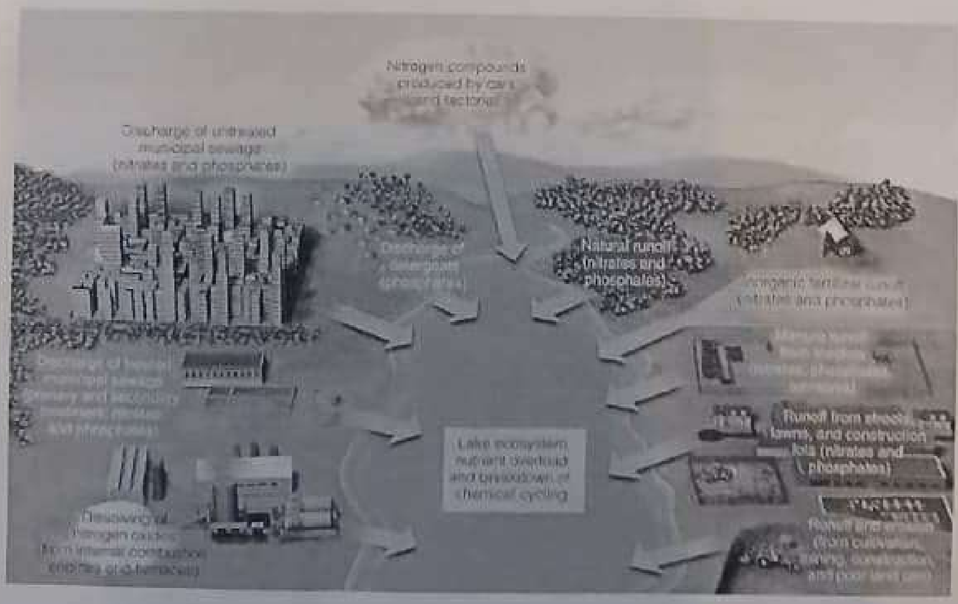
Eutrophication: nutrient enrichment of lakes mostly from runoff of plant nutrients (nitrates and phosphates) أنواع الجريان المغذيات

- During hot dry weather can lead to algae blooms ازدهار الطحالب
- Decrease of photosynthesis انخفاض التمثيل الضوئي
- Dying algae then drops DO levels
- Fish kills, bad odor قتل الأسماك والرائحة السيئة

موت الطحالب يؤدي إلى انخفاض مستوى الأكسجين الذائب

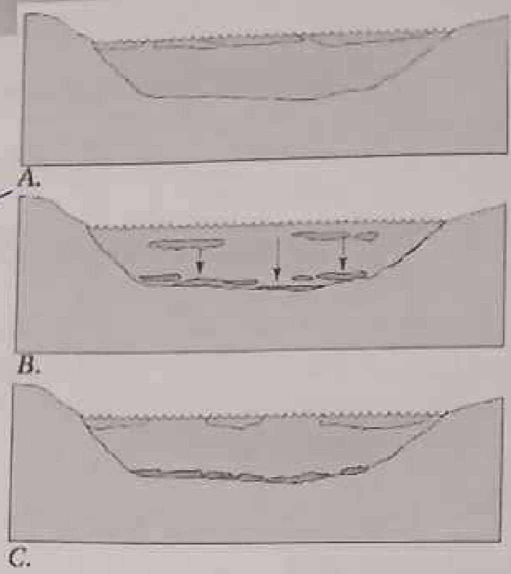
← من مخلفات معالجة مياه العادمة

Nutrient loading and Eutrophication



© 2005 Brooks/Cole - Thomson

Eutrophication in Lakes

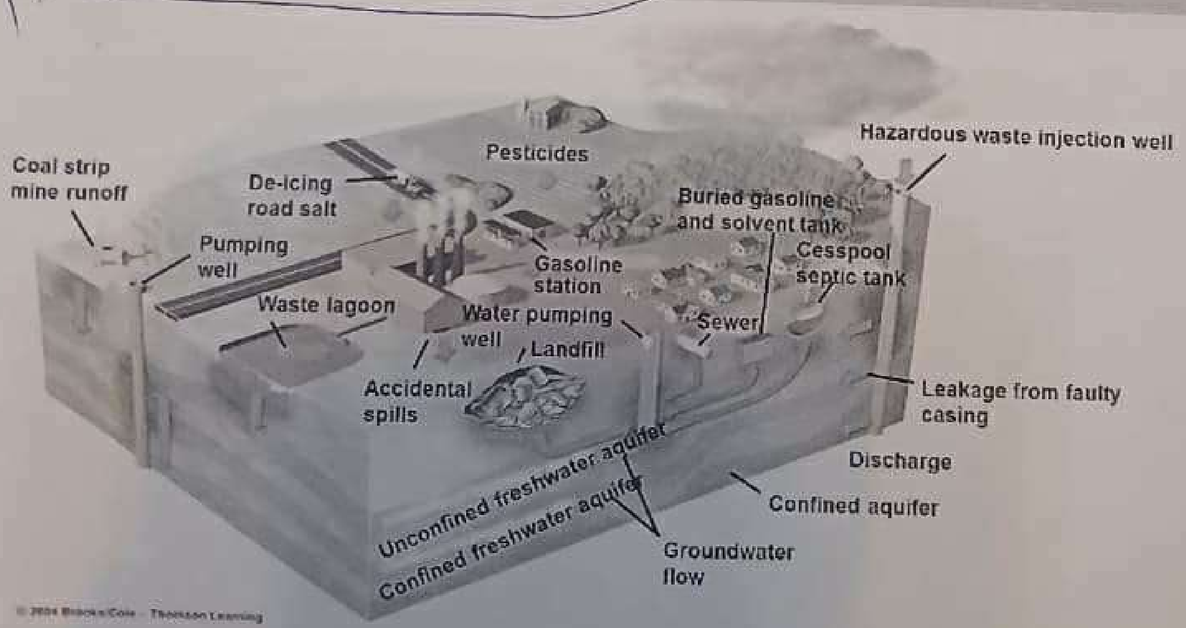


Schematic Diagram showing effects of algal bloom on water quality. (A) Abundant growth of algae in sunlit shallow water when nutrients are abundant. (B) In colder weather, algae die and sink to the lake bottom. (C) The next growing season, more algae thrive at the surface while older material decays at the bottom, increasing BOD and releasing more nutrients to fuel new growth.

Solutions:

- Advanced sewage treatment (N, P)
- Household detergents
- Soil conservation
- Remove excess weed build up
- Pump in oxygen or freshwater

Groundwater Pollution



lec 5

Water Treatment

wast water treatment مياه الصرف الصحي

315

Dr. Motasem Saidan

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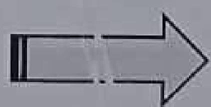
This means that the outcome, quality or characteristics of water can change depending on where the water comes from either surface water or ground water

surface water: water that is found above ground in lake, river and freshwater. It is often exposed to pollution from the environment

Drinking Water Treatment

ground water: water located below the earth's surface, stored in soil or rock layers (aquifers). It is usually cleaner but may contain minerals or be harder to access.

- It depends on the source: Surface (مياه سطحية) or Ground Water (مياه جوفية)



Coagulation : يتم فيها إضافة مادة كيميائية (مثل الشبه أو كلوريد الحديديك) إلى السائل عشان اختزال واحتمال الشحنات السالبة على الجسيمات الدقيقة العالقة في الماء مما يؤدي إلى عدم استقرارها وتجمعها في تكتلات صغيرة microflocs.

flocculation : التكون التكتلات الصغيرة يتم تحريك السائل ببطء عشان التكتلات تتصادم وتندمج مع بعضها البعض مشكلة كتل أكبر وكثافة أكبر بالتالي تترسب في قاع الخزان بفعل الجاذبية لاحقاً ويتم ترشيحها بسهولة

filters to remove bacteria, viruses and particles that can cause disease

- Treatment technologies largely based on **coagulation and flocculation**

These are the key processes used to remove suspended solids and prepare water for further purification.

floc floc

هو تحريك الكيميا في مجرى الزيت Coagulation تخزن تجميعها في حبيبات أكبر floc

mixing rate → عشان ما أكسر particle

Coag floc chemical 3 unit

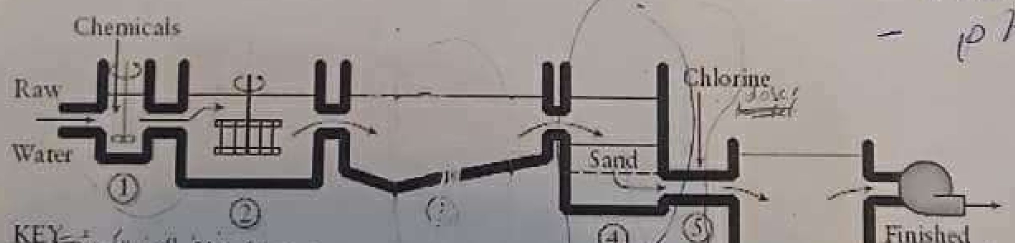
Coagulation
flocculation

يضيف اجزاء حتى تغير التركيب الكيميائي

Alum
يعمل بالسطح
كانسون بدن ناخذها

يعدل الملمس يكونوا مع بعضا

chemical Addition unit
- Coagulation
- flocculation
- pH



KEY
1. Chemical mixing basin
2. Flocculation basin
3. Settling tank
4. Rapid sand filter
5. Disinfection with clorine
6. Clean water storage basin (clear well)
7. Pump

Coagulation and flocculation and pH

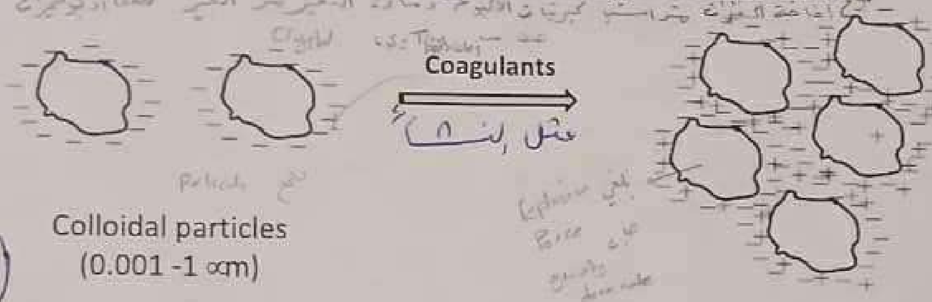
Figure 10.11 A typical water treatment plant.

95% من particle يكون مصدرها طبيعية

particle negative

Coagulation and Flocculation

- ***Coagulation*** is the chemical alteration of the colloidal particles to make them stick together to form larger particles called ***flocs*** that readily settle.
  - Tiny (colloidal) clay and silt particles: negative surface charge
  - Particles repel so suspension is considered stable
  - Coagulants (alum (aluminum sulfate), and coagulant aids, such as lime and polymers) are added to the water to neutralize the charge on the particles.



Colloidal particles
(0.001 -1 ∝m)

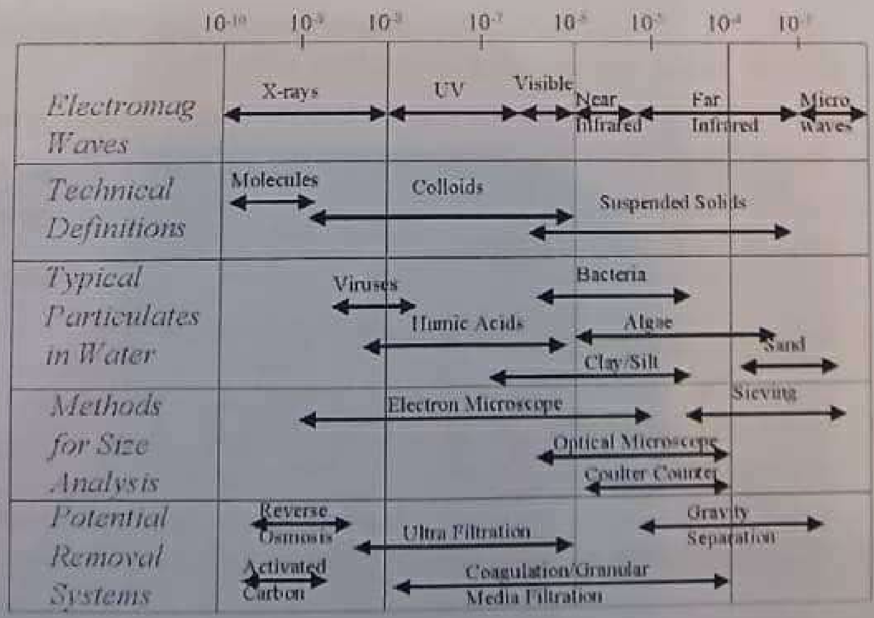
−floc
(1 -100 ∝m)

+2 , +4

polymer →
- bio polymer

① Coagulants هو تحييد الشحنة على الجزيئات
To neutralize the charg on the particles
② المساعدة في جعل الجزيئات الصغيرة "لزجة"
to making the tiny particle "sticky" so they can coalesce and form larg, quick settling part

Particulate size (meters)

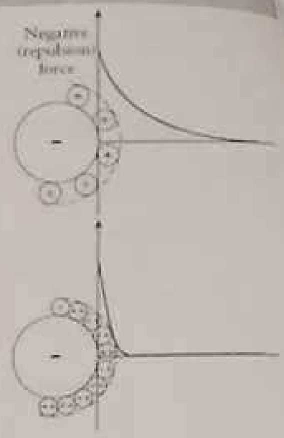


Coagulation: charge neutralization and bridging

اتحاد الخثر

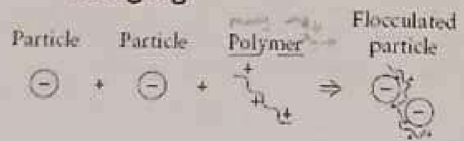
- **Charge neutralization:** تعادل الشحنة
  - will cause instability and collision

تصطدم الجزيئات بسهولة أكثر مما يؤدي إلى التجمع وتكوين كتل أكبر

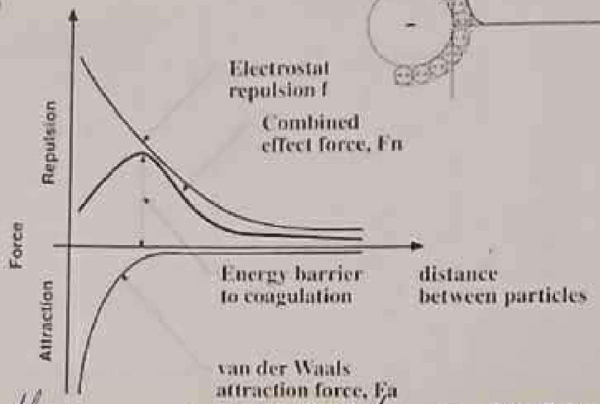


- **Bridging** الجسر

تقوم مواد بوليمرية بربط جزيئات مع بعضها بالارتباط بعدة جزيئات لتكوين الكتل.



intermolecular force between them



M.saidan

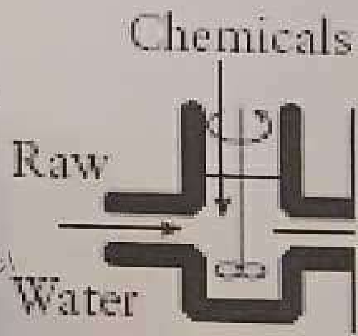
The specific combination of these compound is depen.
- PH of the water
- The Temperature
- method of mixing

Rapid mixing

خلط سريع للخثر مع الماء لتوزيعه بشكل متساو وتحفيز التصادم بين الجزيئات

إضافة الخثر والخلط السريع

Addition and rapid mixing of a coagulant with the water to:



- ✓ neutralize surface charges تعادل الشحنات السطحية — إزالة الشحنات الكهربائية السالبة التي تسبب تنافر الجزيئات الزوجية مما يساعد على تقاربها.
- ✓ collapse the surface layer around the particles تدمير الطبقة السطحية الزوجية — تدمير هذه الطبقة الزوجية الكهربائية وإزالة الحواجز التي تمنع تقارب الجزيئات
- ✓ allow the particles to come together and agglomerate السماح للجزيئات بالتقارب والتكتل — بعد إزالة التنافر تصطدم الجزيئات ببعضها بسهولة وتتجمع لتكوين كتل أكبر
- ✓ allow formation of floc that can readily settle تكوين كتل (flocs) يمكن أن تترسب بسهولة

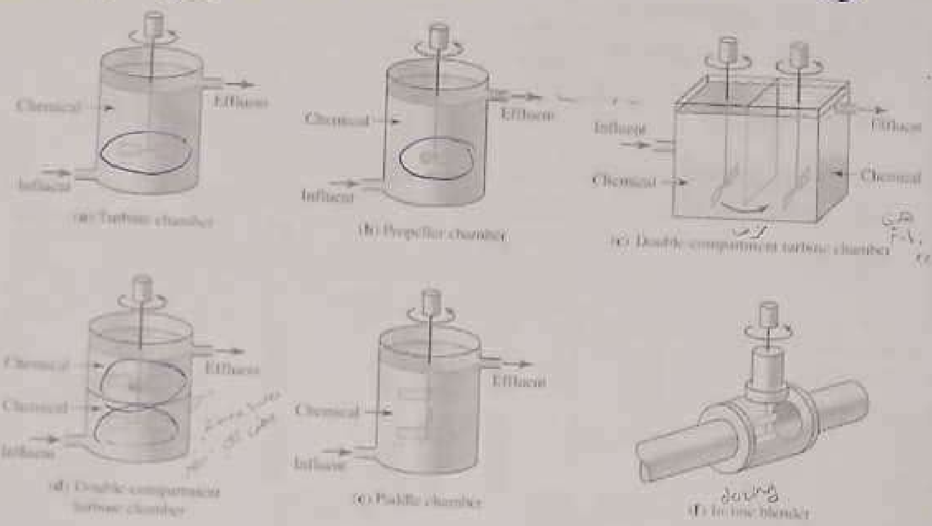
هذه الكتل تكون أكبر حجما وأثقل وزنا مما يسهل ترسيبها في المرحلة التالية من المعالجة.

The Alkalinity also measured (Alum) because there Salts react with the Alkalinity in the water and reducing its buffering capacity

Resist

bubbles → ~~resistance~~ time

Flow → . geometry الهدف من تغيير



Mach number

Coagulants: Non-toxic and relatively inexpensive

- **Alum**
  - ✓ Hydrated aluminum sulfate $[Al_2(SO_4)_3 \cdot 18H_2O]$
  - ✓ Alum, when added to water, will be hydrolyzed to form gelatinous hydroxide $[Al(OH)_3]$ precipitate. This will carry suspended solids as it settles by gravity.

  gel effect

- **Anhydrous Fe^{3+}**
  - ➢ Forms $Fe(OH)_3(s)$ in a wide range of pH 4-11
- **Anhydrous Fe^{2+} $(FeSO_4 \cdot 7H_2O)$**
  - ➢ Must be oxidized to Fe^{3+} first at pH higher than 8.5

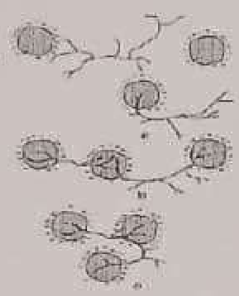
  polysaccharides.

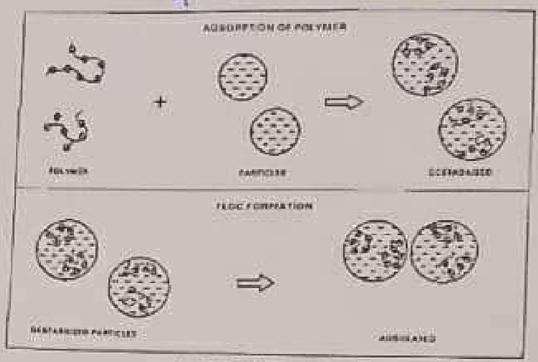
- **Coagulant Aids (Polyelectrolytes)**
  - ➢ Natural: Starch, cellulose derivatives, and gums (polysaccharides)
  - ➢ Synthetic polymers

Flocculation

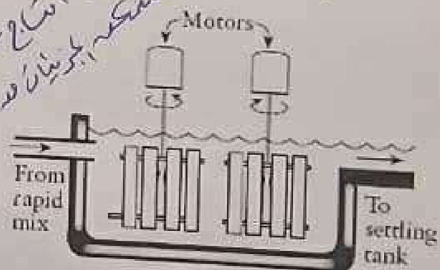
- It is the agglomeration of destabilized particles into a large size particles known as flocs which can be effectively removed by sedimentation or flotation.
- It needs gentle mixing.
- To enhance the agglomeration, organic polymers (flocculent) are added.

The chain is long enough to allow active groups to bond to multiple colloids





- The intent of the process of flocculation is to produce differential velocities within the water so that the particles can come into contact.



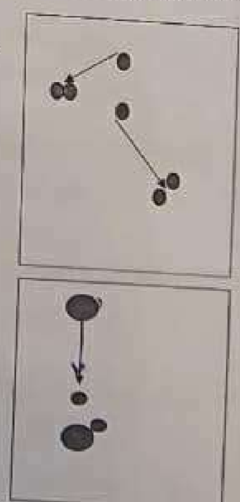
Typical flocculator used in water treatment.

Transport Mechanisms:

particle ↓ liquid ↑ concentric

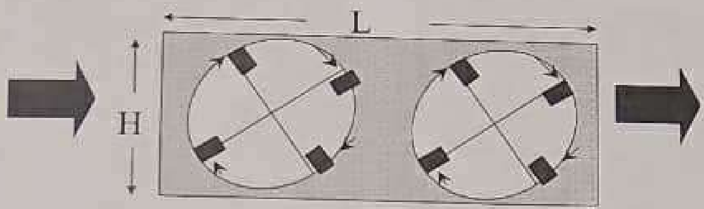
- ***Brownian motion:*** for relatively small particles which follow random motion and collide with other particles (perikinetic motion)

- ***Differential settling:*** Particles with different settling velocities in the vertical alignment collide when one overtakes the other (orthokinetic motion)

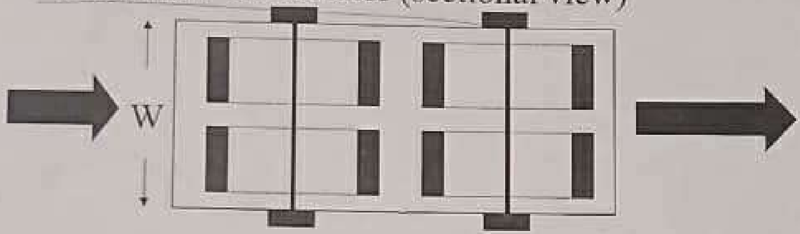


Mechanical Flocculator

Transverse paddle



Cross flow Flocculator (sectional view)



Plan (top view)

Hydraulic Flocculation

Small Volum [illegible] resists time particle settling down

- *Horizontally baffled tank*

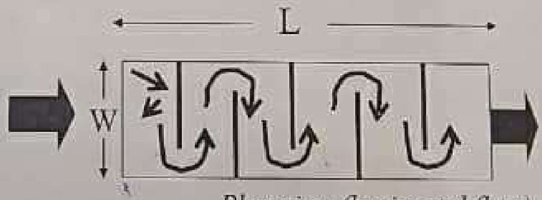
  The water flows horizontally.
  The baffle walls help to create turbulence and thus facilitate mixing

  [illegible]

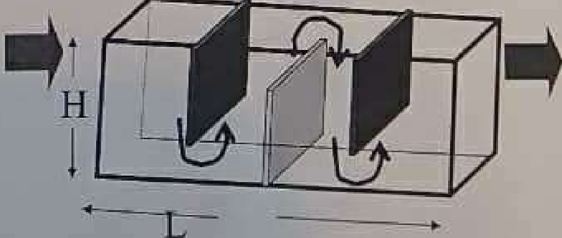
- *Vertically baffled tank*

  The water flows vertically. The baffle walls help to create turbulence and thus facilitate mixing [illegible]

  [illegible]



Plan view (horizontal flow)



Isometric View (vertical flow)

Flocculator perforated wall

المياه بتدخل عبر هاي الثقوب

للسؤال مهم

Determining Coagulant Dose

Jar Tests

pH افضل درجة حموضة

Coagulant Dose

- ❑ The jar test – a laboratory procedure to determine the optimum pH and the optimum coagulant dose

رح نثبت parameter ونغير الثاني

- ❑ A jar test simulates the coagulation and flocculation processes. وبعدين بنرجع نعمل العكس

Determination of optimum pH

particle → بحالة معلقة او ذائبة

- Fill the jars with raw water sample (500 or 1000 mL) – usually 6 jars

لازم نفس Volume

- Adjust pH of the jars while mixing using H_2SO_4 or NaOH/lime (pH: 5.0; 5.5; 6.0; 6.5; 7.0; 7.5) (5-8.5) range المياه اللي بتوصلنا
- Add same dose of the selected coagulant (alum or iron) to each jar (Coagulant dose: 5 or 10 mg/L)

نغير pH ونثبت does.

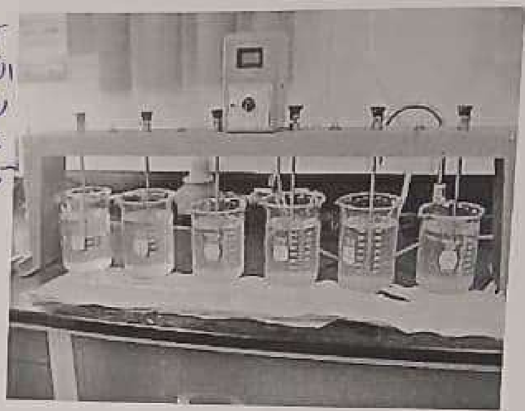
Beaker 5-10 mg/L

Jar Tests – determining optimum pH

- ❑ Rapid mix each jar at 100 to 150 rpm for 1 minute. The rapid mix helps to disperse the coagulant throughout each container

- ❑ Reduce the stirring speed to 25 to 30 rpm and continue mixing for 15 to 20 mins. This slower mixing speed helps promote floc formation by enhancing particle collisions, which lead to larger flocs

Flocculation



- ❑ Turn off the mixers and allow flocs to settle for 30 to 45 mins

- ❑ Measure the final residual turbidity in each jar

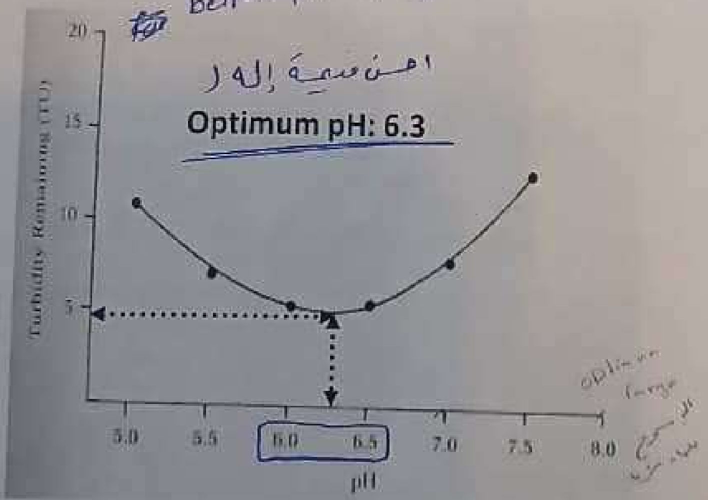
- ❑ Plot residual turbidity against pH

turbidity effect pH less turbidity so coagulant floc

Jar Tests – optimum pH

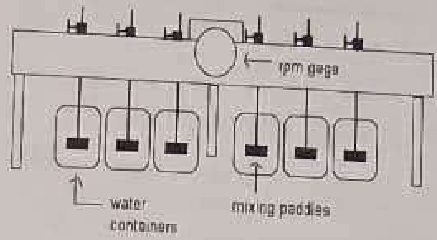
➤ The pH with the lowest residual turbidity will be the optimum pH

better pH range



Jar Test: Optimum coagulant dose

- ❑ Repeat all the previous steps
- ❑ This time adjust pH of all jars at optimum (6.3 found from first test) while mixing using H_2SO_4 or NaOH/lime

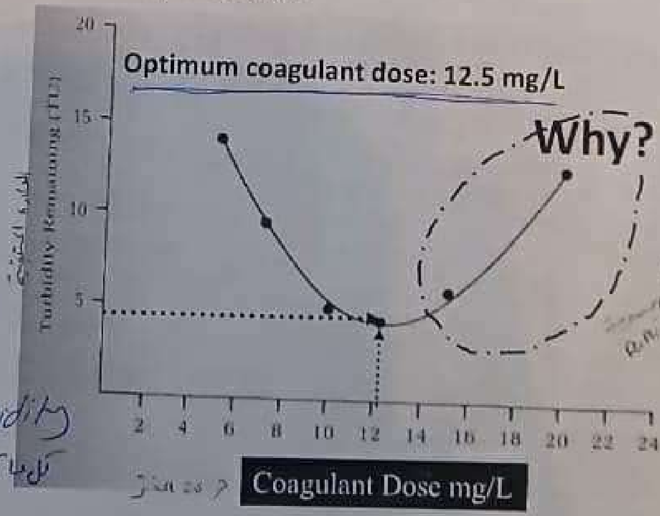


- ❑ Add different doses of the selected coagulant (alum or iron) to each jar (Coagulant dose: 5; 7; 10; 12; 15; 20 mg/L)
- ❑ Rapid mix each jar at 100 to 150 rpm for 1 minute. The rapid mix helps to disperse the coagulant throughout each container
- ❑ Reduce the stirring speed to 25 to 30 rpm for 15 to 20 mins

particle surface charge + ~~optimum~~

Optimum coagulant dose

- ❑ Turn off the mixers and allow flocs to settle for 30 to 45 mins
- ❑ Then measure the final residual turbidity in each jar
- ❑ Plot residual turbidity against coagulant dose



➢ The coagulant dose with the lowest residual turbidity will be the optimum coagulant dose

lowest point is the best because they less turbidity separation between liquid (carrier fluid) and suspension - inside.

إزالة الركد المتكونة

Sedimentation

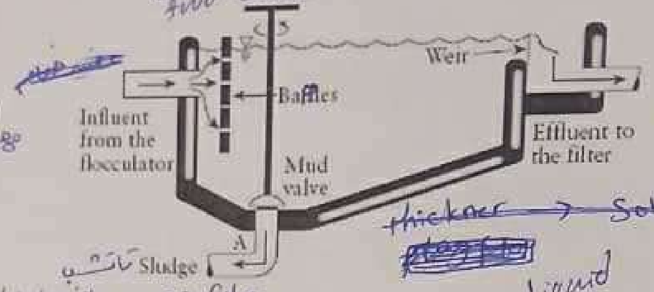
- Separation of formed flocs from water in *gravity settling tanks* that simply allow the heavier-than-water particles to settle to the bottom.

one inlet
two outlet

> Settling depends on:

- particle size (volume)
- particle shape مهم جدا
- particle density
- fluid density
- fluid viscosity.

particle have particle size low move with flow but the gravity force affect on it → so we happen velocity profile



~~thickner → solid~~

liquid
solid 5%

Particle Diameter (mm)	Typical Particle	Settling Velocity (m/s)
1.0	Sand	2×10^{-1}
0.1	Fine sand	1×10^{-2}
0.01	Silt	1×10^{-4}
0.001	Clay	1×10^{-6}

horizontal settling

الفرق بين clarifier و thickner
water ← clarifier
particle ← thickner

clarifier

Ideal settling tank

design + geometry
and the out let should to deal with it

- visualized hydraulically as perfect plug flow reactors

Surface Area of thickner or clarifier optimize

gal / day.ft

Overflow rate:

horizontal < settling velocity
overflow velocity

$$v_0 = \frac{m}{s} = \frac{Q}{A_s} = \frac{m^3/s}{m^2}$$

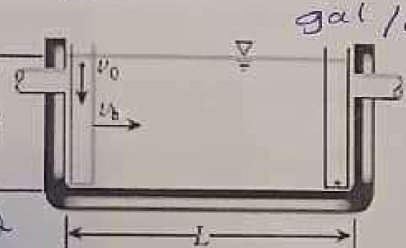
← flow velocity of water

$A_s = WL$

$$v_0 = \frac{H}{\bar{t}}$$

→ velocity of particle to reach the bottom

depth



two velocity
→ horizontal → with flow

retention time.

Examples: 10.16 10.17 10.18

$V = HLW$ $\quad \bar{t} = \frac{V}{Q} = \frac{HWL}{(HW)v} = \frac{L}{v}$

$V = HWL$
$A_s = WL$
$V = A_s H$

porosity ← هي اللي تفلتر tiny particle اللي ماشية.

Filtration → slow / rapid

إزالة هباء الجزيئات التي لم تتخلص منها الترسيب

Filtration

أنواع فلاتر رمل بطيء وسريع

- Removal (is a most) of those particles that are too small (tiny) to be effectively removed during sedimentation
  المخلفات السائلة

لتم إزالتها بشكل فعال أثناء الترسيب

> ➢ Sedimentation effluent: 1 -10 JTU
>
> ➢ Desired effluent level: <0.3 JTU (turbidity)

الحد الأدنى هو Flow rate

- Slow Filtration: لازم أزيد Surface Area حتى يقلل Flow rate
- rapid Filtration: لازم أقلل من Surface Area حتى A زيد Flow rate

- Slow sand filters
- Rapid sand filters

الـ skimmer بنحطه في البرك حتى ينظف سطح المياه من الأوساخ العائمة بسبب الماء من سطح البركة يعني النظام الفلترة

Filter موجودة قبل stand by

انا ما عندي filter فضيف (ازداد) يوصل له

Rapid sand filter

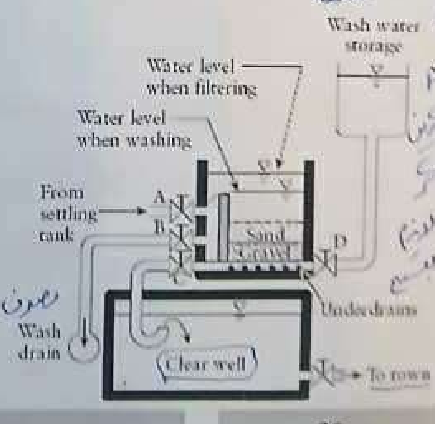
ΔP بسبب شد particles في porosity ويقلل في Flow

➢ The operation of a rapid sand filter involves two phases: filtration (main perpose) and washing.

- **Rapid-sand filters** (فلتر رمل سريع) : force water through a 0.45-1 m layer of sand (dp=0.4-1.2mm) and work faster, needing a smaller area. But they need frequent back-washing
  يحتاج إلى غسيل عكسي دوري

ويصبح فلتر الرمل مسدود بطريقة مما يؤدي لفقدان أكبر للضغط عبره لذا يجب تنظيفه مسدود

> ✓ rapid sand filter becomes clogged, resulting greater head loss through the filter, so it must be cleaned. This cleaning is performed hydraulically by a process called backwashing (10 - 15min).



لما يكون filter مفتوح يكون A, C مفتوحين و DB مغلقين لما يفلتر لحد ما تقل porosity بعدها أغلق filter و B, D وبعدين أفتح A, C

distributed

مسايل

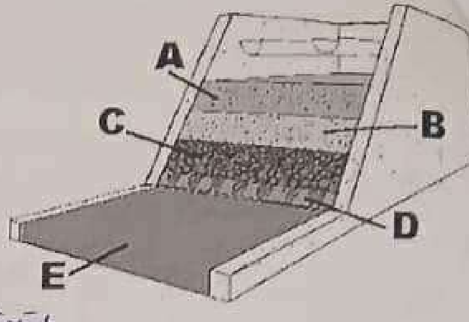
ع مسايل قبل ما نفتح A نفتح C وبعدين نفتح أكبر شوي ثم نفتح A

لما نوصل لهاد الوضع لازم نفتح B والمياه اللي سبب Tiny particle بسد porosity ح يصرفوا من B وبعدها نفتح A ويدخل المياه من فوق ويتسقط من الأعلى وزيادة porosity, ومع مرة ثانية liquid

D لما نفتح بدخل الماء الى bed ← expansion, sand + gravel turbulent medium جلسات جزء من المياه

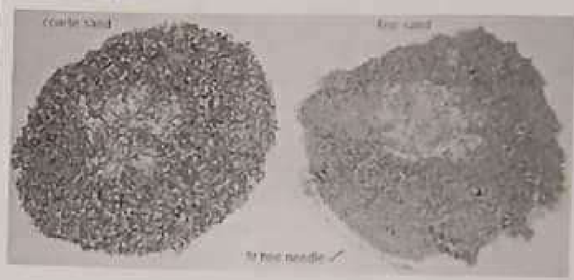
لما نفتح ونرفعها وتحرك

Rapid Filter Media



الأكثر شيوعاً مهم

- Single media: sand — رمل وسط مفرد
- Dual media: anthracite coal and sand — وسط مزدوج
- Multimedia: anthracite coal, sand and garnet — وسط متعدد — العقيق



خشن رمل بطيء

Slow sand filter

رمل filter كله خزان تجميع

surface area nearly larger than a rapid filter.

يتكون على السطح ترسيب للبكتيريا والفيروسات طبقة بيولوجية

تحتاج إلى مساحة السطح من الشيء

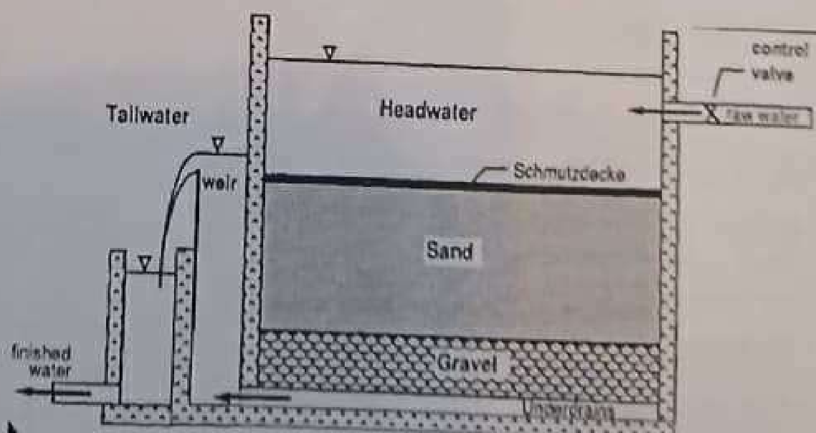
- **Slow-sand filters:** (dp=0.15-0.35mm) require a much larger area. The top 1 inch must be periodically scraped off and the filter occasionally back-washed

يجب كشطه بشكل دوري وغسل الفلتر بشكل عكسي من حين لآخر

طاردة شديدة في الأشياء البكتيريا او الطحالب

biofilm ⇒ قشرة طبقة

ان يتشكل طبقة بيولوجية



خبث الأوساخ

Biological Layer: The Schmutzdecke

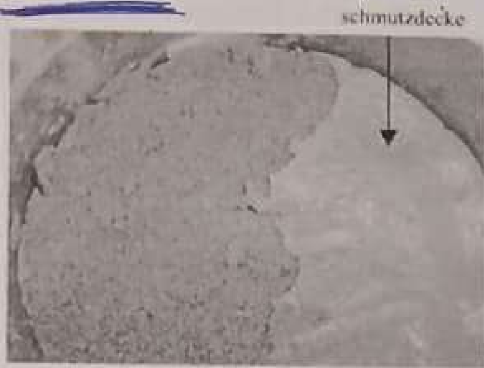
- Due to the organic and biological matter in the water to be filtered, a bio-layer grows on top of the sand layer

- The bio-layer contributes to water treatment by consuming organic contaminants including bacteria and viruses

- The majority of biological activity occurs in the top 20 cm of the filter

Biofilm Development

تنشأ طبقة شبكية ويشكل حاجز بكتيري Boundary



Layer of Schmutzdecke

oxidizing agent

التطهير

Disinfection

- water completely free of suspended sediment is treated with a powerful oxidizing agent usually chlorine, chlorine then ammonia (chloramine), or ozone. $O_3 \rightarrow$ very oxidizing agent but the life time is short

Ammonia Chlorine

- Disinfection is typically the last step in a water / wastewater treatment system

منع الإصابة مرة أخرى

- A residual disinfectant is left in the water to prevent reinfection.

- Chlorine can form harmful byproducts and has suspected links to stomach cancer and miscarriages.

- Many agencies now residually disinfect with Chloramine.

Disinfectants

سريع الذوبان

sodium hydrochloride calusuim hydrochloride

- **Gaseous Cl_2**
  - Most commonly used
  - **Advantage**: provide residual chlorine for the protection from bacterial growth in distribution system
  - **Disadvantage**: The formation of disinfection by-products (trihalomethanes) presents a health risk
- **Chlorine dioxide (ClO_2):**
  - No disinfection by-products such as trihalomethanes
- **$Ca(ClO)_2$:**
  - Safer than Cl_2
- **Ozone**: generated on site
- **UV lamps**

Chemistry of Chlorine in Water

HOCl = Hypochlorous acid
OCl = Hypochloride ion

- $Cl_2 + H_2O \rightarrow H^+ + Cl^- + HOCl$
  - HOCl is a weak acid with Ka = 4.5×10^{-4} ($HOCl == H^+ + OCl^-$)
  - HOCl and OCl^- are free available chlorine which are very effective in killing bacteria
- Small amount of ammonium (NH_4^+) in water is desired
  - Chloramines: NH_2Cl, $NHCl_2$, NCl_3
  - Chloramines (combined available chlorine) are weaker disinfectants than free available chlorine but are desired residual chlorine to be retained in water distribution system
- Excessive amount of ammonium (NH_4^+) in water is undesirable because it consume excess demand of Cl_2

وجود كمية زائدة من الامونيوم في الماء امر غير مرغوب فيه لأنه يستهلك الطلب الزائد من ثاني أكسيد الكلور

Disinfectant	Minimum Residual* (mg/L)		MRDL** (mg/L)	MRDLG*** (mg/L)
	Leaving Plant	In Distribution System		
Chloramines (as Cl_2)	2.0		4.0	4.0
Combined residual		0.5		
Chlorine (as Cl_2)	2.0		4.0	4.0
Chlorine dioxide (as ClO_2)	2.0		0.8	0.8
Free chlorine residual		0.2		

* From Illinois and Missouri regulations

** MRDL = maximum residual disinfectant level

** MRDLG = maximum residual disinfectant level goal

Chlorine Demand or Breakpoint Chlorination

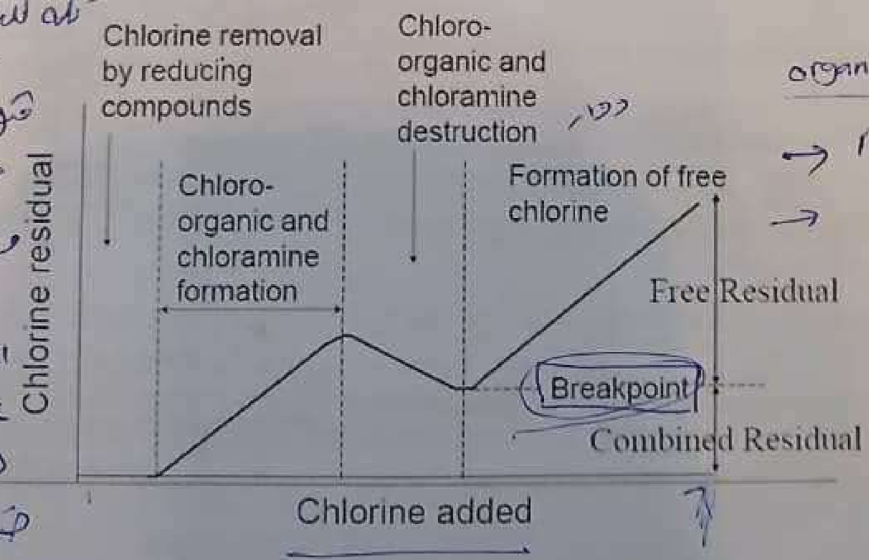
وبصير عنا عملية Addition of chlorine, وما نضل عنا residual بصير لأنه للتعقيم وتتفاعل مع organic matter Amonia. شو؟ وتكون chloramines ولما نوصل لل Reation formation أعلى ما يكون هاد بنقل عنا Residual وبعد هيك تبدا استهلاكه حتى يقل تعقيم وينزل الى lowest point

هاد السطر بحدد كم عنا ~~Residual~~ Residual وتم free organic matter (Amonica)

→ residual y axis

→ dose x axis.

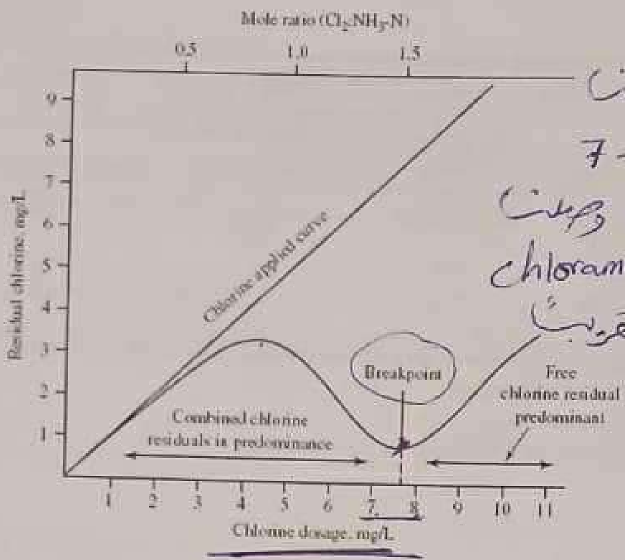
ومن breakpoint وتتم التركيز



Final Residual = Free concentration + Combined concentration

~~Flo~~ ~~tofa~~ chloramines → Combined

free → عالحرف اي واحد



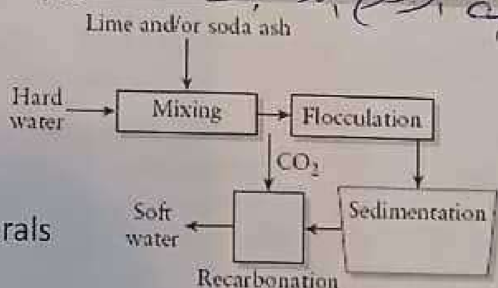
* على اي dose وصلت breakpoint → 7-8

* على اي dose وصلت maximum لل chloramine → عند 4 وشوي تقريباً

Groundwater Treatment

← نشوف لون لم نحن Dissolved solid

* وتم نسبة الاملاح الذائبة TDS



➤ **Primary objectives are to**

إزالة العسرة والمعادن الاخرى

1. Remove hardness and other minerals

القضاء على الكائنات الممرضة

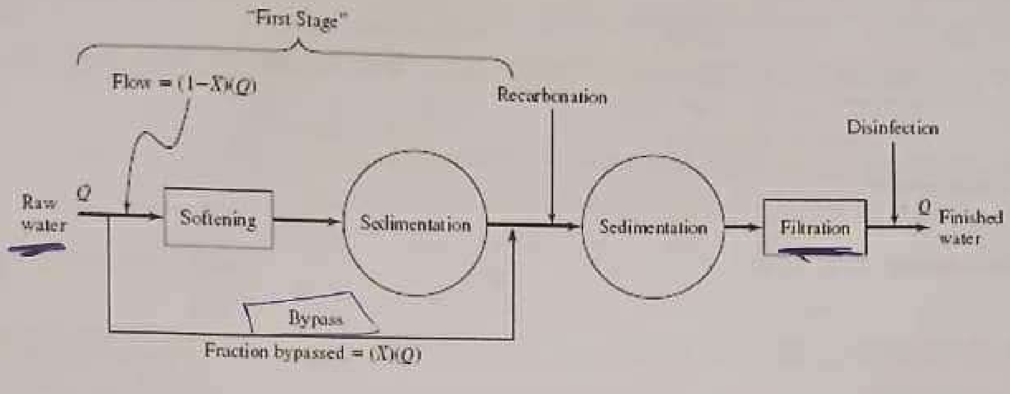
2. Eliminate pathogenic organisms

- Treatment technologies largely based on chemical precipitation

الترسيب الكيميائي

we need chemical reaction

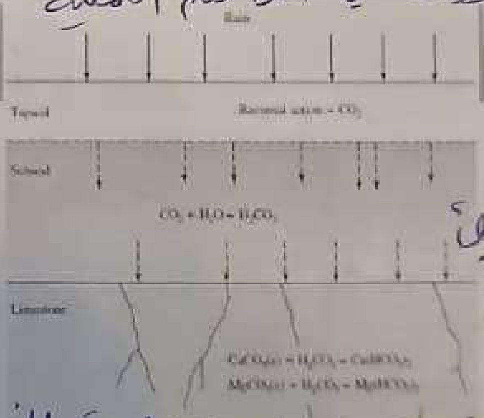
احسن طريقة تعدل فيها pH هو نضخ CO_2 inside



بدنا نصمم اداة تخلي يروح منها أكثر ملوحة لاقل ملوحة وهاي بكون بدها ضغط عكسي حتى تتم العملية

إزالة العسرة للمياه . إزالة القساوة

Water Softening



مثل زعانف السمك وهيك بنحلي مي البحر

- Groundwater is generally harder than surface water. طبقة كلس
- Hard waters produce scale in hot-water pipers, heaters and boilers.
- The removal of ions that cause hardness is called softening.

العملية العكسية للخاصية الأسموزية للنباتات .

- Softening can be accomplished by the lime-soda process, ion exchange, nanofiltration, or reverse osmosis. multivalent
- Principal cations causing hardness and the major anions associated with them (in decreasing order of abundance in natural waters)
  - Cations: Ca2+, Mg2+, Sr2+, Fe2+, Mn2+
  - Anions: HCO3-, $SO_4$2-, Cl-, NO_3-, $SiO_3$2-

بالترتيب التنازلي للموجودة في المياه الطبيعية

السبب الرئيسي

Water Softening Methods

كربونات الصوديوم **1. LIME-SODA SOFTENING**

اللي بس نضيف عليه الماء بتصير

عند وجود بيكربونات استخدام الجير فقط

➢ **Quicklime** (CaO), commonly called ***lime***, *and* hydrated lime [$Ca(OH)_2$]:

عند غياب بيكربونات استخدام الجير وصودا كاربونات

الجير الحي

- *Slaking:* $CaO + H_2O \rightleftharpoons Ca(OH)_2 + heat$

التهدرج

Softening Methods;

- **lime-only process:** when Ca^{2+} is present primarily as "bicarbonate hardness"
- **lime-soda [$Ca(OH)_2$-Na_2CO_3] process:** when bicarbonate is not present at substantial level

على مستوى أكبر

عشان اتخلص من Hardness لازم اترسب الكالسيوم والمغنيسيوم، الكالسيوم تترسب ك ~~كالسيوم كاربونات~~ Calcium Carbonat
والمغنيسيوم تترسب ك magnisum hydroxide

RXNs

كيف اترسب كالسيوم وكيف اترسب مغنيسيوم

كربونات المغنيسيوم ما بتذوب (ما بتترسب) عشان اتخلص منها لازم اضيف كربونات ~~الـ~~ الكالسيوم

كربونات الصوديوم الهدف منه احول CO_3 + Mg

Neutralization of carbonic acid

$$CO_2 + Ca(OH)_2 \rightarrow CaCO_3(s) + H_2O$$

Precipitation of carbonate hardness

$$Ca^{2+} + 2HCO_3^- + Ca(OH)_2 \rightarrow 2CaCO_3(s) + 2H_2O$$

$$Mg^{2+} + 2HCO_3^- + Ca(OH)_2 \rightarrow MgCO_3 + CaCO_3(s) + 2H_2O$$

$$MgCO_3 + Ca(OH)_2 \rightarrow Mg(OH)_2(s) + CaCO_3(s)$$

Precipitation of noncarbonate hardness due to calcium

$$Ca^{2+} + Na_2CO_3 \rightarrow CaCO_3(s) + 2Na^+$$

Precipitation of noncarbonate hardness due to magnesium

$$Mg^{2+} + Ca(OH)_2 \rightarrow Mg(OH)_2(s) + Ca^{2+}$$ precipitate

$$Ca^{2+} + Na_2CO_3 \rightarrow CaCO_3(s) + 2Na^+$$

هاي الطريقة تنشر على مستوى كبير
large scale
عشان المشاكل محلها
أروع
Ion exchange

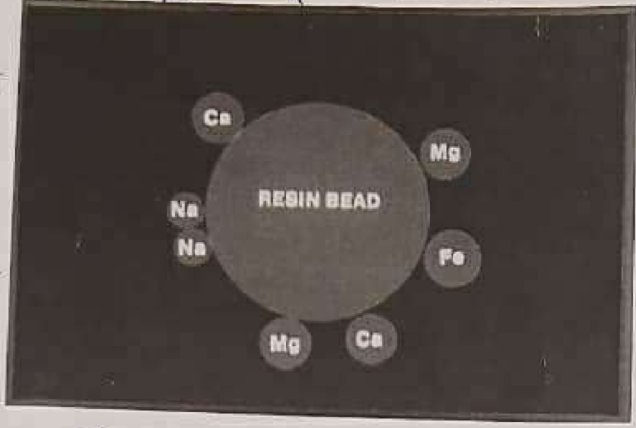
polymer thermoset
مبلمرات من أكثر الزجاجية
الشكل وتركيبة شبه زجاج
بلاستيك

اطاء بعد softing مائي Hardness
بسبب مادة لأني شبعتها بالصوديوم.
تتساءل من السطح صوديوم زيادة

Resin

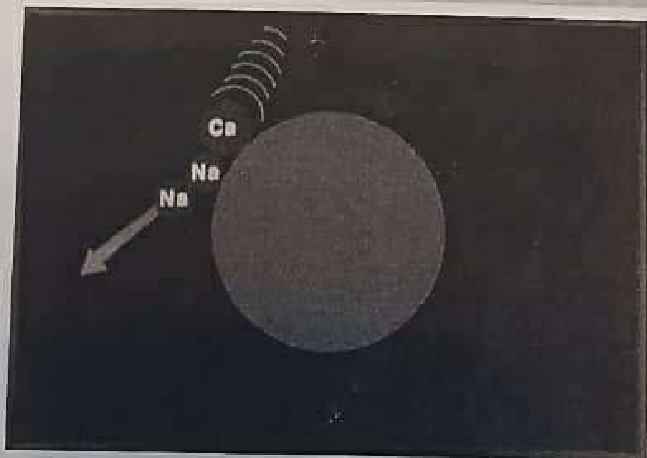
Therm set
يعني إذا سخنتها ما تنصهر
اللي تنصهر اسمه Thermoplastic
قادرة تأخذ شحنة وتعطي شحنة
فأنا جاي بشحنها بالصوديوم
يعني ملح ب
fixed bed.

وتعطي مكانها صوديوم
يعني هي اعطاء ايون carrier

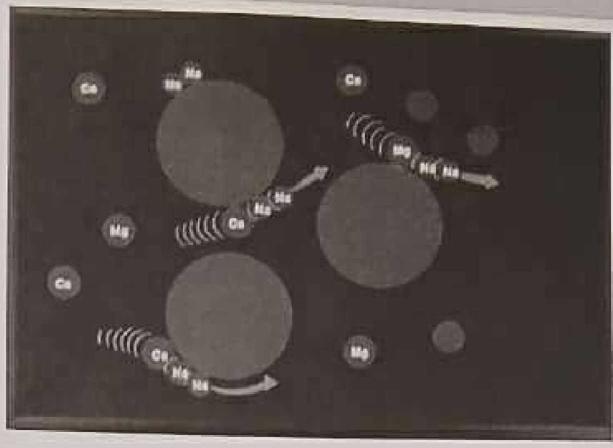


- Cation resin bead attract and hold positively charged ions.
- Those ions remain on the bead until the bead encounters other ions for which it has a greater affinity.

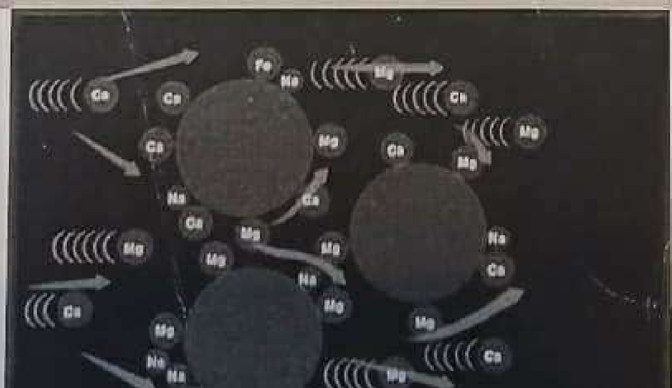
bead تتعلق على
لحد ما تلتقي بأيون أكثر
أيون لها تفاعل أكبر معه



- Resin bead releases Na^{+} and absorbs Ca^{+2} and Mg^{+2} ions for which it has a greater attraction. تركيز
- Ions are not destroyed or changed chemically; they are simply replaced on the resin bead.
- This process is known as ion exchange. (Softner)



- Resin beads attract Ca^{+2} and Mg^{+2} ions and release Na^{+}
- Water has been softened because the Ca^{+2} and Mg^{+2} concentrations, which cause water hardness have been reduced.



واضح

Resin

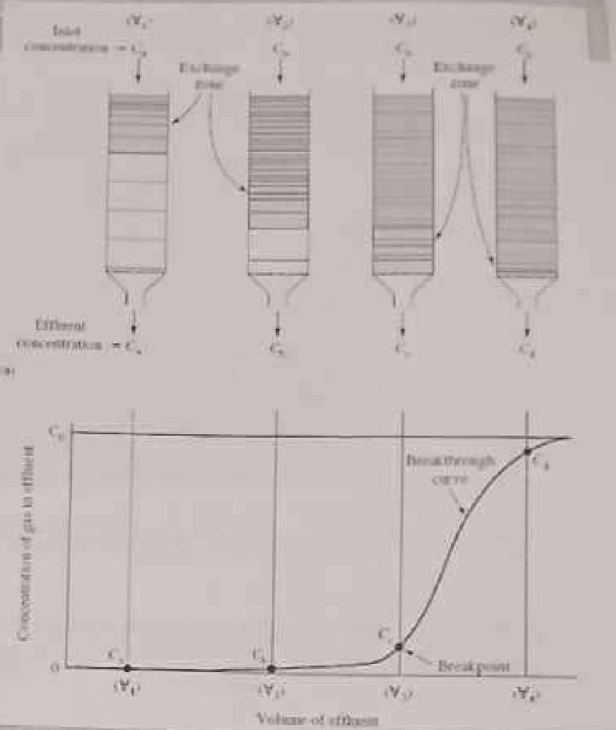
لم يعد قادر على تليين الماء

- After a vast number of Ca^{+2} and Mg^{+2} ions have become attached to the resin beads, and most of the Na^{+} ions have been released, the resin can no longer soften the water. وارد
- If no new chemical reaction is set, the incoming Ca^{+2} and Mg^{+2} ions flow untouched through the unit because there is no room for them on the resin beads.

دفعة جديدة شحنة بالأدوات

Breakthrough Curve

- It is more typical at municipal plants for the breakthrough criterion to be set much lower, for example, at 5% to 10% of the influent concentration.

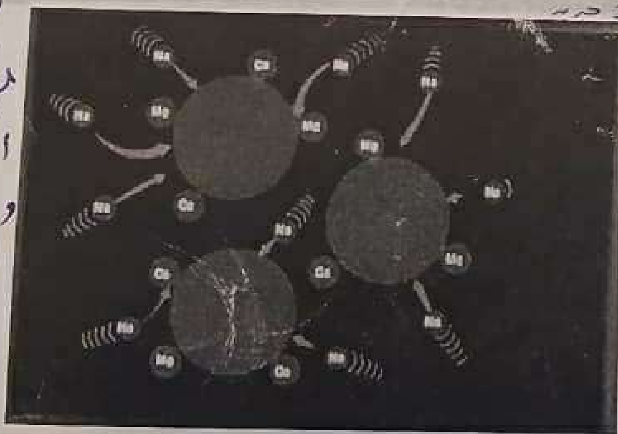


اي softner في جنبه tank وبتكون عادة عينة الماء أقل من تركيز الملح
full with sodium (ملح) فانا اوصل لمرحلة saturation

Resin Regeneration

اعادة شحن (مرة كل يوم) بتخلص من الكالسيوم والمغنيسيوم

باستخدام محلول غني بالصوديوم



- The reaction can be reversed by greatly increasing the concentration of sodium in the solution.
- Reverse process drive the Ca^{+2} and Mg^{+2} ions off the resin beads and replace them with Na^{+} ions.
- Although the resin beads prefer Ca+2 and Mg+2 ions, the excessive concentration of Na+ ions overcomes this affinity.

Wastewater Treatment

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Wastewater Treatment

- **Wastewater:**
  - Usually refer to sewage مياه المجاري treatment, or domestic wastewater treatment مياه صرف صحي
  - process of removing contaminants ملوثات from wastewater, both runoff جريان سطحي and domestic المنزلي

- **Wastewater comes from:**
  - Residences (kitchen, bathroom) مناطق سكنية
  - Commercial institution مباني تجارية
  - Industrial institution (usually require specialized treatment process)

WW is collected and transported via a network of pipes and pump stations to a municipal treatment plant

عشان نعرف الـ Quality لعينة من المياه العادمة

Typical Wastewater Characteristics

COD ضعف BOD

Parameter	Concentration (mg/L)
Biochemical Oxygen Demand (BOD)	250
Total suspended solids (TSS)	250
Chemical oxygen demand (COD)	500
Nitrogen, Total	40
Ammonia	30
Organic	10
Nitrate	0
Phosphorus, Total	10
Ortho	6
Organic	4
Total organic carbon (TOC)	150
Chloride	50

250–300

500–800

مهم نحفظهم

أي مادة عادمة داخلة كمحطة بتكون محتوية على هاي المواصفات

An estimate of the flow rate : 600L/capita-day

تعريفًا ← اختلاط مياه الصرف مع المياه العادمة ووصولها إلى البشر عن طريق الطعام والماء.

Purpose:

To control

- To manage water discharged from homes, businesses, and industries to reduce the threat of water pollution.

لتقليل خطر تلوث المياه

- To reduce the amount of pollutants in the water to such a level that the water can be returned to the environment without causing stress on aquatic life and be of sufficient quality for subsequent users.

تقليل كمية الملوثات في المياه إلى مستوى الذي يسمح بعودة المياه إلى البيئة دون التسبب في ضغط على الحياة المائية وتكون ذات جودة كافية للمستخدمين اللاحقين

ممكن تكون واصلة quality level صالحة للاستخدام

لازم المياه بعدما تطلع من المحطة تكون لها معايير خاصة مثل تقلل BOD ، TDS مشان ما تسبب ضغط على الكائنات الحية

بشيل الاجسام الصلبة من خلال gravity حتى اتقى المياه من الاساس ⇒ clarifier
force العالقة منها

Types of Treatments

1. ▪ **Mechanical treatment** primary → Remove all of suspended
   - Influx (Influent) → screening, filter 5cm >>>
   - Removal of large objects → TSS
   - Removal of sand and grit
   - Primary Sedimentation

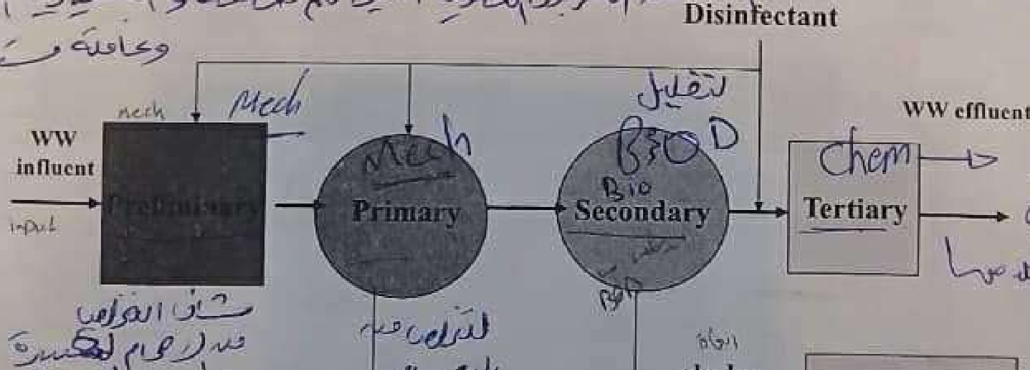
   خفف من المواد العالقة في المياه
   هون بستخدم clarifier
   ازالة الاجسام الكبيرة
   بيدا بالحجم الاكبر ثم الاصغر
   الجاذبية
2. ▪ **Biological treatment** secondary → partial ازالة جزئية
   - Trickling bed filter (fixed bed, Biofilm) تقليل BOD
   - Activated sludge → اشهرهم

   معالجة المياه من كل مركبات كربونية عضوية حيوية
   to settling down [sedimentation]
3. ▪ **Chemical treatment** Tertiary
   - Disinfection تعقيم المياه

① ازالة TSS
② ازالة TSS [Bio]
③ تعقيم chemical

← المياه اللي بتطلع من محطة عادةً بتكون BOD الها اقل من 20 وهي بتكون قبل 250

* Activated sludge ⇒ عبارة عن 2 tank بنستخدم فيه البكتيريا الاول للتهوية للبكتيريا الهوائية والتي بتكون ذوبت الاكسجين لكي تتغذى على organic matter وتتكاثر والثاني secondary clarifier
Wastewater treatment stages
مشان اتجمع الاجسام العالقة والكربون العضوي بتترسب في القاع Bottom
وتتقدم البكتيريا بوزنها وتتحول mass
تعقيم
من الكربون العضوي اللي تم تحليله والبكتيريا اللي تشكلت وعالقة ومستوطنات



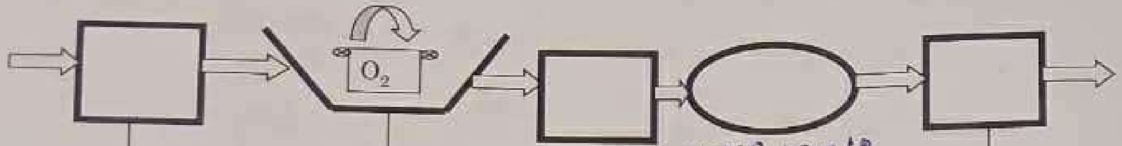
اللي طلع من clarifier بيكون اسمه

Soln particle نسبة (الجزء) sludge
من 20% - 10%

.حرق ال Biogass عشان اعرض فحمة ب electric power الازوفة

Thickener ← Clarifier ← sludge

Wastewater Treatment Processes



oxygen فابدها

Primary treatment (mech)
- screening
- grit removal
- removal of oil
- sedimentation

Flotation

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

it's not filter

يعتمد على البكتيريا

Tertiary treatment (chemical)
- Nitrate removal
- Phosphorus removal
- Disinfection

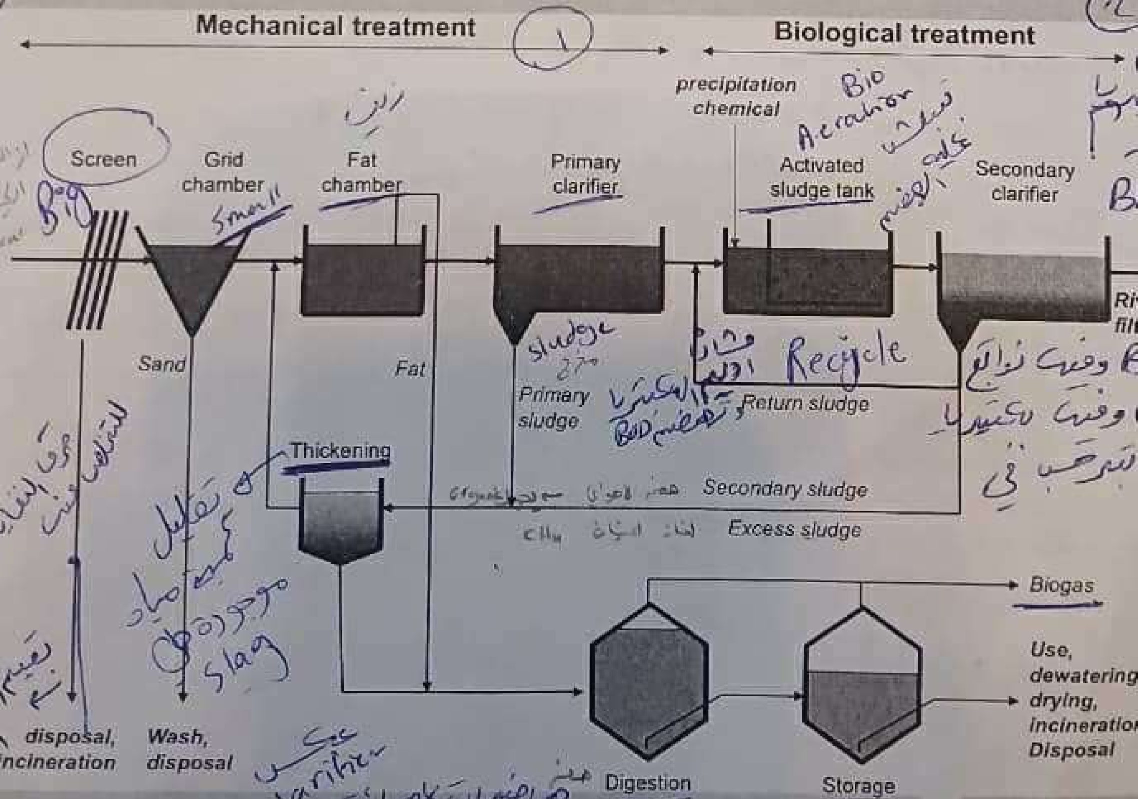
stage الاهم Disinfection

Aerobic ⇒ CO_2 H_2O Anaerobic ⇒ biogas ⇒ غاز ميثان + CO_2

* إذا ما كان عنا نظام Digestion في محطة مفروض افرز sludge وأعالجه farther treatment

Flowsheet

Layout of a WWTP



Biomass

BOD in 200

ميثان + CO_2

Thickner ⇒ زيادة تركيز solid particle عن طريق ازالة المياه

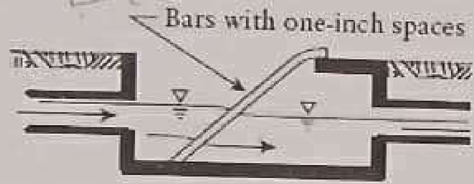
Preliminary Treatment

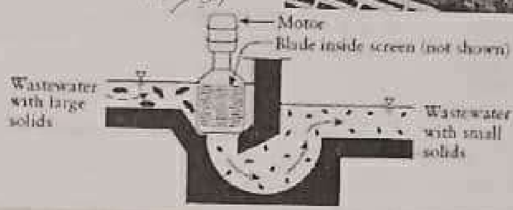
- removes large objects and non-degradable materials
- protects pumps and equipment from damage
- bar screen and grit chamber

bars

❑ Bar Screen

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





surface hardness →

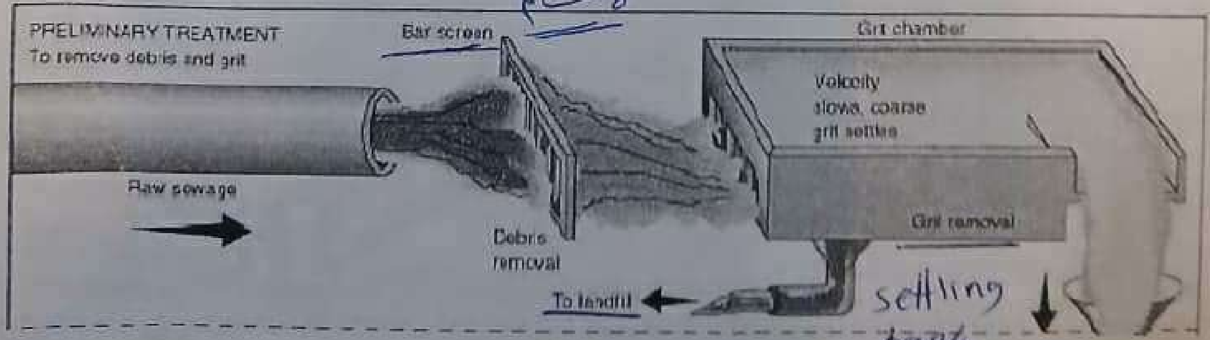
Preliminary Treatment

particles

Density

❑ 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)



particle have large density

1 inlet , 2 outlet → one inlet (influent)

اهم جهاز

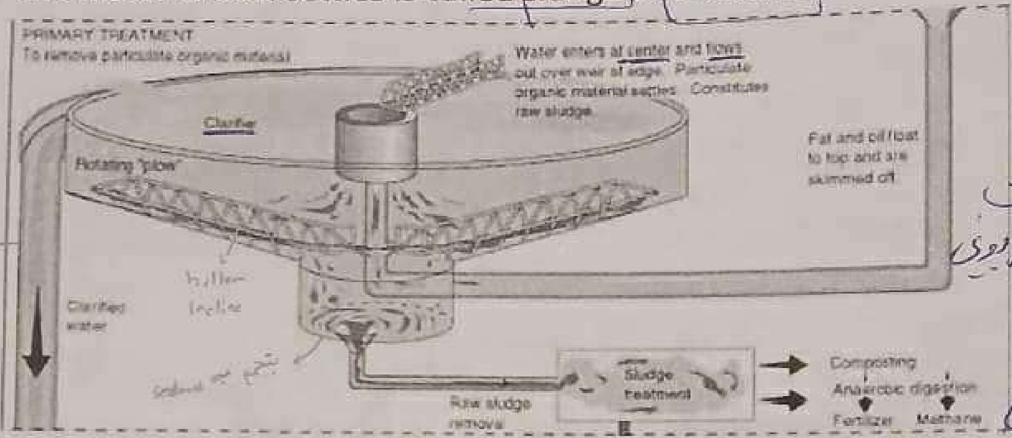
Primary Treatment clarifier

→ two outlet

gravity force

- 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

overloaded



input → influent

output (1) → sludge

output (2) → clarified water

اللي بترسب تحت بكون فيه محتوى عضوي حيوي Sludge (Biosolid)

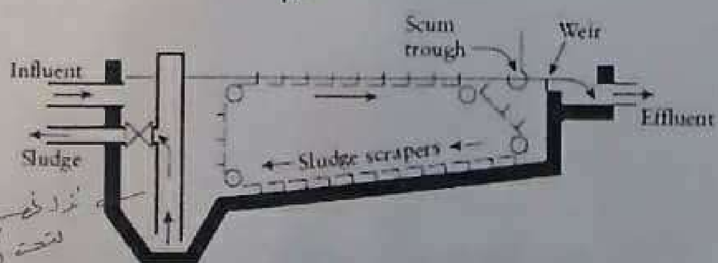
Sedimentation tanks and clarifiers

- The settling tank that follows preliminary treatment, such as screening and grit removal, is known as the *primary clarifier*.

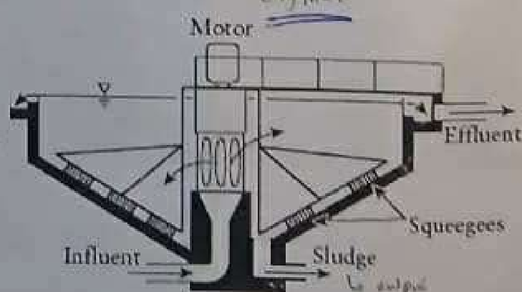
→ clarifier 30% COD BOD

- 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).

rectangular

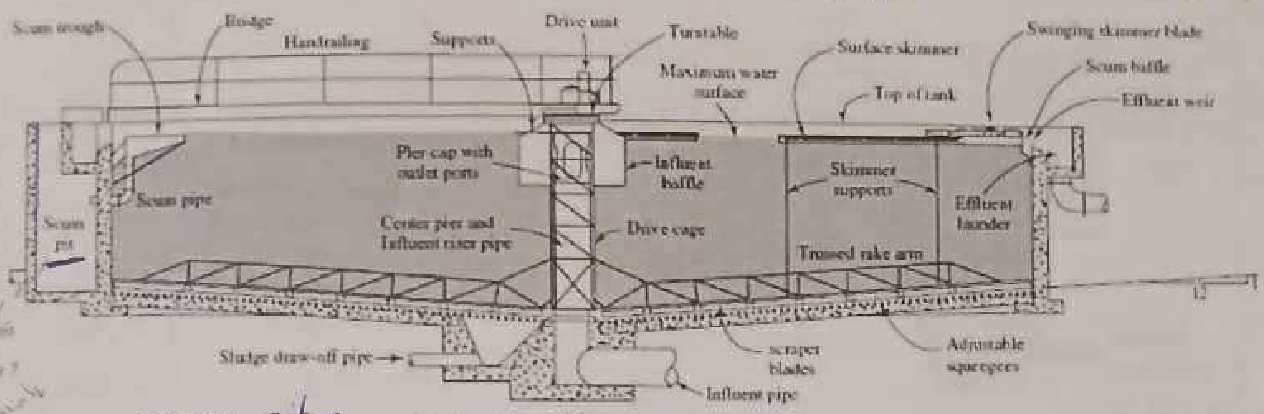


Cylinder



the clyndrical

بالتوب في زي قاشطات مشان تلتقط الزيت او المواد او الرغوة .



scum pit → أكثر من الرغوة لازم بتكون مليانة
ملوثات بالأخص الملوثات الدهنية والزيت

rectangular.

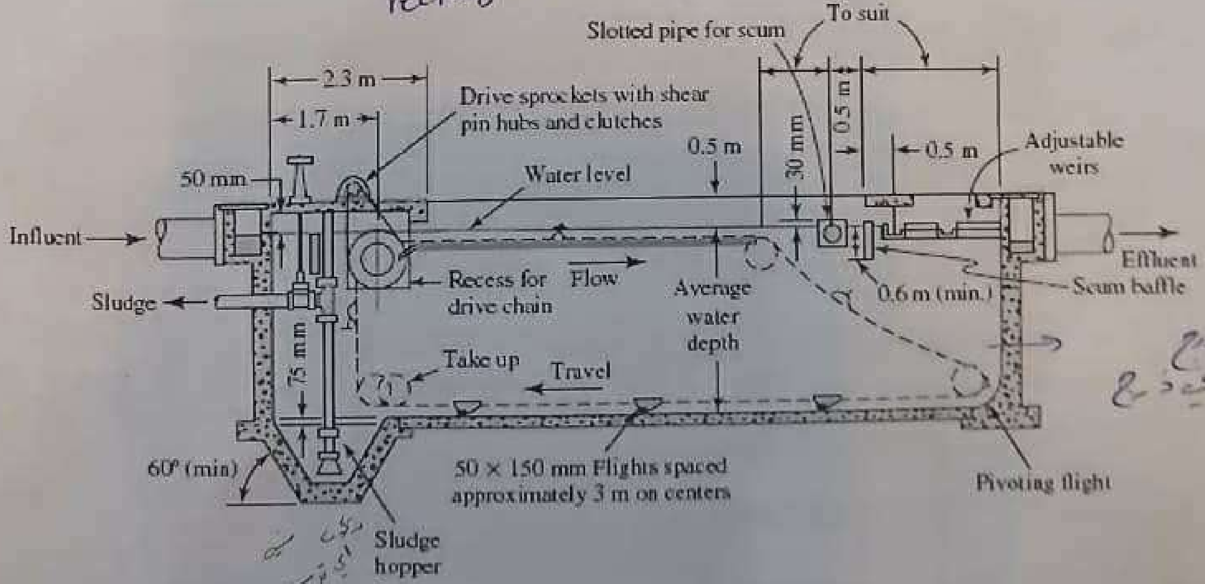
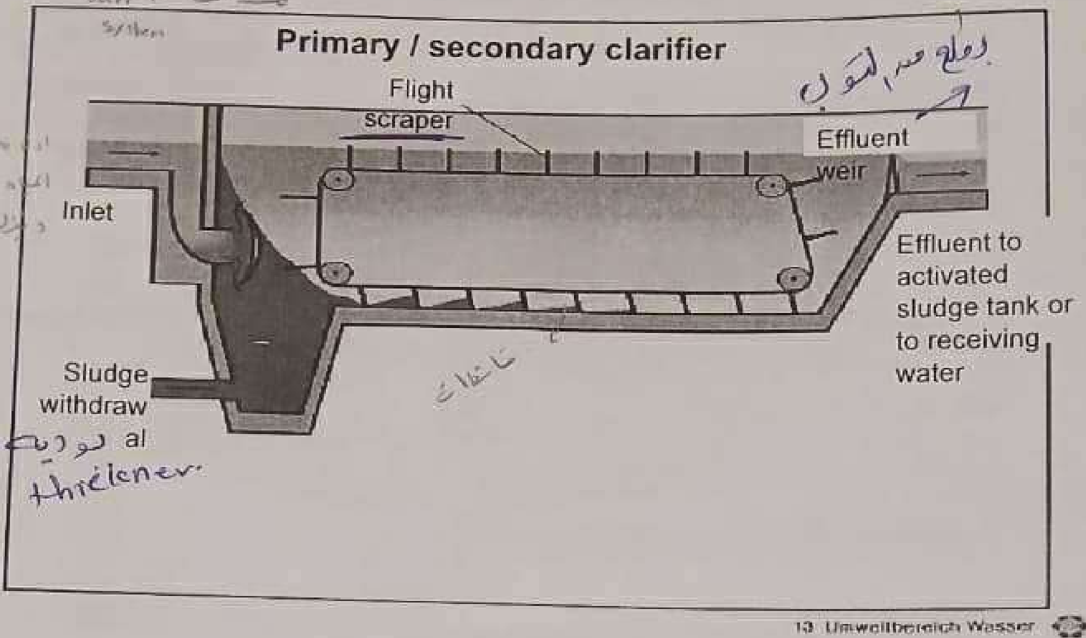


FIGURE 21-3
Rectangular primary settling tank. (*Source:* Davis and Cornwell, 2008.)

buffle system



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%

6 primary

350 m^3

reduce primary clarifier

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

Secondary Treatment

Bio mass

A Biological Process

secondary

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

Substrate

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

Oxygen

1 part per million

tank

secondary ⇒ settling tank

tank

(activated sludge (Bio mass)

① Organic Matter

organic Matter ⇒ substrate

③ ② بكتيريا

Aerobic + Anaerobic ⇒ جدول بدمج BOD بالتالي تستقبل عليه وتهضمه
Aerobic ⇒ CO_2 H_2O ⟵ BOD
Anaerobic ⇒ غاز الميثان ⟵ BOD

Secondary clarifier
Surface BOD

Trickling filter :-
fixed bed عبارة عن ... media ...
porosity ... BOD ...

...W...

...on ... methods

... att... | ...erobic and anaerobic

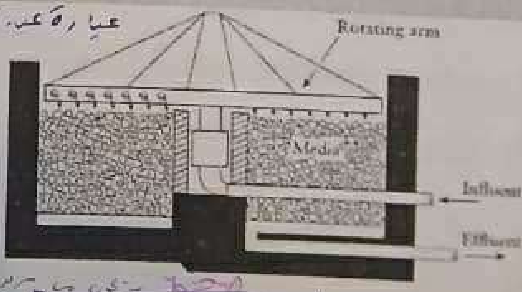
... pro... in... mai... suspension while converti... matter to gases and cell tissue (Activated sludge).	...logical treatment is a ...hich the pollutants in ...vater (organic matter) ...d by microorganisms in the presence of molecular oxygen.
(2) Attached growth is a biological w.w.t in which microorganisms 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).	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

مرشح التنقيط

porosity. | granular
media

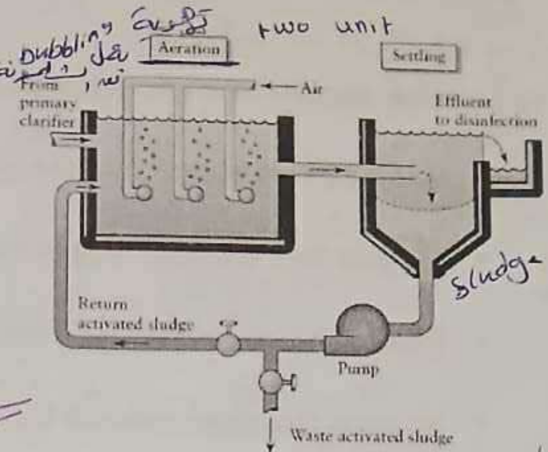


- It does not "filter" the water.
- It consists of a bed of media (such as fist-sized rocks or various plastic shapes) over which the waste is trickled.
- An active biological growth forms on the media, and the organisms obtain their food from the waste stream dripping over the bed.
- Air is either forced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

البكتيريا بوجود الاكسجين تحلل BOD

Activated sludge system

- Air is bubbled into this tank (called the *aeration tank*) خزان التهوية
- 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.***

هو sludge اللي رجعناه من secondary clarifier الى Aeration tank حتى يحلل BOD الداخل على Aeration tank بوجود الاكسجين

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.

Low flow rate

biomass ب pipe

لازم sludge اللي في ال Bottom اقسمه
Volume
flow rate
resist time

لازم اشيل sludge اللي بترسب في Bottom
volume clarifier

Basic Ingredients & Conditions

BOD microorganisms

- High density of microorganisms (keep organisms in system)
  - Good contact between organisms and wastes (provide mixing)
  - Provide high levels of oxygen (aeration)
  - Favorable temperature, pH, nutrients (design and operation)
  - No toxic chemicals present (control industrial inputs)

bubbling

Biological Growth Type

- **Suspended Growth –Activated Sludge** secondary clarifier
  - Bacteria are kept in suspension by mixing
  - Sludge age is controlled by reactor volume or biomass recycle following sedimentation
- **Attached Growth – Biofilter (Trickling Filters , Rotating Biological Contactors)**
  - Bacteria are attached on supporting media or entrapped between supporting media

suspended attached

Dispersed growth vs. Fixed Growth

- ❑ ***Dispersed Growth*** *–suspended organisms*
  - ✓ Activated sludge
  - ✓ Oxidation ditches/ponds
  - ✓ Aerated lagoons, stabilization ponds
- ❑ ***Fixed Growth*** *–attached organisms*
  - ✓ Trickling filters
  - ✓ Rotating Biological Contactors (RBCs)

لازم الأكسجين يكون أعلى من 4 part per million
<< 4 mg/L

Design of Activated Sludge Systems

- Wastewater is aerated in a tank
- Bacteria are encouraged to grow by providing
  - Oxygen
  - Food (BOD)
  - Nutrients N, P
  - Correct temperature (معتدلة)
  - Time
- As bacteria consume BOD, they grow and multiply
- Treated wastewater flows into secondary clarifier
- Bacterial cells settle, removed from clarifier as sludge
- Part of sludge is recycled back to activated sludge tank, to maintain bacteria population
- Remainder of sludge is wasted

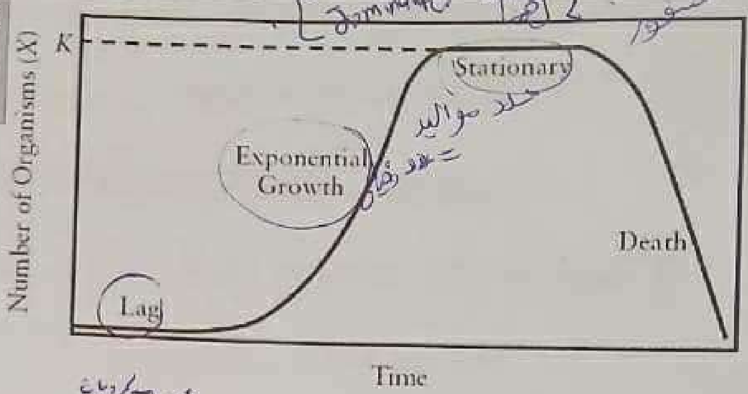
The microbial growth curve

Biochemical reaction

$$Food + O_2 + nutrients \xrightarrow{Bacteria} CO_2 + NH_3 + new \cdot biomass + other \cdot end \cdot products$$

Nutrients such as carbon, nitrogen, phosphorus, sulfur, and the elements required for the synthesis of proteins, nucleic acids, and other structural parts of the cells

The number of microorganisms is proportional to the growth rate:



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

$$X = X_0 e^{\mu t}$$

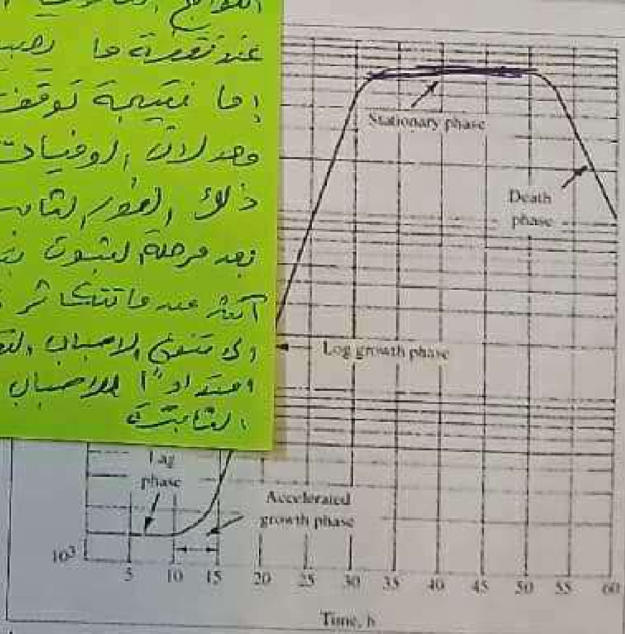
where X = number of microorganisms

μ = instantaneous, specific growth rate

تتم عملية تكاثر البكتيريا عن طريق الانشطار الثنائي (تنقسم كل خلية لتنتج خليتين جديدتين) ويتبع ازدياد في عدد السكان تقدما هندسيا

تتضاءل مرحلة نمو جذري الانشطار تدريجيا مع استنفاد الركيزة او تراكم المواقع الثانوية السامة وعند نقطة ما يصبح عدد السكان ثابت اما نتيجة توقف الانشطار او توازن معدلات الوفيات و التكاثر ويوضح ذلك الطور الثابت على منحنى النمو بعد مرحلة الثبوت تبدأ البكتيريا بالموت اكثر مما تتكاثر ترجع مرحلة الموت هذه الى تنوع الاسباب التي تعد في الاساس امتداد للاسباب التي تؤدي الى المرحلة الثابتة

- Bacteria reproduc... fission (each cell di... new cells), the inc... follows in geometri...
  $1 \xrightarrow{\times 2} 2 \xrightarrow{\times 2} 4 \xrightarrow{\times 2} 8 \xrightarrow{\times 2} 1...$
- The log growth pha... substrate become... toxic byproducts ... some point the p... constant either as ... of fission or a balance in death and reproduction rates. This is depicted by the stationary phase on the growth curve.



Following the stationary phase, the bacteria begin to die faster than they reproduce. This death phase is due to a variety of causes that are basically an extension of those that lead to the stationary phase.

The Monod Equation

$$\mu = \hat{\mu}\frac{S}{K_S + S} = \frac{1}{\theta_c}$$

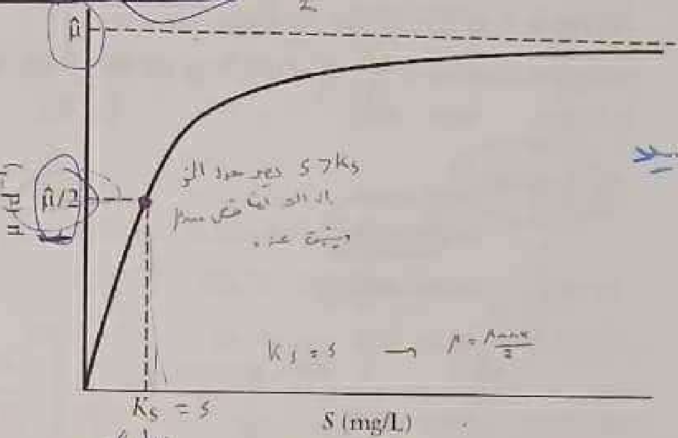
where $\hat{\mu}$ = maximum specific growth rate (at nutrient saturation)

S = substrate or nutrient concentration

K_S = saturation, or half-velocity constant

Two constants are used to describe the growth rate:

- α (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 $\alpha = \alpha/2$



Biomass production

$$\frac{dX}{dt} = growth \cdot rate - death \cdot rate = \mu X - k_d X$$

Where k_d represents the endogenous decay rate (d^{-1}) (i.e., microorganism death rate).

Substituting the growth rate constant:

$$\frac{dX}{dt} = \left(\frac{\mu_m S}{K_s + S}\right)X - k_d X$$

- Substrate utilization

$$-\frac{dS}{dt} = \frac{1}{Y}\frac{dX}{dt}$$

Where Y is the yield factor →
(mg of biomass produced/mg of food consumed)

- Y range:

  Aerobic: 0.4 - 0.8 mg/mg

  Anaerobic: 0.08 – 0.2

$$\frac{dS}{dt} = \frac{1}{Y}\frac{dX_{growth}}{dt} = \frac{1}{Y}\left(\frac{\mu_m SX}{K_s + S}\right)$$

- Food to microorganism ratio (F/M)
  - Represents the daily mass of food supplied to the microbial biomass, X, in the mixed liquor suspended solids, MLSS
  - Units are Kg BOD_5/Kg MLSS/day

$$\frac{F}{M} = \frac{BOD_5(Kg/m^3)\,x\,Influent\ flow(m^3/d)}{Reactor Solids(Kg/m^3)\,x\,Reactor Volume(m^3)}$$

$$F/M = \frac{QS_0}{VX} = \frac{S_0}{\bar{t}X}$$

mg/L or kg/m³

Where hydraulic retention time, $\theta c = \frac{VX}{QX} = \frac{V}{Q}$

$\bar{t} = \frac{V}{Q}$ average time the liquid remains in the reactor.

> Typical F/M ratio is between 0.2 – 0.5 kg BOD5/Kg MLSS/day

mix liquor suspended

Design Parameters for ASS

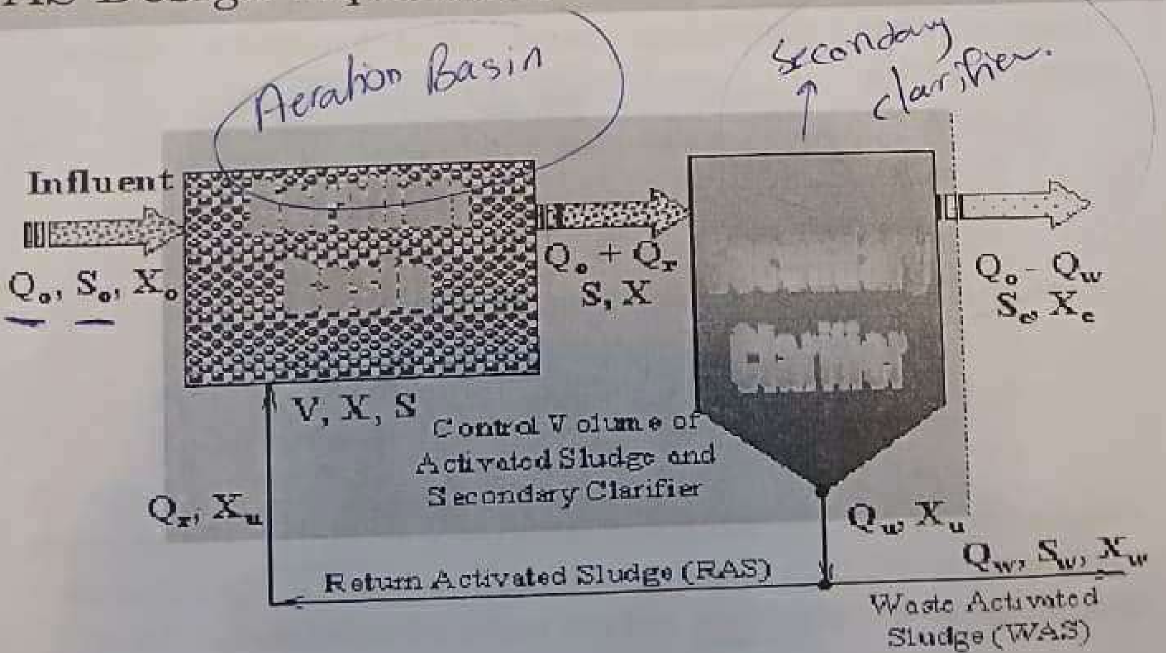
√/2

Design parameters for activated sludge treatment processes

Type of process	Mean cell residence time (days)	F/M (kg BOD_5/ kg MLSS)	Loading (kg BOD_5/ m^3-d)	Hydraulic retention time (hr)	MLSS (mg/L)	Recycle ratio
Conventional	5 - 15	0.2 - 0.4	0.3 - 0.6	4 - 8	1500 - 3000	0.25 - 1.0
Step aeration	5 - 15	0.2 - 0.4	0.6 - 1.0	3 - 5	2000 - 3500	0.25 - 0.75
Completely mixed	5 - 30	0.1 - 0.6	0.8 - 2.0	3 - 6	2500 - 4000	0.25 - 1.5
Contact stabilization	5 - 15	0.2 - 0.6	1.0 - 1.2	0.5 (contact) 3 - 6 (stabil.)	1000 - 3000 4000 - 10000	0.50 - 1.5
High-rate	5 - 10	0.4 - 1.5	1.6 - 16	2 - 4	4000 - 10000	1.0 - 5.0
Extended aeration	20 - 30	0.05 - 0.15	0.16 - 0.4	18 - 36	3000 - 6000	0.75 - 1.5
Pure oxygen	8 - 20	0.25 - 1.0	1.6 - 3.2	1 - 3	3000 - 8000	0.25 - 0.5

Substrate or BOD_5 BOD

AS Design Equations



chemical And toxicological Risk

Mass balance of biomass production (CSTR)

Influent biomass + biomass production = effluent biomass + sludge wasted

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

Substitute biomass production equation

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

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

influent — effluent — waste

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

Substitute substrate removal equation

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

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:

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

Overall equations

- Combine the mass balance equations for food and biomass:

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

The cell residence time is:

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

Restane time

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

Bio mass

Substitute and rearrange:

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

initial - final

Compute the F/M ratio

$$\frac{F}{M} = \frac{S_o}{\theta X} \qquad \frac{F}{M} = \frac{S_o}{(V/Q_o)X} = \frac{Q_o S_o}{VX}$$

Values of growth constants for domestic wastewater

Parameter	Basis	Value[a] Range	Typical
K_s	mg/L BOD5	25–100	60
k_d	d^{-1}	0–0.30	0.10
μ_m	d^{-1}	1–8	3
Y	mg VSS/mg BOD_5	0.4–0.8	0.6

[a]Values are for 20°C

Sources: Metcalf & Eddy, 2003; and Shahriar et al., 2006.

S in the effluent is exactly the same as S in the reactor is assumed to be perfectly mixed.

Ref. Book: Vesilind

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

Phosphorus Removal

depends on

- Phosphorus is typically found as mono-hydrogen phosphate (HPO_4^{2-}) in wastewater.

فوسفات العادي الهيدروجيني

تتم ازالة الفوسفور لمنع او تقليل eutr عادة عن طريق الترسيب بالكيميائي باستخدام احد المركبات الثلاثة.

- The removal of phosphorus to prevent or reduce eutrophication is typically accomplished by chemical precipitation using one of three compounds.
- The precipitation reactions for each are shown below:

ازالة الفسفور

- ferric chloride: $FeCl_3 + HPO_4^{2-} = FePO_4 + H^+ + 3\,Cl^-$
- alum: $Al_2(SO_4)_3 + 2\,HPO_4^{2-} = 2\,AlPO_4 + 2\,H^+ + 3\,SO_4^{2-}$
- lime:

$$5\,Ca(OH)_2 + 3\,HPO_4^{2-} = Ca_5(PO_4)_3OH + 3\,H_2O + 6\,OH^-$$

يرفع الـ pH

- You should note that ferric chloride and alum reduce the pH while lime increases it.
  - The effective range of pH for alum and ferric chloride is between 5.5 and 7.0.
  - If there is not enough naturally occurring alkalinity to buffer the system to this range, then lime must be added to counteract the formation of H^+.

اذا لم يكن هناك ما يكفي من القلوية الطبيعية لموازنة النظام بهذه الحالة فيجب اضافة lime لمقاومة تكوين H+

- The precipitation of phosphorus requires:
  - a reaction basin and حوض تفاعل
  - a settling tank to remove the precipitate.

- When ferric chloride and alum are used, the chemicals may be added directly to the aeration tank in the activated sludge system.
  - Thus, the aeration tank serves as a reaction basin
  - The precipitate is then removed in the secondary clarifier with biological solids.
- This is not possible with lime since the high pH required to form the precipitate is detrimental to the activated sludge organisms !!

> - In some wastewater treatment plants, the $FeCl_3$ (or alum) is added before the wastewater enters the primary sedimentation tank.
>   - This improves the efficiency of the primary tank
>   - But: this may deprive the biological processes of needed nutrients.

Nitrogen Control

- Nitrogen in any soluble form (NH_3, NH_4^+, NO_2^-, and NO_3^-, but not N_2 gas) is a nutrient and may need to be removed from wastewater to help control algae growth in the receiving body.

- In addition, nitrogen in the form of ammonia: يفرض طلباً على الأكسجين
  - exerts an oxygen demand and
  - can be toxic to fish.

- Removal of nitrogen can be accomplished either biologically or chemically:
  - The biological process is called *nitrification / denitrification*.
  - The chemical process is called *ammonia stripping*.

Nitrification/de-nitrification (Bio.):

- The natural nitrification process can be forced to occur in the activated sludge system by maintaining a cell detention time of 15 days or more.
- The nitrification step is expressed in chemical terms as follows:

$$NH_4^+ + 2\,O_2 = NO_3^- + H_2O + 2H^+$$

- Bacteria must be present to cause the reaction to occur. This step satisfies the oxygen demand of the ammonium ion.
  - If the nitrogen level is not of concern for the receiving body, then wastewater can be discharged after settling.
  - If nitrogen is of concern, the nitrification step must be followed by anoxic denitrification by bacteria:

$$2\,NO_3^- + \text{organic matter} = N_2 + CO_2 + H_2O$$

إزالة النيتروجين عن الأكسجين بواسطة البكتيريا.

lec7

معالجة الحمأة التخلص من

Sludge Treatment & Disposal

Dr. Motasem Saidan

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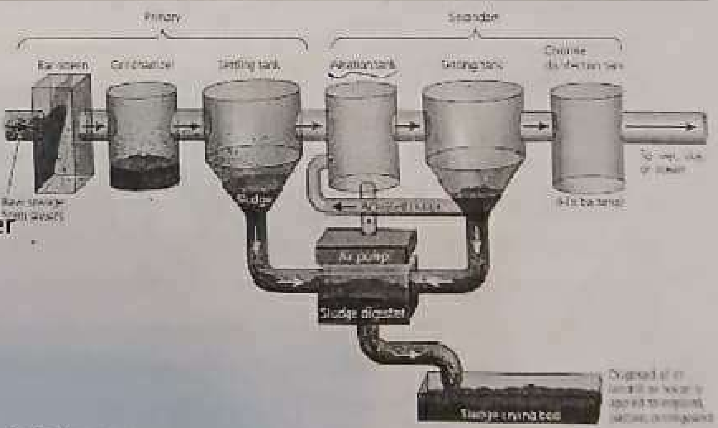
Sludge Sources

Sources of sludge حمأة

- Primary sedimentation tank حوض ترسيب الأولي
- Aeration basin or secondary clarifier حوض التهوية حوض ترسيب ثانوي
- Screening and grinder
- Filter backwash water مياه غسيل المرشحات



Sludge must be treated because:

- they are aesthetically displeasing, غير مرغوبة من ناحية جمالية
- they are potentially harmful, ضارة
- and they contain too much water.

Sludge Types

لا يوجد نوعين متماثلين من حمأة مياه الصرف الصحي في جميع النواحي

- 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

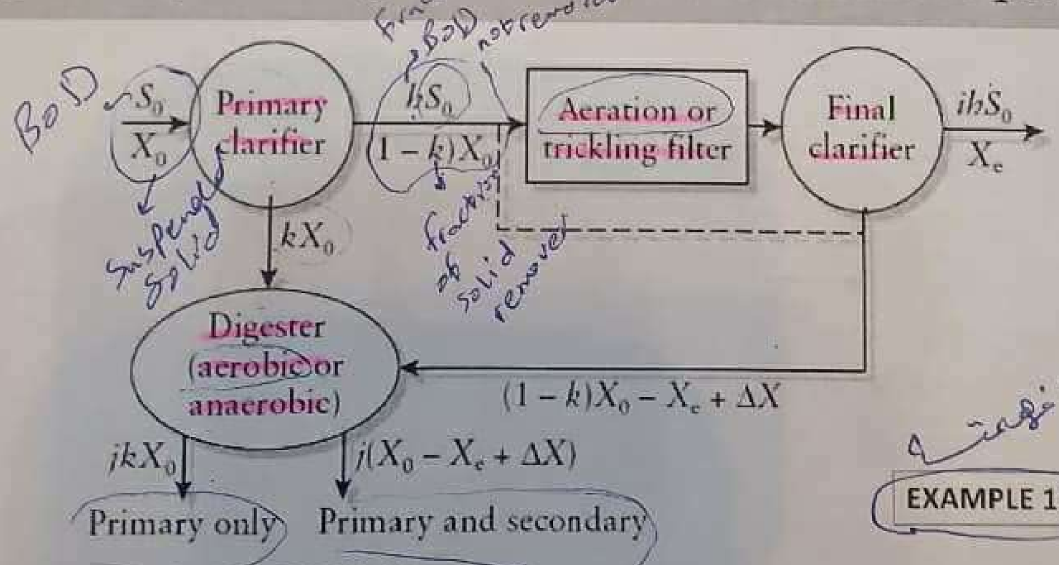
Tertiary sludge

- 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

Wast activated sludge-

The quantity of sludge produced in a treatment plant

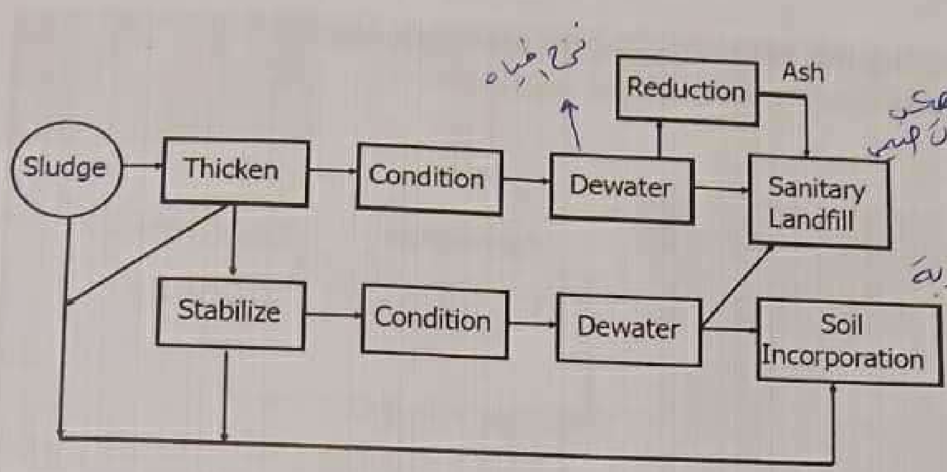
385



EXAMPLE 11.9

S_0 = influent BOD, lb/d (kg/h)
X_0 = influent suspended solids, lb/d (kg/h)
h = fraction of BOD not removed in the primary clarifier
i = fraction of BOD not removed in activated sludge system
X_e = plant effluent suspended solids, lb/d (kg/h)
k = fraction of influent solids removed in the primary clarifier
ΔX = net solids produced by biological action, lb/d (kg/h)
Y = yield, or the mass of biological solids produced in the aeration tank per mass of BOD destroyed, or

Sludge Treatment



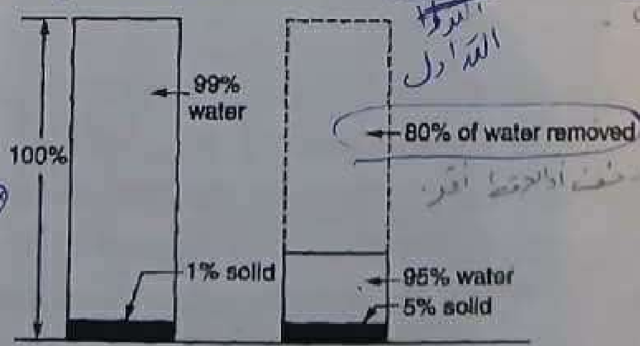
تكثيف الحمأة

Sludge Thickening

- Sludge thickening is a process in which the concentrations of solids is increased and the total sludge volume is decreased, but the sludge still behaves like a liquid instead of a solid.
- The advantages of sludge thickening are substantial. When sludge with 1% solids is thickened to 5%, the result is an 80% reduction in volume. Reducing from 1 % solids to 20% solids, which might be achieved by sludge dewatering, would result in a 95% reduction in volume. The volume reduction translates into considerable savings in treatment, handling, and disposal costs.

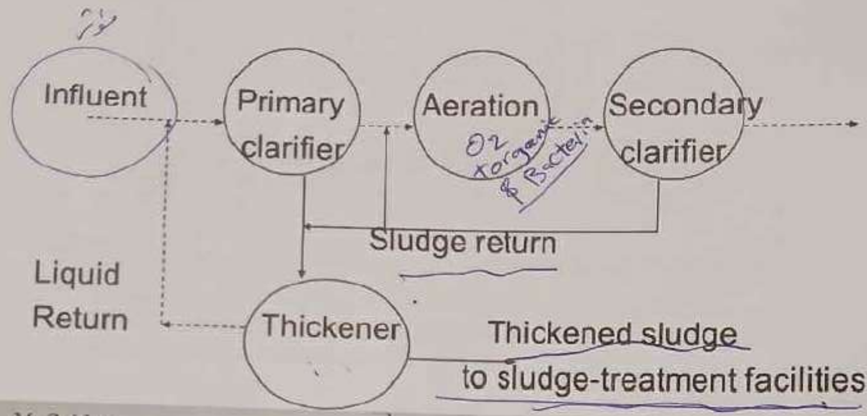
تكثيف الحمأة

benefits



Sludge Thickening

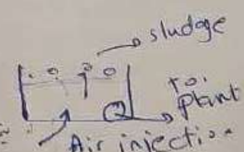
➢ Reducing the water in primary and secondary sludges.



Sludge Thickening Methods

Methods

- Gravity thickening : using an additional clarifier to remove more water
- Dissolved air flotation (DAF)
  - ➢ Used to concentrate secondary sludges
  - ➢ Sludge is pressurized and injected with air; releasing into a settling tank (when the pressure is released, the extra air comes out of solution; attaching to the sludge particles as microscopic bubbles); the sludge is floated to the surface in a concentrated form the underflow returns to the head of the plant.



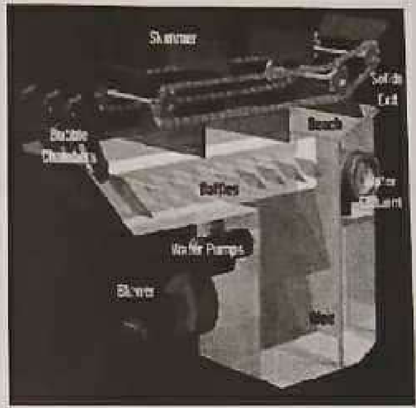
Gravity Thickener

Gravity thickening

- Best with primary sludge → there is more solid particle rather than secondary
- Increases solids content from 1-3% to 10%

Flotation DAF

- Especially effective on activated sludge or secondary
- Increases solids content from 0.5 -1% to 3-6%



Flotation

Gravity Thickening

- Accomplished in circular sedimentation basins
- Degree of thickening: 2~5 times the incoming solids conc. 1-3% 2-5 times ↓ 9%
- Max. achievable solids concentration: < 10%
- Chemical and waste activated sludges are difficult to thicken under gravity.

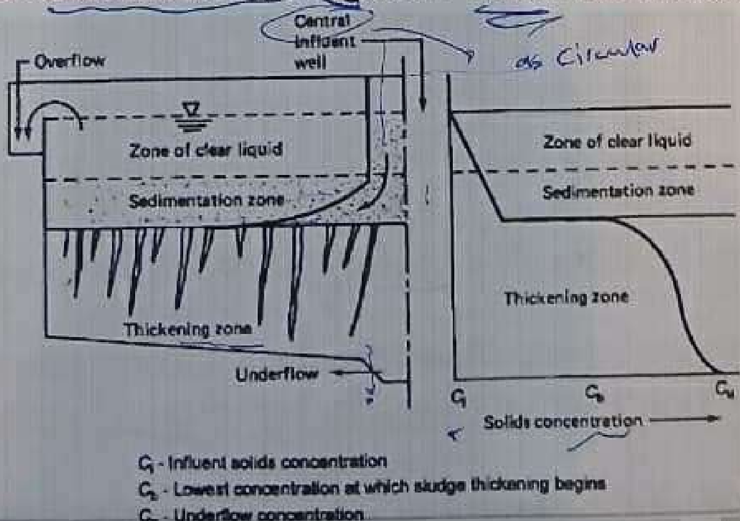
→ under flow

Thickned solid

→ over flow

water nearly clear

as Circular



Gravity Thickener Equipment

➢ Generally circular concrete tanks with bottom sloping toward the center.

خزان خرساني دائري

over flow

to drain

Equipment

- Rotating bottom scraper arm
- Vertical pickets
- Rotating scum-collection mechanism with scum baffle plates
- Overflow weir

الواح حاجزة للرغوة

Other configurations

- Circular steel tank: Generally cheaper because of simplicity of construction, equipment installation, and operation and maintenance
- Rectangular concrete and steel tanks

Dissolved Air Flotation (DAF)

- Primarily used to thicken the solids in chemical and WAS

waste Activated Sludge

- Separation of solids is achieved by introducing fine air bubbles created under pressure of several atmosphere into the liquid, attaching to solids to cause flotation of solids
- Degree of thickening: 2~8 times the incoming solids concentration
- Max. solids concentration: 4~5%

0.5-1% to 3%-6%

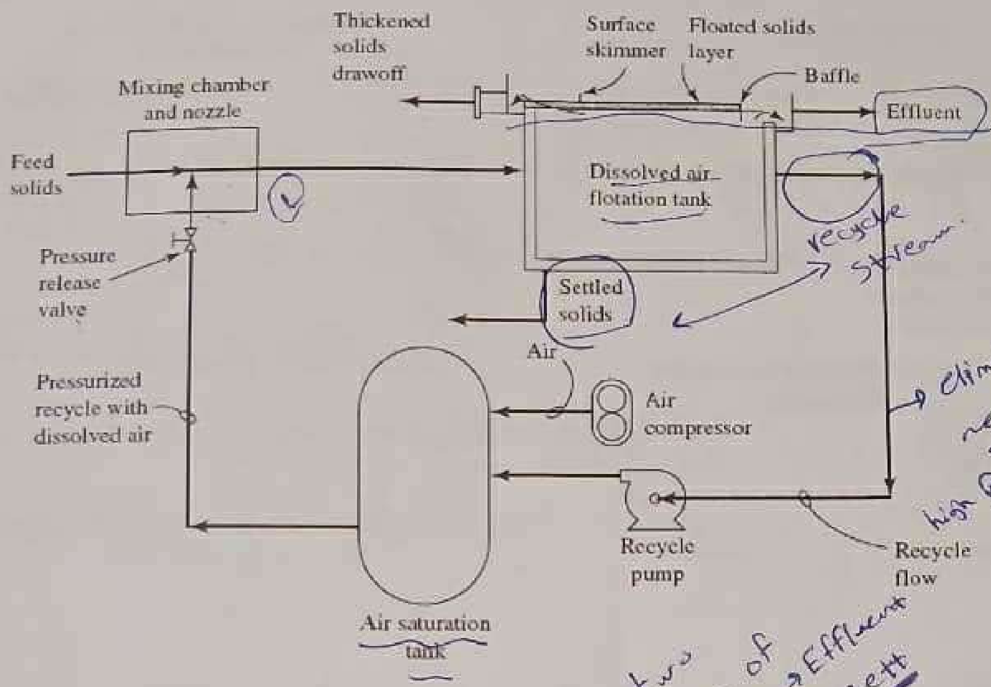
- DAF Variations

2-8 times

  - Pressurize total or only a small portion of the incoming sludge
  - Pressurize the recycled flow from the flotation thickener –preferred because it eliminates the need for high-pressure sludge pumps.

لانه يلغي الحاجة الى مضخات sludge ذات الضغط العالي.

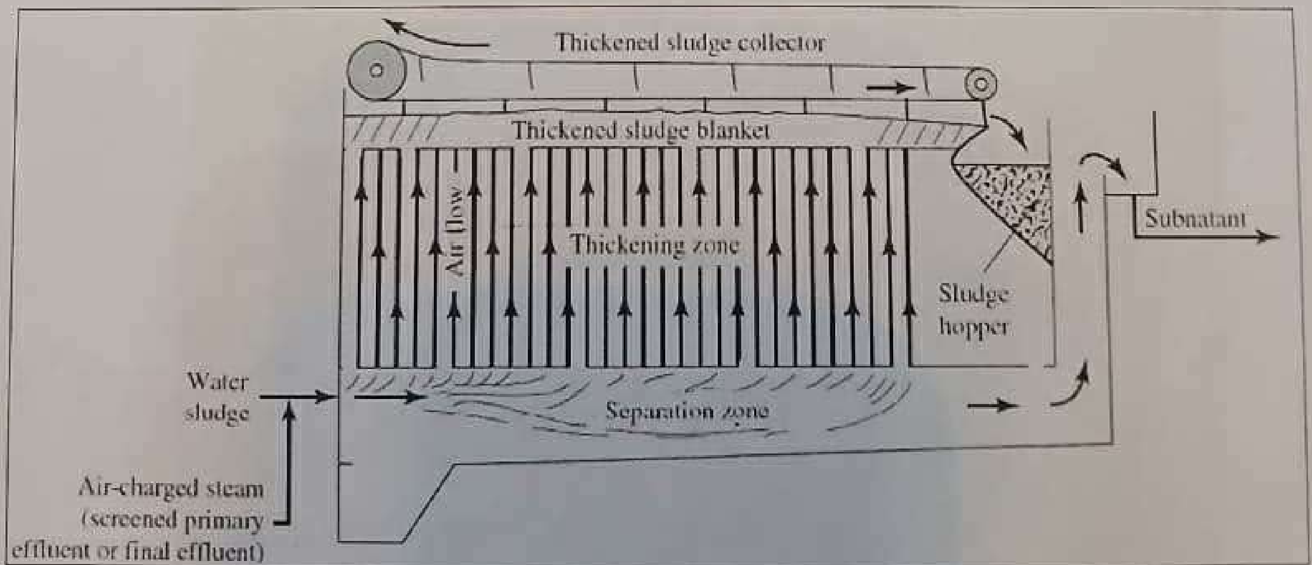
Schematic of DAF thickener system



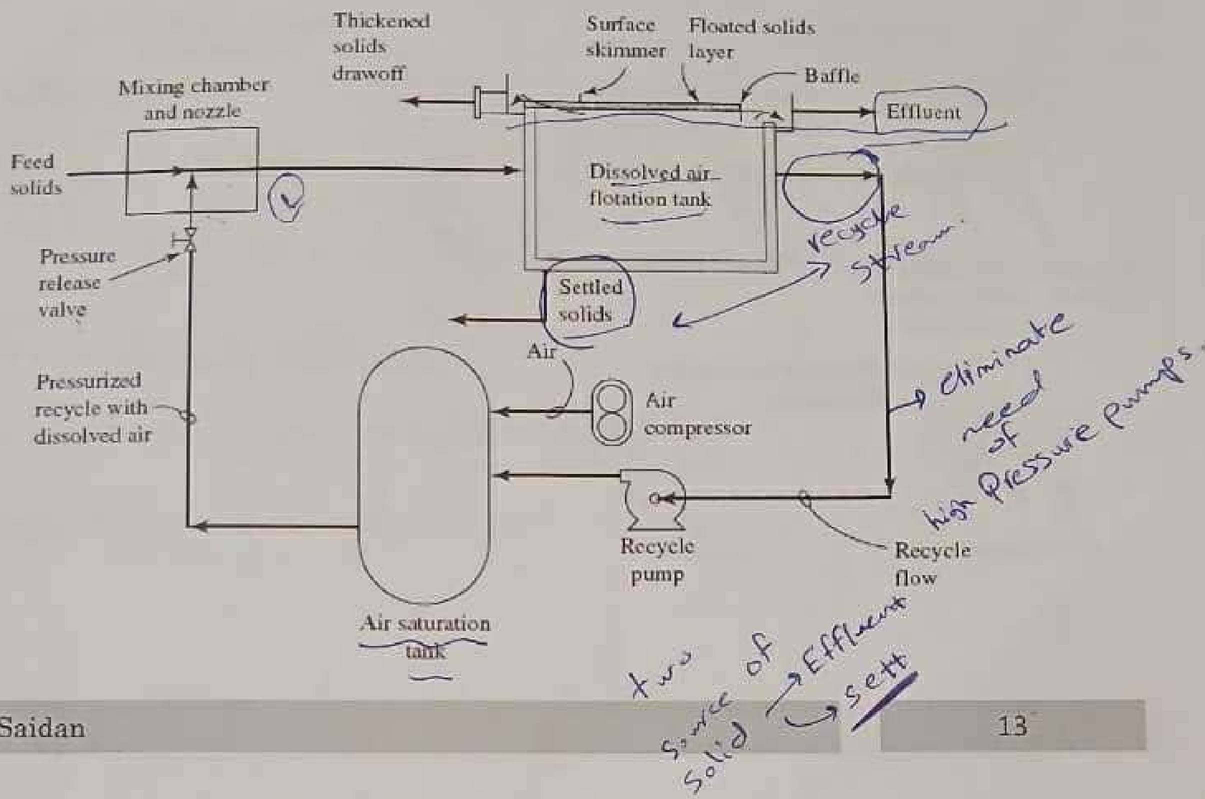
recycle stream

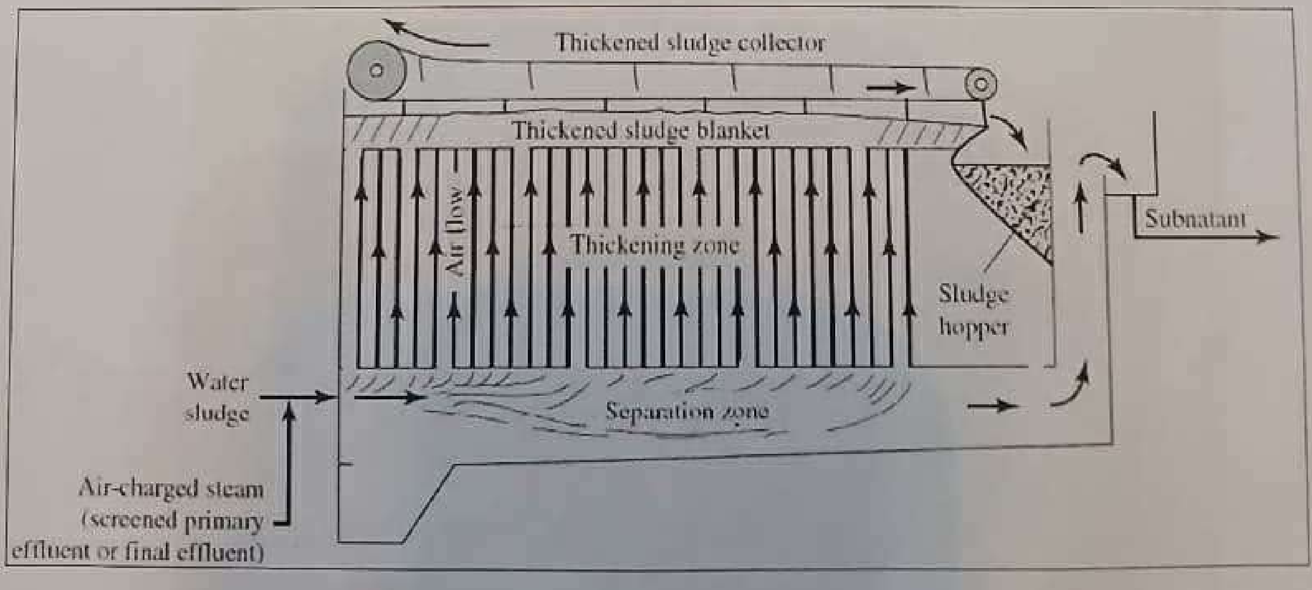
→ eliminate need of high pressure pumps.

two source of solid → Effluent → sett



Schematic of DAF thickener system





تثبيت الحمأة

Sludge Stabilization Means

- **Biological Treatment**
  1. Aerobic Digestion
  2. Anaerobic digestion
  3. Lagoons
  4. Composting
- **Chemical Treatment**
  1. Wet combustion
  2. Lime stabilization
  3. Chlorination
  4. Heat stabilization
  5. Irradiation

اهم ثلاثة

lime
Aerobic
Anaerobic

Lime stabilization is achieved by adding lime to the sludge, which raises the pH to about 11 or above. This significantly reduces the odor and helps in the destruction of pathogens. The major disadvantage of lime stabilization is that it is temporary. With time (days), the pH drops and the sludge once again becomes putrescent.

عفن

الهضم الهوائي

Aerobic digestion is merely a logical extension of the activated sludge system. Waste activated sludge is placed in dedicated aeration tanks for a very long time, and the concentrated solids are allowed to progress well into the endogenous respiration phase, in which food is obtained only by the destruction of other viable organisms.

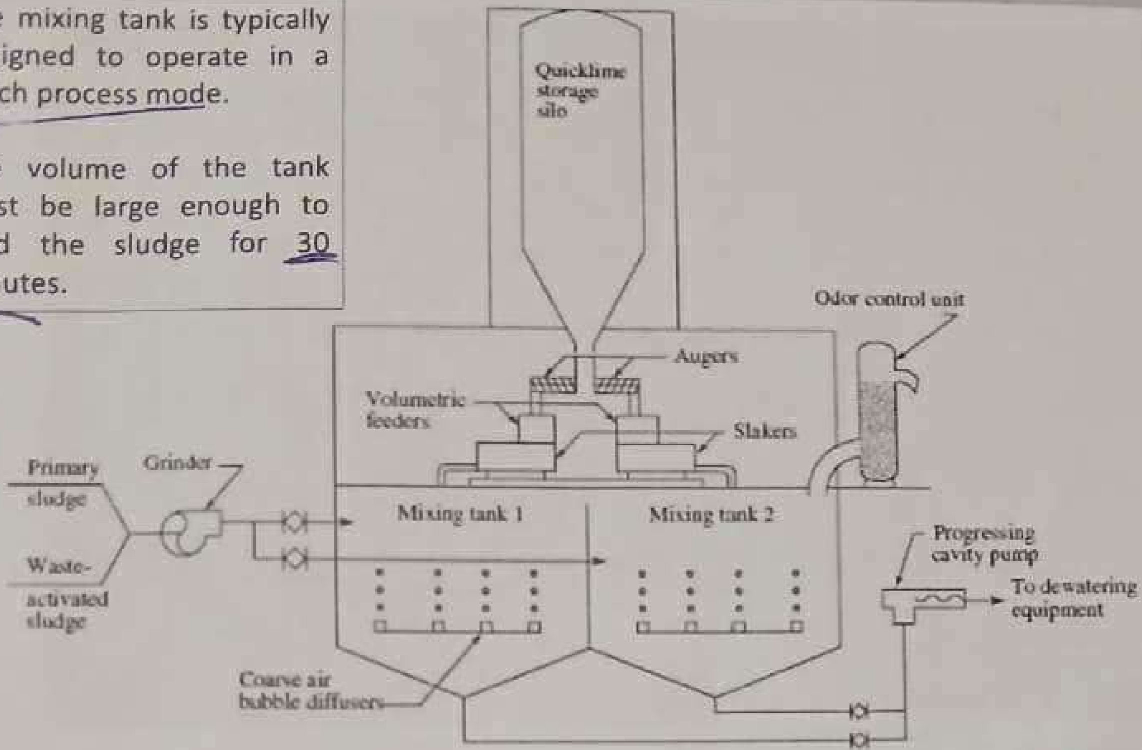
This results in a net reduction in total and volatile solids. Aerobically digested sludges are, however, more difficult to dewater than anaerobic sludges.

يصعب تجفيف الحمأة المهضومة هوائياً مقارنة بالحمأة اللاهوائية.

Conceptual design for a lime stabilization facility

The mixing tank is typically designed to operate in a batch process mode.

The volume of the tank must be large enough to hold the sludge for 30 minutes.



Second + Final.

Anaerobic Digestion

ثلاث مراحل متميزة.

The anaerobic treatment of biological sludges involves three distinct stages:

- In the first stage, complex waste components, including fats, proteins, and polysaccharides, are hydrolyzed to their component subunits.
- The second stage is commonly referred to as acid fermentation. In this stage, organic material is simply converted to organic acids, alcohols, and new bacterial cells.

  التخمير الحمضي
- In the third stage, the end products of the second stage are converted to gases (mainly methane, CH_4, and carbon dioxide, CO_2) by several different species of strictly anaerobic bacteria.

Theory of Anaerobic Digestion

تحلل البكتيريا المكونة للاحماض المواد العضوية المعقدة لـ مركبات ابسط وخاصة الاحماض الدهنية

1. Acid forming bacteria break down complex organic substances to simpler compounds, notably fatty acids.

   Carbohydrates ⟶ fatty acids

   Proteins ⟶ Amino acids ⟶ NH_3 + fatty acids

تحلل البكتيريا المكونة للميثان نواتج المرحلة الاولى الى ميثان وثاني اكسيد الكربون

2. Products of the first stage are further broken down, by methane forming bacteria, to methane and carbon dioxide.

   NH_3 + fatty acids ⟶ $CH_4 + CO_2$

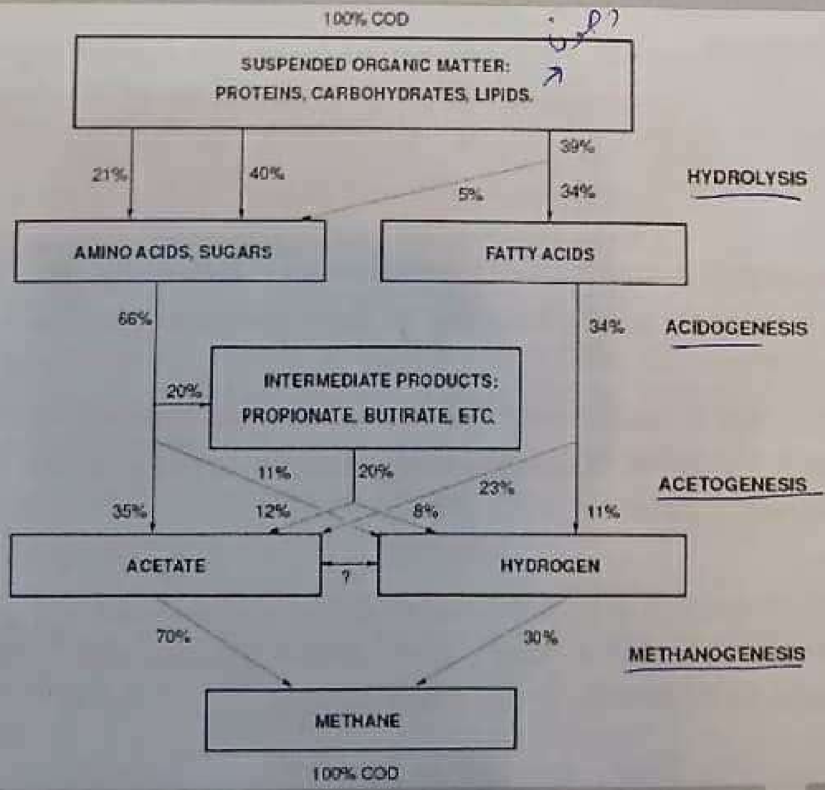
- Methane forming bacteria work in pH range 6 to 8 (better in 7.2 – 7.4).
- Lime is added to adjust pH.

لضبط درجة الحموضة

تحلل الحمأة المنشطة الزائدة

Decomposition of excess activated sludge

هون النسب ما فش



Anaerobic Digestion

المواد العضوية المتطايرة

- Anaerobic digestion of sludge decrease the volatile organics by 40-50% and reduce the numbers of pathogenic organisms in sludges.

تقليل عدد كائنات مرضية

يتم ذلك

- Accomplished by holding the sludge in $\boxed{\text{closed tanks}}$ for periods of 10 to 90 days.

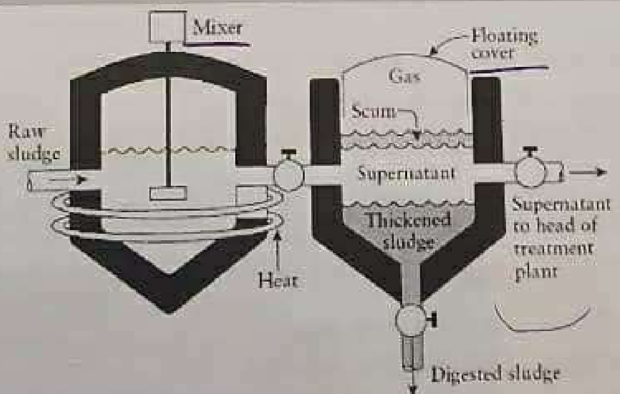
حفظ

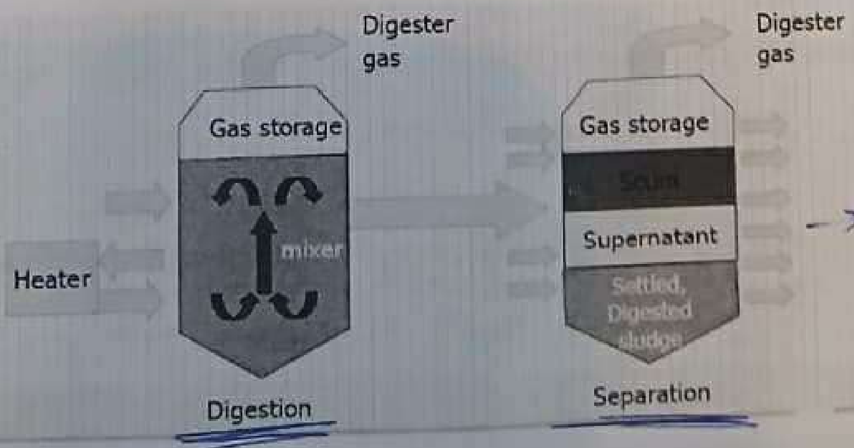
فترة احتجاز طويلة

- Old process : unmixed, unheated, long detention time (30-90 days)
- Recent process : complete mixing, heating (35-45°C), detention time 10-20 days

العملية الحديثة

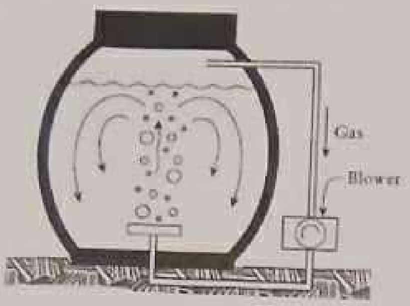
Two-stage anaerobic digestion

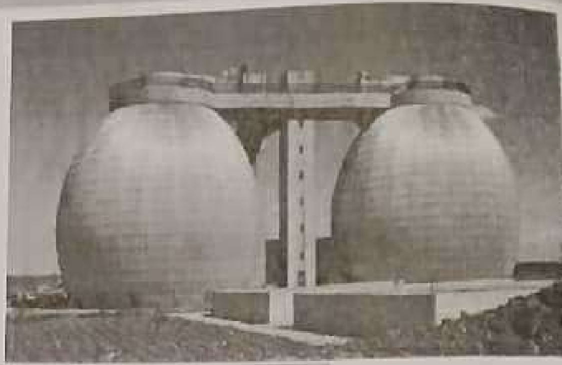




الأجسام العلوية

Egg-shaped anaerobic digesters





Second True or false

Egg-shaped anaerobic digesters

Advantages

درجة عالية من تثبيت النفايات   عند معدلات تحميل عضوية عالية

- High degree of waste stabilization at high organic loading rates

انتاج قليل جداً من الحمأة   أو عضوية قابلة للتحلل

- Very little sludge production (< 5% of biodegradable organic matter being converted to cell material) (10% of aerobic sludge production)

سهولة ازالة الماء من الحمأة الزائدة.

- Easy dewatering of the excess sludge

احتياج منخفض للمغذيات

- Low nutrient requirement (10% of aerobic process requirement)
- No aeration equipment
- Methane production –very low energy input (if the methane gas is used to heat the digester)

تسخين هاضم

Egg-shaped anaerobic digesters

Disadvantages

ناتج بكتيري منخفض

- Low bacterial yield

مهم

فترات طويلة من تراكم كتلة حيوية بطيء

- prolonged periods of biomass build-up,

فترة بدء تشغيل طويلة

- requiring longer start-up period (8 to 12 weeks).

حساسة للعناصر السامة

- Temperature, pH, toxic sensitive

تكلفة إنشائية مرتفعة

- High capital costs

تشغيل معقد يحتاج إلى مشغلين مهرة

- Complex operation requiring skilled operators

مشغلين مهرة.

Digester Heating

اي

رفع درجة حرارة الحمأة الداخلة ~~...~~ خزان الهضم ولتعويض الفاقد

- To raise the incoming sludge to digestion tank temperatures, to compensate for the heat losses through the walls, floor, and roof of the digester, and to make up the losses that might occur in the piping between the source of the heat and the tank.

الحراري من خلال الجدران والأرضية وسقف الخزانات ولتعويض الفاقد الذي قد يحدث في الأنابيب بين مصدر الحرارة والخزان

مبادلات حرارية داخلية وخارجية

- Internal or external heat exchangers

متطلبات الحرارة.

- Heat requirements

$$q = UA\Delta T$$

where

q = heat loss, BTU/h (W);

U = overall coefficient of heat transfer, BTU/ft²·hr·°F (W/m²·°C);

A = cross-sectional area through which the heat loss is occurring, ft² (m²); and

ΔT = temperature drop across the surface in question, °F (°C).

تكييف الحمأة .

Sludge Conditioning

عملية استخدام إضافات كيميائية لتحسين قابلية تكييف الحمأة من خلال العمل كمواد تخثر

لتحسين قابلية نزع الماء وذلك من خلال عملها كمخثرات لمعالجة الكيميائية

Chemical Conditioning: Chemical additives may be used to improve sludge dewaterability by acting as coagulants. Chemicals commonly used for this are ferric chloride ($FeCl_3$), lime (CaO), and organic polymers

اساسا تتم بالحرارة

Physical Conditioning: Physical conditioning is primarily by heat. Heat conditioning involves heating at High temperatures (175-230 °C) and High pressures (10 to 20 atmospheres).

تكثيف الماء بشكل دراماتي

Dewaterability is improved dramatically and pathogens are destroyed as well.

يساهم ذلك في تحسين قابلية نزع الماء من الحمأة بشكل كبير بالإضافة إلى القضاء على مسببات الأمراض

Sludge Dewatering and Drying

نزع الماء يقلل من محتوى الرطوبة في الحمأة مما يجعل من السهل التخلص منها عبر الردم الصحي

الحرق التجفيف الحراري تسميد عضوي أو طرق أخرى

- Dewatering reduces the moisture content of the sludge so that it can more easily be disposed of by landfill, incineration, heat drying, composting or other means.

مكب النفايات الحرق التسميد

تكثيف الحمأة

نادراً ما تستخدم عملية تجفيف المياه كعملية وسيطة إلا إذا كان من المقرر حرق الحمأة.

- Unlike sludge thickening, where the treated sludge continues to behave as a liquid, dewatered sludge will behave like a solid after treatment. Dewatering is seldom used as an intermediate process unless the sludge is to be incinerated. Most wastewater plants use dewatering as a final method of volume reduction before ultimate disposal.

كطريقة نهائية لتقليل الحجم قبل التخلص النهائي منه

- The objective is a moisture content of $\boxed{\text{60 to 80 percent}}$ depending on the disposal method.

احواض تجفيف رملية

- By applying the sludge to sand drying beds

استخدام معدات نزع مياه ميكانيكية

- By using mechanical dewatering equipment

مكابس الترشيح بالحزام

Belt Press Filtration

- Belt filter presses employ single or double moving belts to continuously dewater sludges through one or more stages of dewatering. تستخدم مكابس الترشيح بالحزام حزاما واحدا او زوجين
لازالة المياه الحرة بشكل مستمر عبر مرحلة او اكثر من مراحل ازالة الماء

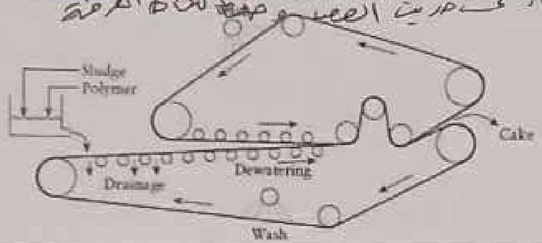
- All belt press filtration processes include three basic operational stages:

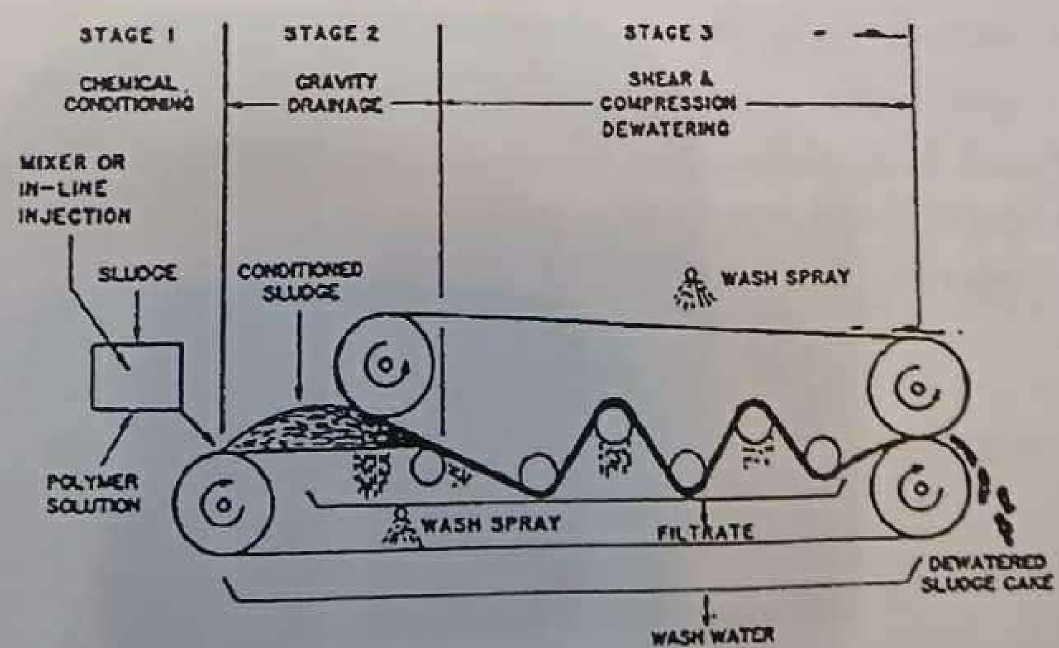
معالجة كيميائية للحمأة المغذية

  - chemical conditioning of the feed sludge;
  - gravity drainage to a non-fluid consistency; تصريف بالجاذبية الى قوام غير سائل.
  - shear and compression dewatering of the drained sludge.

ازالة الماء عن طريق القص والضغط للحمأة المصرفة

بالقص والضغط





Sludge drying beds

الصرف

تعتمد احواض تجفيف الحمأة على التصريف والتبخر لتقليل الرطوبة

- Sludge drying beds rely on drainage and evaporation to effect moisture reduction.

تعتمد — شديدة التأثر

هذه الأحواض مفتوحة وبالتالي فهي شديدة التأثر بالظروف المناخية مثل الهطول

- These beds are open; and as such, are very susceptible to climatic conditions such as precipitation, sunshine, air temperature, relative humidity, and wind velocity. For example, sludge drying in 6 weeks in the summer would take at least 12 weeks to dry in the winter.

تستغرق الحمأة حوالي 6 أسابيع لتجف في فصل الصيف بينما تحتاج إلى 12 اسبوع في فصل الشتاء

- Sludge bed drying efficiency can be improved significantly by covering the bed with glass or plastic and by providing artificial heat.

توفير الحرارة الاصطناعية

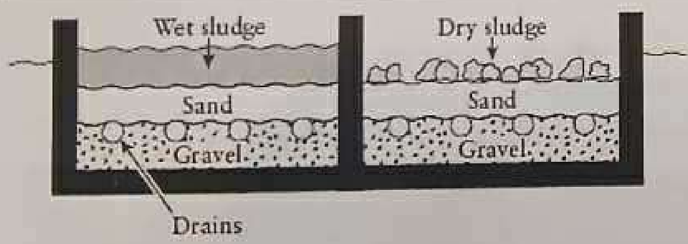
يمكن تحسين كفاءة تجفيف أحواض الحمأة بشكل كبير من خلال تغطية الحوض بالزجاج أو بلاستيك وتوفير حرارة صناعية

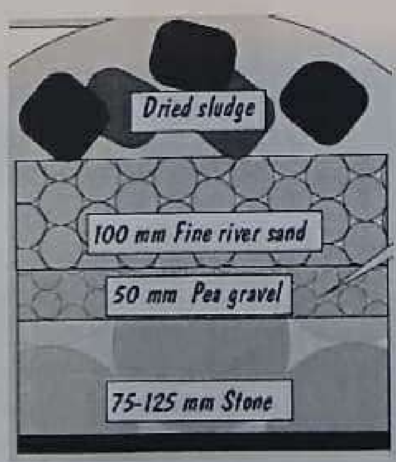
- Heat could be supplied using waste biogas as a fuel or waste heat from the base power plant.

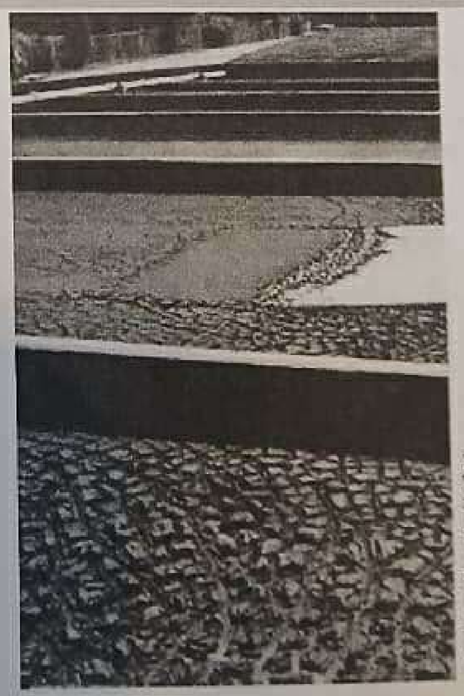
غاز حيوي

يمكن توفير الحرارة باستخدام غاز حيوي ناتج عن نفايات كوقود او من خلال الحرارة المهدرة من محطة الطاقة الرئيسية

من محطة الطاقة الأساسية







The principle advantages of drying beds

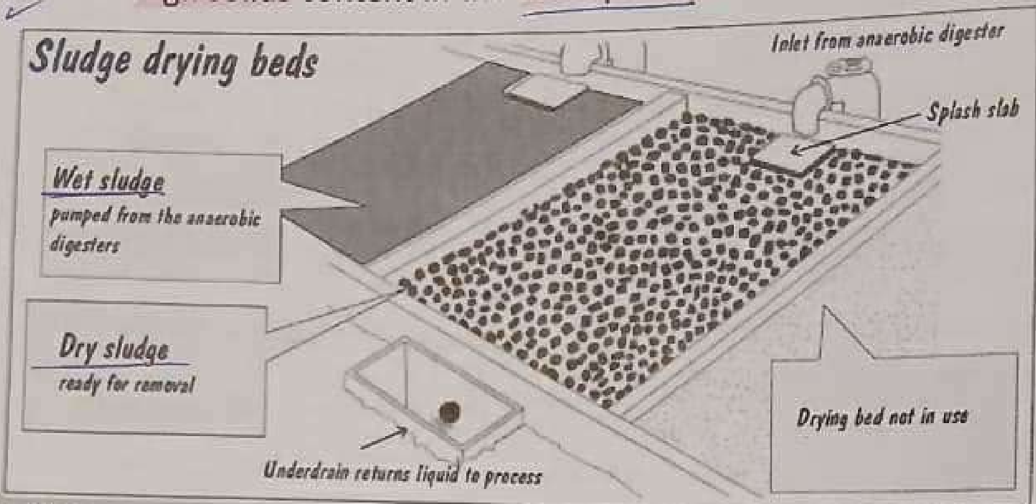
1. Low cost,

لا تحتاج متابعة متكررة

2. Infrequent attention required, and

محتوى عالي من المواد الصلبة في المنتج المجفف

3. High solids content in the dried product



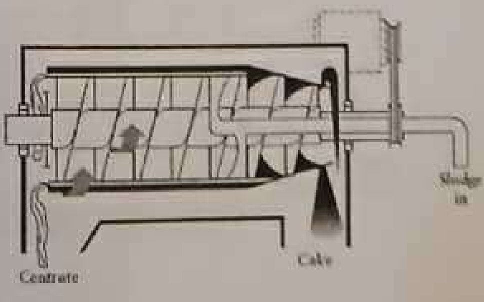
Centrifugal dewatering

مهم final.

هي عملية تستخدم القوة الناتجة عن الدوران السريع لأسطوانة

- Centrifugal dewatering of sludge is a process which uses the force developed by fast rotation of a cylindrical drum or bowl to separate the sludge solids from the liquid.

- In the basic process, when sludge slurry is introduced to the centrifuge, it is forced against the bowl's interior walls, forming a pool of liquid.



- Density differences cause the sludge solids and the liquid to separate into two distinct layers. The sludge solids "cake" and the liquid "centrate" are then separately discharged from the unit.

أي طبقتين منفصلتين

Air Pollution:

Air Pollutants & Human Health Effects

Dr. Motasem Saidan

m.saidan@gmail.com

highest efficiency for course particle >50 µm ?? cyclones

mobile measurment stations → قطار بتستقل وهي بتشتغل بتكون بتاخذ عينات من الهواء وبتطلع تقرير عنه

أكبر مصدر ل SO_2 هو ~~Coal~~. sources smelter

تركيز CO_2 حالياً 370

Air Pollution

Natural - طبيعي
Anthropogenic - مصنوع الإنسان

Air Pollution Definitions

- Transfer of harmful and/or of Natural/Synthetic materials into the atmosphere as a direct/indirect consequences of human activity (OECD).

Volatile organic compounds.

- The introduction of chemicals, particulate matter, or biological materials that cause harm or discomfort to humans or other living organisms, or damages the natural environment into the atmosphere

- The overwhelming scientific consensus is that the earth's atmosphere is warming rapidly mostly because of human activities, and that this will lead to significant climate change during this century

سؤال مهم

weather

Because the Human activity for example.
- increasing in Burning Fossil fuels use oil, coal, drive cars that release huge amount of carbon dioxide (CO_2)
- Deforestation: Trees absorb and store CO_2 when forests are cut down, this CO_2 back into atmosphere.
- Global Temperature rise.
- Rising sea level due to melting ice and thermal expansion of water.

Air Pollutants

chemical reaction can be triggered from light (give it energy)

> Pollutants mix in the air to form industrial smog, mostly the result of burning coal, and photochemical smog, caused by motor vehicle, industrial, and power plant emissions

smoke + fog → الدخان الضبابي

secondary

combustion plant ⇒ source of pollution.

Nautral gas

> An air pollutant can be a gas or a particulate.

or Aerosol ⇒ الهباء الجوي

> Sources: liquid

- Natural sources
  - ✓ Dust blown by wind
  - ✓ Pollutants from wildfires and volcanoes
  - ✓ Volatile organics released by plants

Aerosol ⇒ localized

- Human sources: mostly in industrialized and/or urban areas
  - ✓ Stationary sources
  - ✓ Mobile sources

Air Pollutants Classification

Final

Classified as:

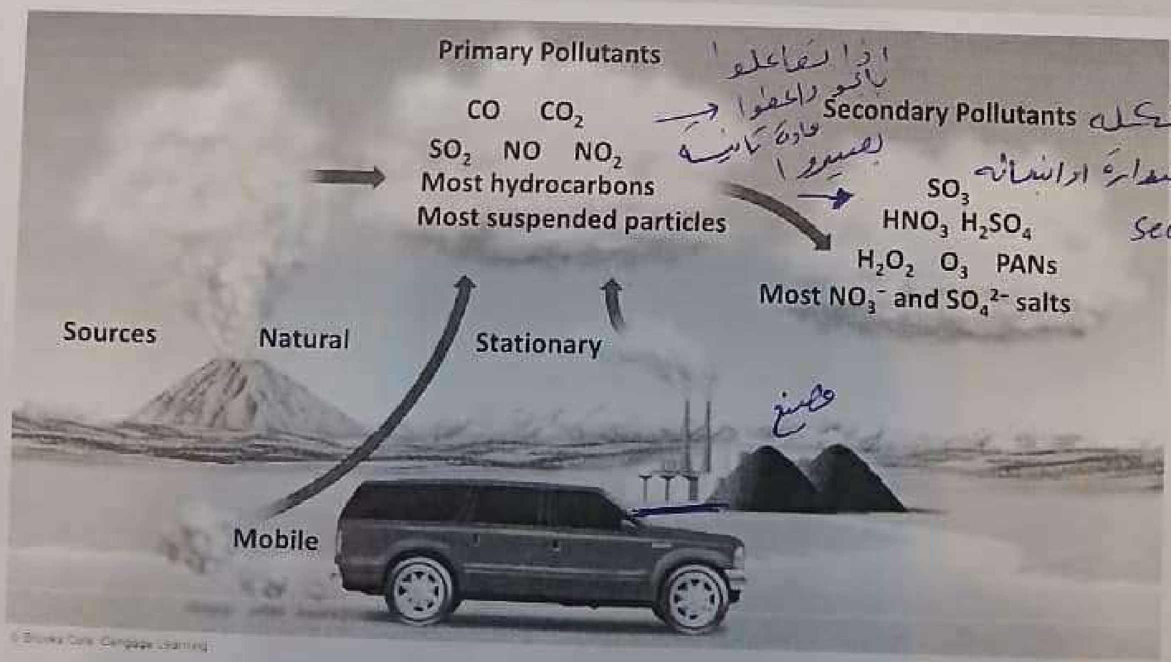
أي materials ، gases ، pollutant يطلع على الجو ويضل stable as is

1. **Primary pollutants**: foreign matter injected into the atmosphere by human activities. مواد غريبة تدخل الغلاف الجوي نتيجة للأنشطة البشرية

تنتج عن التحولات الكيميائية عادة بالملوثات الأولية وغالبا بوجود الشمس.

2. **Secondary pollutants**: resulting from chemical transformations, typically with primary pollutants and (often) sunlight.

رطوبة ، اكسدة مع الجو.



PM 2.5 → combustion particles, organic compounds, metals.
PM10 → Dust, pollen, mold.
الغبار حبوب العفن
اللقاح

Major Air Pollutants

particulate Matter Air pollutants solid state.
suspended

Suspended particulate matter (SPM):

Size of SPM

- Consists of a variety of solid particles and liquid droplets small and light enough to remain suspended in the air.

PM10 → 10 Mm

- The most harmful forms of SPM are fine particles (PM-10, with an average diameter < 10 micrometers) and ultrafine particles (PM-2.5). Smaller than PM10

وكالة حماية البيئة Environmental protection Agency

- According to the EPA, SPM is responsible for about 60,000 premature deaths a year in the U.S. you can't catch it

fume → sources → Heating, vaporization, condensation of solid
main composition → Fine solid particles (metal oxides) that have cooled from a gas.
particle size → much smaller often invisib
example → welding fumes, smelting operation.

smoke → Source → incomplete combustion. (burning)
→ main composition → Solid and liquid particles. (soot, tar) ultrafine solid.
→ particle size → Generally larger.
visibility → easily visible, cloudy
Example → campfire, car exhaust, burning cigarette.

Major Air Pollutants

Size

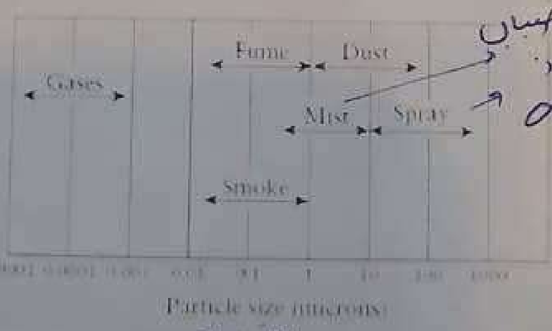
- Particulate matter or pollutants can be further classified as dusts, fumes, mists, smoke, or spray.

droplet

condensation

melting point

drops
pressurized from nozzle



Particle size (microns)

Terminology	Abbreviation	Diameter Range (μm)
Ultrafine	–	< 0.1
Fine	$PM_{2.5}$	< 2.5
Coarse	PM_{10}	2.5 – 10

Particulate Matters

- Dust is defined as solid particles. التسامي
- A fume is also a solid particle, frequently a metallic oxide, formed by the condensation of vapors by sublimation, distillation, calcination, or chemical reaction processes. The particles in fumes are quite small, with diameters from 0.03 to 0.3 μ. التسخين للمواد

جسيم سائل من احد شيئين تشكل نتيجة تكاثف بخار وربما تفاعل كيميائي

- A mist is an entrained liquid particle formed by the condensation of a vapor and perhaps by chemical reaction. Mists typically range from 0.5 to 3.0 μ in diameter.

يتكون من جسيمات صلبة عالقة نتيجة احتراق غير كامل للمواد الكربونية

- Smoke is made up of entrained solid particles formed as a result of incomplete combustion of carbonaceous materials. Smoke particles have diameters from 0.05 to approximately 1 μ.

رذاذ السائل الاصلي

- a spray is a liquid particle formed by the atomization of a parent liquid. Sprays settle under gravity

تترسب بفعل الجاذبية

مثل عملية خوشنات / تحريك في غبرة

Measurement of Particulates

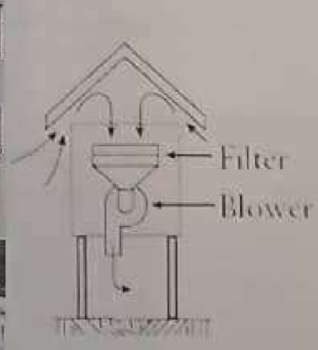
عبارة عن نظام فلترة الهواء يدخل من فوق وعليه غطاء diffuser بعمل negative pressure والهواء يطلع من bottom

المروحة عم تضغط من تحت بصير اسمه Vacuum

- The measurement of PM10 has been historically done by using the high-volume sampler (or hi-vol).
- The high-volume sampler operates much like a vacuum cleaner, forcing up to 86,000 ft3 of air through a filter in 24 hr. The analysis is gravimetric; the filter is weighed before and after, and the difference is the particulates collected.

التحليل وزني

ما فيها بالمجرى ح بتكون negative تنضغط الهواء الخارجي بده يدخل حتى يعوض هاد الفراغ



ozone O_3
مادة محظمة في بلاد
لو إذا انتشرت في
الجو رح تصير
عسرطنة

عاليصير برد ورعد توقع أنه
تكون عندنا O_3 على سطح
الأرض و الساعات اللي فيها
electrical field
اعرف انه
فيه

such fume.

Gaseous Pollutants

- Gaseous pollutants include substances that are gases at normal temperature and pressure as well as vapors of substances that are liquid or solid at normal temperature and pressure.

ground level
إذا موجود على
pollutant

على Tranphere
يعتبر طبقة حماية
من ultraviolet

Name	Formula	Properties of Importance	Significance as Air Pollutant O_3
Sulfur dioxide (SO_x $x \rightarrow (2,3)$)	SO_2	Colorless gas, intense choking odor, highly soluble in water – forming sulfurous acid H_2SO_3	Damage to property, health and vegetation
Sulfur trioxide	SO_3	Soluble in water – forming sulfuric acid H_2SO_4	Highly corrosive
Hydrogen sulfide	H_2S	Rotten egg odor at low concentrations, odorless at high concentrations	Highly poisonous
Nitrous oxide	N_2O	Colorless gas, used as carrier gas in aerosol bottles	Relatively inert; not produced in combustion
Nitric oxide (NO_x)	NO	Colorless gas	Produced during high-temperature high-pressure combustion, oxidizes to NO_2
Nitrogen dioxide	NO_2	Brown to orange gas	Major component in the formation of photochemical smog
Carbon monoxide	CO	Colorless and odorless	Product of incomplete combustion, poisonous
Carbon dioxide	CO_2	Colorless and odorless	Formed during complete combustion, greenhouse gas
Ozone (CO_x)	O_3	Highly reactive	Damage to vegetation and property, produced mainly during the formation of photochemical smog
Hydrocarbons	C_xH_y or HC	Many	Emitted from automobiles and industries, formed in the atmosphere
Methane	CH_4	Combustible, odorless	Greenhouse gas
Chlorofluorocarbons	CFC	Nonreactive, excellent thermal properties	Depletes ozone in upper atmosphere

كل اشي فيه C و H واقل اشي اسمه light hydrocarbons

خليط من فلورات

→ ozone Depleting substances
المواد المستنزفة للاوزون

Air Pollution Effects

- **Effects on Human Health**
  - ➢ Respiratory problems مشاكل بجهاز التنفس
  - ➢ Allergies حساسية
  - ➢ Risk for cancer خطر الإصابة بالسرطان

- **Effects on the environment**
  - ➢ Acid rain (Regional) المطر الحمضي (الدول اللي فيها مناجم فحم)
  - ➢ Ozone depletion (Stratospheric) استنفاد
  - ➢ Greenhouse Effect (Global warming) climate change
    تأثير الاحتباس الحراري

Human Health Effects

التعرض

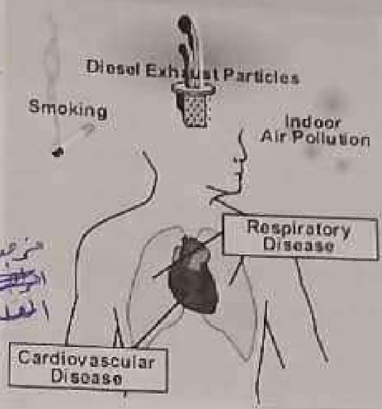
- Exposure to air pollution is associated with numerous effects on human health, including pulmonary, cardiac, vascular, and neurological impairments. (handwritten: ترتبط، قلبية، وعائية، اعاقات)

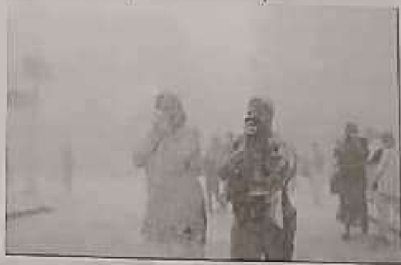
تتباين   الرضع   الحوامل

- The health effects vary greatly from person to person. High-risk groups such as the elderly, infants, pregnant women, and sufferers from chronic heart and lung diseases are more susceptible to air pollution. (handwritten: مرضى القلب، الرئة المزمنة)

- Children are at greater risk because they are generally more exposed to outdoor environment and their lungs are still developing stage. الرئة

لا تزال في مرحلة النمو





للمعرفة

للمعرفة welfare → Ecosystem → انسان وبيئة

Pollutant	Description	Sources	Health Effects	Welfare Effects
Carbon Monoxide (CO)	Colorless, odorless gas (غاز عديم الرائحة واللون)	Motor vehicle exhaust, indoor sources include kerosene or wood burning stoves.	Headaches, reduced mental alertness, heart attack, cardiovascular diseases, impaired fetal development, death.	Contribute to the formation of smog.
Sulfur Dioxide (SO_2)	Colorless gas that dissolves in water vapor to form acid, and interact with other gases and particles in the air.	Coal-fired power plants, petroleum refineries, manufacture of sulfuric acid and smelting of ores containing sulfur.	Eye irritation, wheezing, chest tightness, shortness of breath, lung damage.	Contribute to the formation of acid rain, visibility impairment, plant and water damage, aesthetic damage.
Nitrogen Dioxide (NO_2)	Reddish brown, highly reactive gas.	Motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels.	Susceptibility to respiratory infections, irritation of the lung and respiratory symptoms (e.g., cough, chest pain, difficulty breathing).	Contribute to the formation of smog, acid rain, water quality deterioration, global warming, and visibility impairment.
Ozone (O_3)	Gaseous pollutant when it is formed in the troposphere.	Vehicle exhaust and certain other fumes. Formed from other air pollutants in the presence of sunlight.	Eye and throat irritation, coughing, respiratory tract problems, asthma, lung damage.	Plant and ecosystem damage.
Lead (Pb)	Metallic element	Metal refineries, lead smelters, battery manufacturers, iron and steel producers.	Anemia, high blood pressure, brain and kidney damage, neurological disorders, cancer, lowered IQ.	Affects animals and plants, affects aquatic ecosystems.
Particulate Matter (PM)	Very small particles of soot, dust, or other matter, including tiny droplets of liquids.	Diesel engines, power plants, industries, windblown dust, wood stoves.	Eye irritation, asthma, bronchitis, lung damage, cancer, heavy metal poisoning, cardiovascular effects.	Visibility impairment, atmospheric deposition, aesthetic damage.

والنحاس سم افضل
جنزاري
reddish. ← حديد
مدائن أوروبا

احدى الطرق التي يتم فيها ازالة SO_2
من الغلاف الجوي هي
acid rain.

Acid Rain المطر الحامضي

sulfric acid
سمو المسير هونا

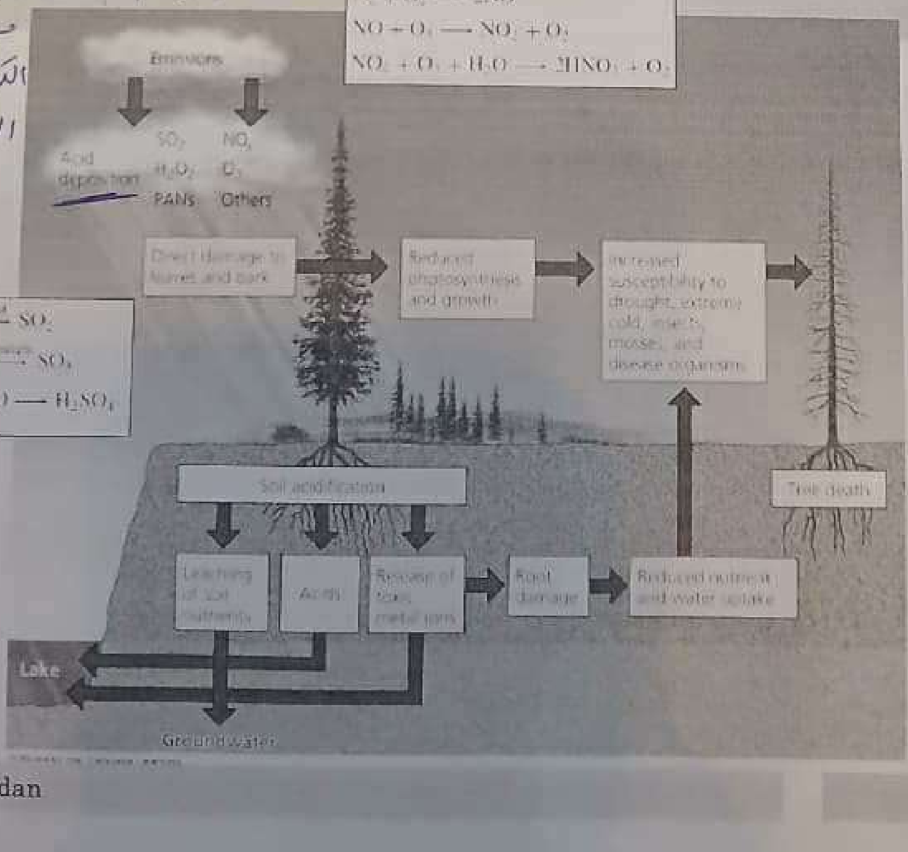
One way in which SO2 is removed from the atmosphere is the formation of acid rain

- contains high levels of sulfuric or nitric acids
- contaminate drinking water and vegetation النباتات
- damage aquatic life يضر الحياة المائية
- erode buildings تآكل المباني
- Alters the chemical equilibrium of some soils يغير التوازن الكيميائي لبعض انواع التربة.

يصير هنا خاصية السموزية عكسية بدال ما
التربة تبعث النبات الرطوبة والمياه يصير العكس
مشان هيك تتدهور ملوحة
التربة وهنالك موت
الغطاء النباتي

$N_2 + O_2 \longrightarrow 2NO$
$NO + O_3 \longrightarrow NO_2 + O_2$
$NO_2 + O_3 + H_2O \longrightarrow 2HNO_3 + O_2$

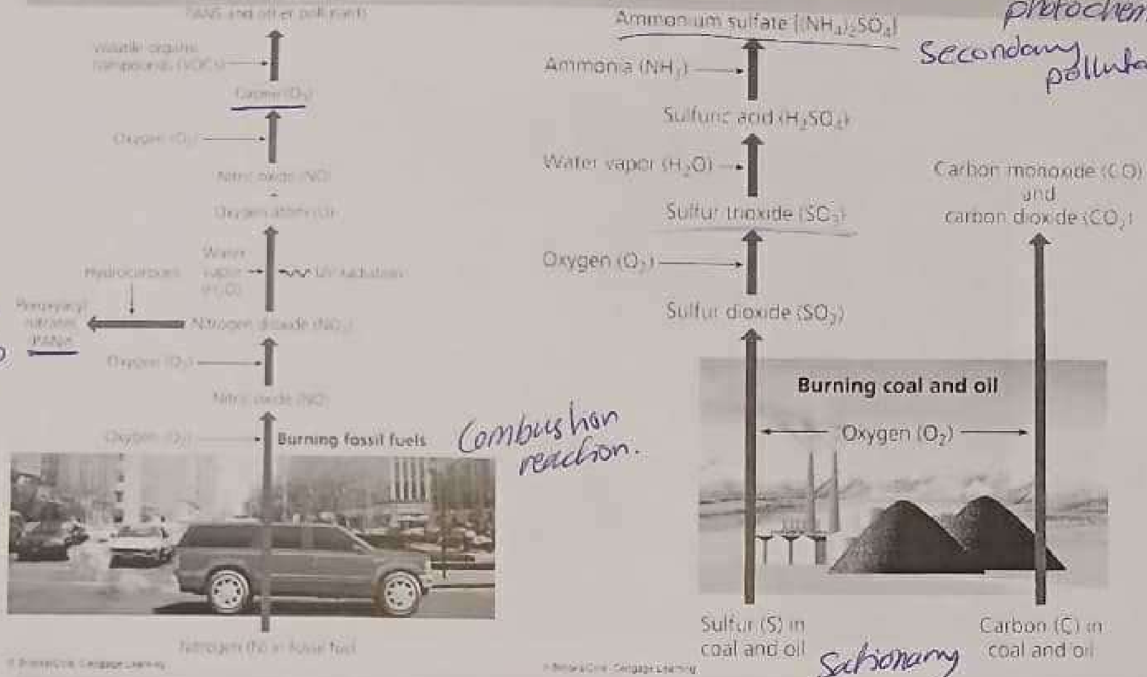
$S + O_2 \xrightarrow{heat} SO_2$
$SO_2 + O \longrightarrow SO_3$
$SO_3 + H_2O \longrightarrow H_2SO_4$



smog ⇒ smoke + fog ⇒ الشيء بعطيني لون فيه علي water Vapor وينتج الفوغ بعطيني لون فيه علي سواد

smoke + fog

Photochemical Smog ⇒ يتم تحفيز التفاعلات اللي فيه عن طريق الضوء photochemical reaction بعض secondary pollutant.



ملوثات هوائية ثانوية

Combustion reaction.

stationary source.

Simplified Reaction Scheme

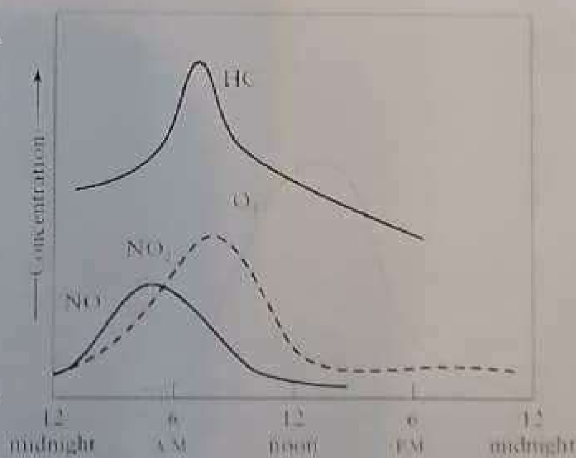
Hydrocarbons + Nox + Sunlight → photochemical smog (oxidants)

الملوثات الاولية المنتشرة

➢ primary oxidants produced: ozone (O_3), formaldehyde, peroxyacetyl nitrate (PAN)

intermediate reaction.

NO_2 + Light	→	NO + O
O + O_2	→	O_3
O_3 + NO	→	NO_2 + O_2
O + HC	→	$HCO^{\cdot}$
$HCO^{\cdot}$ + O_2	→	$HCO_3^{\cdot}$
$HCO_3^{\cdot}$ + HC	→	Aldehydes, ketones, etc.
$HCO_3^{\cdot}$ + NO	→	$HCO_2^{\cdot}$ + NO_2
$HCO_3^{\cdot}$ + O_2	→	O_3 + $HCO_2^{\cdot}$
$HCO_x^{\cdot}$ + NO_2	→	Peroxyacetyl nitrates



الضباب الكيميائي الضوئي.

Photochemical Smog in Santiago, Chile

سماكة الطبقة 0.5 – 1.5 cm

Ozone Depletion

نفاذية أو ثقب طبقة الأوزون

مهيجة للعين

تعتبر مادة مهيجة للعين عند مستوياته الحضرية المعتادة.

- Ozone (O_3) is an eye irritant at usual urban levels, but urban O_3 should not be confused with stratospheric O_3, 7 to 10 mile above the earth's surface.

الخلط

or 12 km

كدرع ضد الأشعة فوق البنفسجية

تغييرة

تعمل طبقة حامية للأشعة ultraviolet

- The latter acts as an ultraviolet radiation shield, and its alteration can increase the risk of skin cancer as well as change the ecology in unpredictable ways.

بطرق غير متوقعة

تغيير البيئة.

هاي العملية cyclic

تعتمد على وجود الأشعة والأوزون على stratospheric

Ozone in the upper atmosphere is created when oxygen reacts with light energy (hv):

light

$$O_2 + hv \dashrightarrow O + O$$
$$O_2 + O \dashrightarrow O_3$$

Light energy also destroys ozone:

ultraviolet

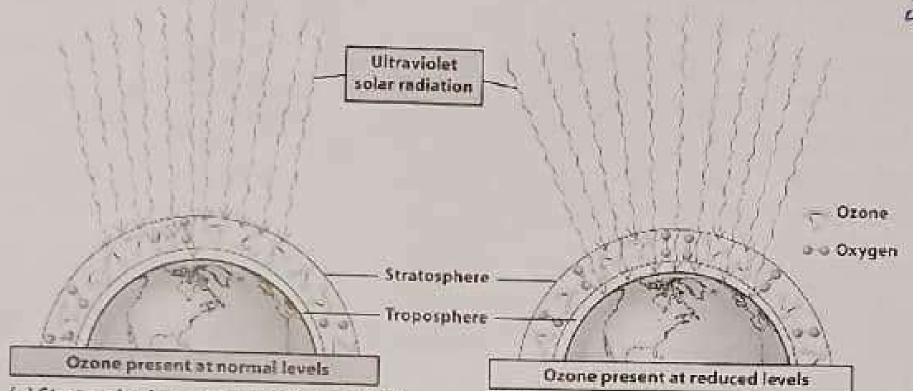
$$O_3 + hv \dashrightarrow O_2 + O$$

This is the mechanism by which ozone prevents ultraviolet radiation from reaching earth's surface. UV

تقب الاوزون
شو بعني
تقب اوزون
تركيز O_3 بهاي
المنطقة يكون
قليل ما يؤدي
الى نفاذ هاي
ultraviolet
من هاي الطبقة
ووصولها الى سطح الارض

✓ Ozone Protects earth from UV radiation Part of the electromagnetic spectrum with wavelengths just shorter than visible light

جزء من الطيف الكهرومغناطيسي باطوال موجية اقصر بقليل من الضوء المرئي



(a) Stratospheric ozone absorbs about 99% of incoming solar ultraviolet (UV) radiation, effectively shielding the surface.

(b) When stratospheric ozone is present at reduced levels, more high-energy UV radiation penetrates the atmosphere to the surface, where its presence harms organisms.

كل ما اتوجه (ابعد عن خط الاستواء) تركيز يكون أكثر

intensity O_3 لمساحة معينة
يكون الـ unit

Dobson units (DU) were developed to measure ozone concentration:

1 DU= 0.01 mm of O_3 at 1 atm and 0◦C

* Certin Value = سماكة طبقة الاوزون جهاز المعان

خطوط العرض الوسطى
القطب الجنوبي
~~القطب~~

At midlatitudes the ozone concentration is typically about 350 DU, at the equator it is 250 DU, and in the Antarctic region it is only 100 DU.

خط الاستواء لأن الحرارة عالية
- بكون عنا اعلى تراكيز للاوزون في هاي layer

على الحواف
ريح O_3 اعلى ما يمكن

Ozone Depleting substances. (ODS) تعمل على تفتيت طبقة الأوزون
$O_3 \rightarrow O_2$

Montreal protocol :-
بروتوكول موجود في كندا
توجد للحد من
تصنيع هاي المواد
Halonds , CFCs
Halone 101
102
تمنع تصنيع
دول

ماهي الملوثات المسببة في ثقب طبقة الأوزون

How O_3 is Depleted in the Stratosphere?

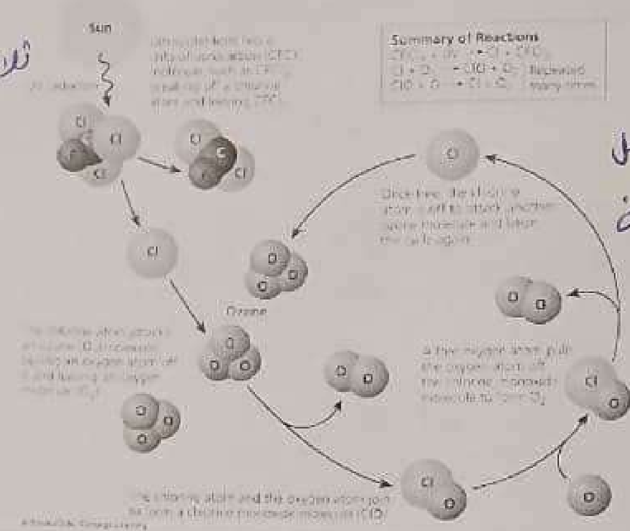
الاستخدام الواسع

- Widespread use of certain chemicals has reduced ozone levels in the stratosphere, which allows for more harmful ultraviolet radiation to reach the earth's surface

هي المواد التي نستخدمها بالبكتيريا

- The chlorofluorocarbons (CFCs). chemicals that found wide use in aerosols and refrigeration systems and are responsible for climate change as well as the depletion of the protective ozone layer in the stratosphere. ثلاجات الهباء الجوي

Two of the most important CFCs are trichlorofluoromethane, $CFCl_3$, and dichlorodifluoromethane, CF_2Cl_2, both of which are inert and not water soluble and, therefore, do not wash out of the atmosphere.



التفاعل لعدد سنين

The ozone hole & risks

القطب الجنوبي

There indeed was a huge monster hole right in the middle of the South Pole.

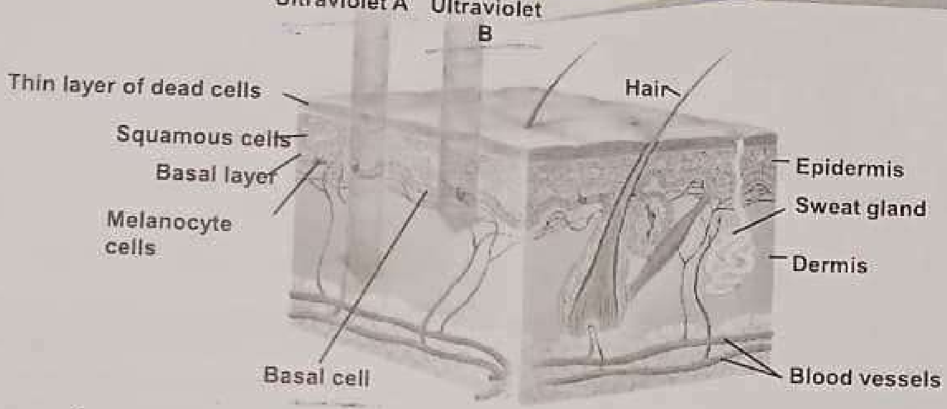
شيخوخة الجلد

شيخوخة مبكرة وتجاعيد

This long-wavelength (low-energy) form of UV radiation causes aging of the skin, tanning, and sometimes sunburn. It penetrates deeply and may contribute to skin cancer.

تسمير

This shorter-wavelength (high-energy) form of UV radiation causes sunburn, premature aging, and wrinkling. It is largely responsible for basal and squamous cell carcinomas and plays a role in malignant melanoma.



Squamous Cell Carcinoma | Basal Cell Carcinoma | Melanoma

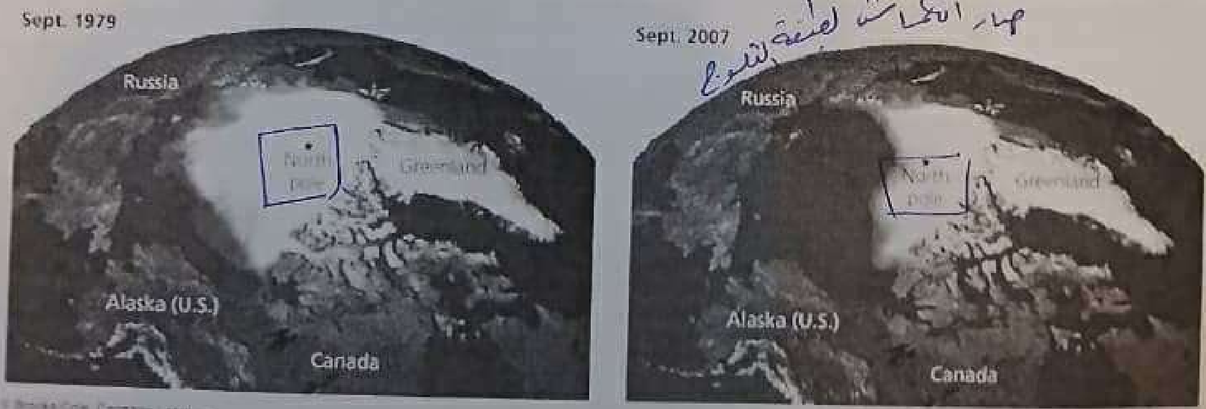
المسيطرة عالمياً

Climate Change

التغير المناخي: هو عبارة عن ارتفاع درجة حرارة الارض اذ الطبقة ... الى تحايل ... حركة تيارات الهواء ورطوبته

- The overwhelming scientific consensus is that the earth's atmosphere is warming rapidly, mostly because of human activities, and that this will lead to significant climate change during this century.

بدأ انحسار الطبقة الثلوج



عينات
ارتفاع الجليد في القطب الشمالي

Temperatures in the Past ?

كل عمود بعبر تاريخ وكل تاريخ إله عينة
تركيز CO_2 في هاي العينة بكون ثابت
CO_2 في الجو مشاري للمذاب بالأرض
تركيز CO_2 عن الطبقات اللي فوق بكون أكثر من الطبقات اللي تحت

Scientists analyze tiny air bubbles trapped in ice cores learn about past: لب الجليد

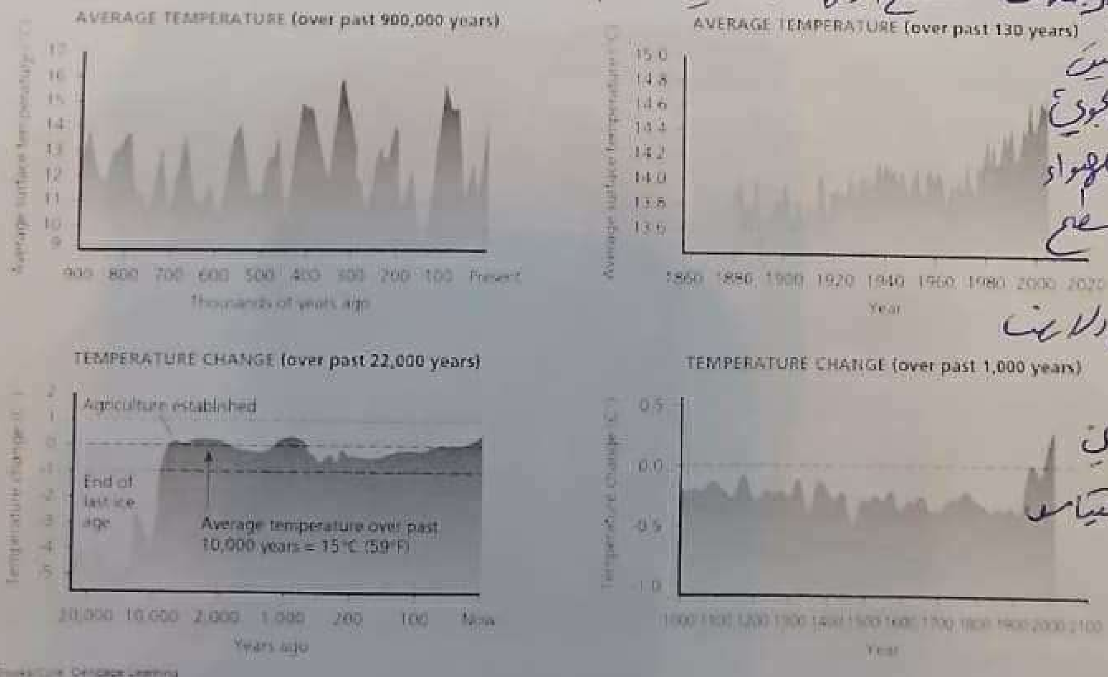
- troposphere composition.
- temperature trends.
- greenhouse gas concentrations.
- solar, snowfall, and forest fire activity.

equilibrium value. CO_2 الموجود في الجو
ما بينه وبين CO_2 لل liquid دائماً
Concentration بالاطراد متزايد

Estimated Changes

عدم وجود الغيوم او الملوثات اللي بتعمل انعكاسات للهيت وترجعها لسطح الارض وصمنها قبل التلوث

ΔT هي المسؤولة عن التغير المناخي
increase كل الانفتاح السنوي اللي عن

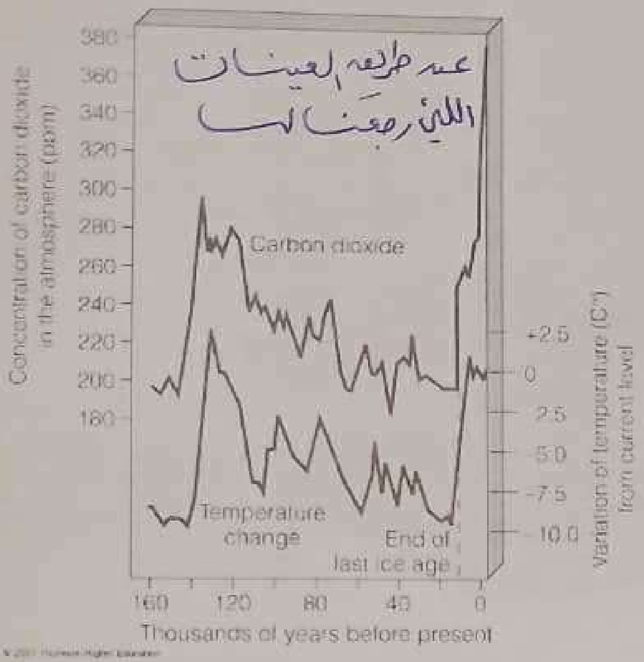


حاجز يمنع الهيت ترجع للغلاف الجوي وضل محسوس للهواء الملامس للسطح ما يؤثر على حرارة سطح الارض

التلوث الجوي ادى إلى الاحتباس الحراري

© Brooks/Cole, Cengage Learning

Carbon Dioxide at highest levels

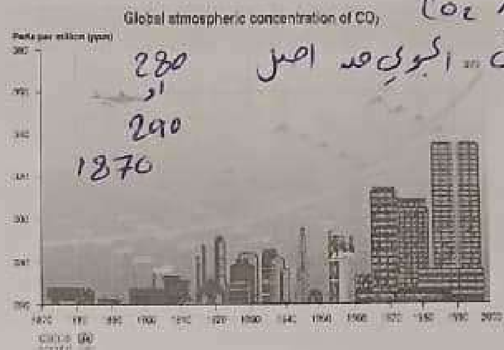


In 2005, an ice core showed that CO_2 levels in the troposphere are the highest they have been in 650,000 years.

2020 → 405 جزء من مليون

تركيز CO_2

في الغلاف الجوي هو الاصل



Climate Change Consequences

نفسها مستزادة

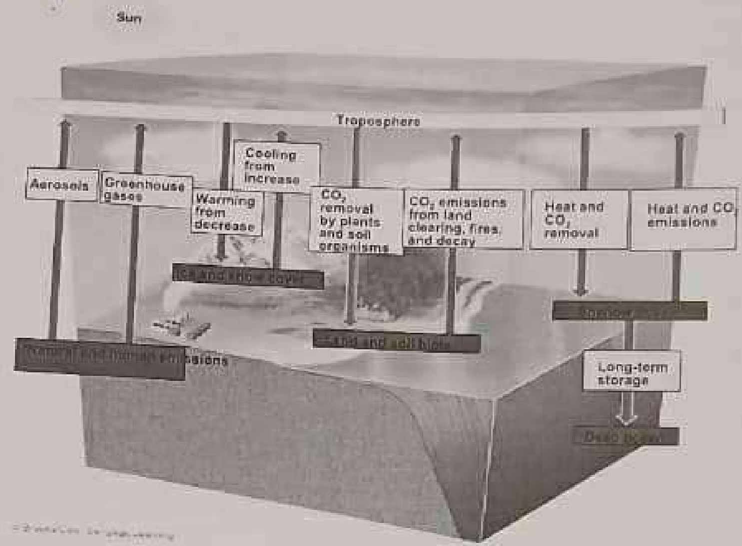
- 90–99% likely that lower atmosphere is warming
- 1906–2005: Ave. temp increased about 0.74°C
- 1970–2005: Annual greenhouse emissions up 70%
- Past 50 years: Arctic temp rising almost twice as fast as the rest of the earth
- Melting of glaciers and floating sea ice
- Prolonged droughts: increasing

جفاف وارتفاع معدل التصحر

- Last 100 years: sea levels rose 10–20 cm
- Warmer temperatures in Alaska, Russia, and the Arctic are melting permafrost releasing more CO_2 and CH_4 into the troposphere.

Greenhouse Gases Effect

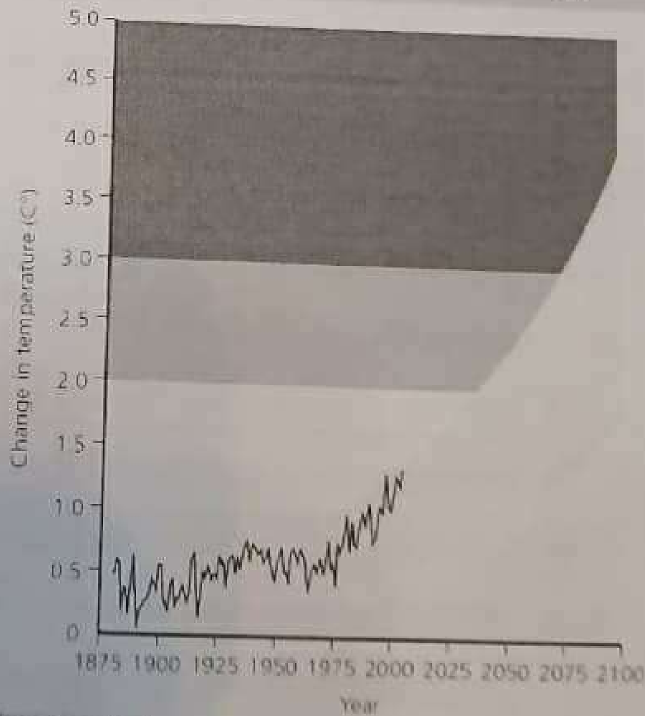
جدار بلاستيكي



Measured Temperature and Projected Changes

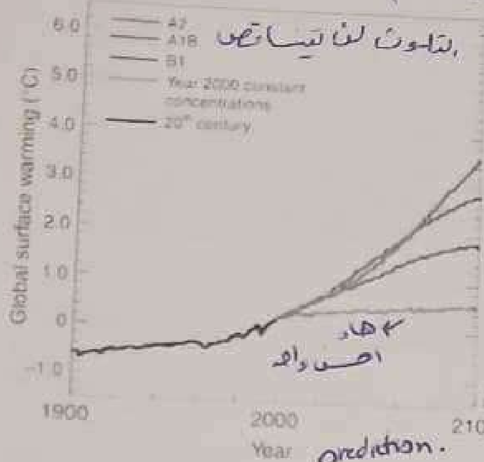
- The projected rapid change in the atmosphere's temperature during this century is very likely to increase drought and flooding, shift areas where food can be grown, raise sea levels, result in intense heat waves, and cause the premature extinction of many species.

زيادة الفيضانات والجفاف
نقل الأراضي التي يمكن الزراعة (زراعة غذاء) فيها
رفع مستويات سطح البحر والتسبب في موجات حر شديدة والانقراض المبكر لكثير من الأنواع



Temperature projections

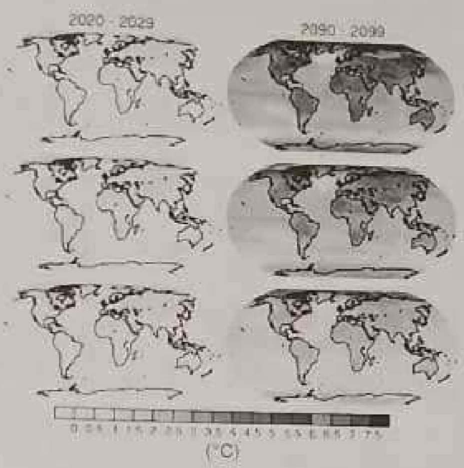
الهدف حاليًا تثبيت الملوثات على ما كانت
عليه في عام 2000



التلوث لن يتناقص

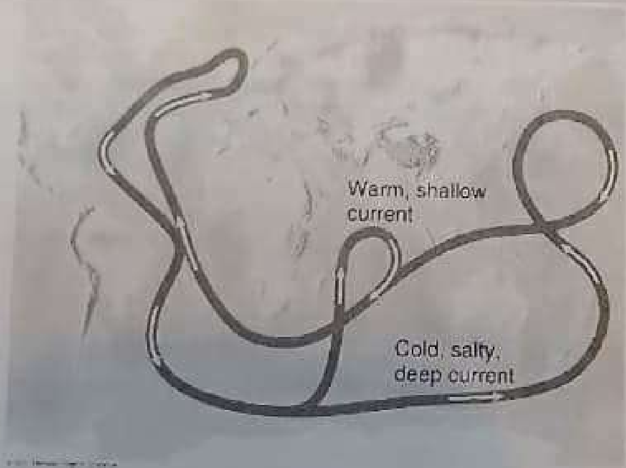
٣ هاد
احسن واحد

prediction.



Changing Ocean Currents

ظاهرة طبيعية
تتم عبر تيارات
مائية مشتركة بالمحيطات
وكيف دفئها وبرودتها



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Treatment معالجة
or purification

Air Pollution:

Flow تدفق
gas

Control of Stationary Sources

pollutant الملوثات هي اللي
ان كانت gasses او particulate matter
emission

Dr. Motasem Saidan

M. Saidan@gmail.com

physical high:
the vertich measurment
of a person or object from
it base to its highest point

Control of Stationary Sources

Control of Stationary Sources:

- Particulate Matter
- Gaseous Emissions

Particulate Matter

يكون عنا بسبب شغله process وبالتالي يكون ب efficiency او عنا شغله بنفس raw materials او reactant اللي بشتغل عليه

- Most of the air pollution produced by stationary sources results from the incomplete combustion of fuel or industrial processing

efficiency ← → raw materials

تنبعث

- The types of inorganic and organic air pollutants stationary sources emit are dependent on the specific process operations

Examples: Fossil fuel fired boilers emit ash, sulfur dioxide, nitrogen oxides and mercury, and or vanadium if contained in the fuel. Metallurgical plants can emit a variety of metal dusts, including iron oxides and sometimes fluorides and chlorides. Industrial plants manufacturing inorganic chemicals will emit various waste gases depending on their product. Odorous organic waste gases can also be emitted from organochemical and petrochemical plants.

مصانع تعدين

Auxiliary losses :- leak اذا كان عنا فيه duckt او من مفتوح او من tank تيجي من
وبخارات اخطر فواد اللي بتهرب من الاماكن اللي فافيث تفادية
وبعده solid ثم liquid

~~Vegetative~~ Fugitive sources. مصادر التهريب

Industrial pollutant sources

Industrial pollutant sources such as these and others can be categorized into several groups based on their specific process operation:

- **Process Operations:** استفاعلات غير مكتملة

  Process operations with incomplete chemical reactions, which include combustion due to unconverted reactants, or a reaction having a final yield that is less than expected theoretical conversion.

- **Atmospheric Releases:** الانبعاثات الجوية

  شوائب

  Atmospheric releases of process's secondary components or impurities of raw materials. في مصانع الاسمنت حتى يصيرعنا خلط الاسمنت اللازم Calcination process

- **Auxiliary Losses:** زي فرن دوّار اسطواني rotarey kilns

  وبعد بلف لخلط الدست موزونة شكل حسك مجرور المصنع الموجود في الغلاف

  اول الخلطة تبعث الاسمنت على اشكاله ويلف هواء بالخلطة counter currently والهواء الساخن على 1200c حتى يتبخر من الخلطة تبعث الاسمنت

  The auxiliary losses of compounds such as volatile organic solvents from fugitive sources or inorganics such as carbon disulfide and hydrogen sulfide in rayon production and fluorine compounds as in the production of aluminum.

فيكون طالع معه gaseous pollutant ناتجه من احتراق
او ناتج من dust material اللي بتطلع drying او calcination process وعادة بمصانع الاسمنت

لازم نحنا نسيطر على الموضوع من خلال جمع ال duckts كلها وتطلع one point وهيك بركب عليها unit
حتى اعمل Treatment او على كل مصدر بعمل emissions بركب unit حتى اعمل capturing
زي ال pollutant ال minimization من يكون متفق مع ال standard او نعمل eliminate بالتالي
بشكل كامل at all

- **Waste Emissions:** وين ماكان عنا Thermal unit متوقع انه يطلع منه اجزاء ال wast emissions
روائح كريهة وانبعاثات النفايات.

Emissions of malodorous substances or oxidation compounds in the exhaust from oxidation, heating or drying processes.

الانبعاثات
Releases from these categories can originate from a variety of emission points and may not be centrally collected before entering the atmosphere.
مركزيا

فتحة تهوية

> ➢ Air release emission points, from industrial process operations, can be categorized as stack, duct, vent, fugitive and area
>
> مدخنة — مجرى — اعلى — controlled على — Enclosure — مصدر
>
> ➢ Fugitive emission points are release points, which are unconfined in a stack or duct before reaching the atmosphere.
>
> ✓ Therefore, whether an emission source is considered a point or fugitive source is dependent on whether the release is confined or unconfined in a stack or duct prior to atmospheric release.

Booths ⇒ solvent افران دهان السيارات عشان هيك بشم كل انواع ال

Vacuum system ⇒ تفريغ الضغط او اختلاف الضغط بعمل driving force بعمل Flow هاد ال Flow فالعمل
مابعد point اللي كان يتم احتواء رح يطلع بالهواء الطلق

Blow molding ⇒ على الحيان بنترك جو القالب البلاستيك ماسورة زي منفاخ عشان تأخذ شكل
القالب بعدين بنبرد ونطلع منها شكل على هاد

spray drying: عبارة عن اسطوانة طولها 20 m مدعومة في اعلاها nozzle بتطلع slurry
drops from و solid particle ومن تحت طالع هواء ساخن
عشان يسحب المياه الي جوا ال drops فبالتالي
تجفيف ولازم هاد الهواء نطلع فيسحب معا
dust ولازم اعمله Treatment عشان اسحب
particle وارجع استخدم مرة ثانية cycles
drying في عنا heating fluid نفسها وين ماكان
وهو هواء واذا دخل رح يطلع من جهة ثانية
ويجففه وجزء منه يطلع معه فلازم انظفه
عشان ما يلوث الجو

...eration Air Emission Points and Categories	
	مصادر التهريب **Fugitive Sources**
	Valves Pump seals → الجلد Flanges/connectors زي الوصلات Compressors Open ended lines Pressure relief devices Equipment cleaning/maintenance
...Surface Area Sources	**Handling, Storage, Loading**
Pond evaporation برك التجفيف Cooling tower evaporation شوفنا top بتعلق Wastewater treatment Land disposal مصانع الفحم	Storage tank breathing losses Loading/unloading Line venting Packaging and container loading

vent إذا انفتح pipe عنه سخان السخانة
melting بصير عنا للغازات عشان تطلع
عالطبيعة مفتوحة للجو
مكبات النفايات

ودفعنا الهواء سحب من الشام تحت الشوفرع حوالة وتطلعها للجهة الثانية

بتاعة هواء أو غاز ال tank ما يكون ناخص غازات إذا استخدم clean material وطبيعة وحقيقه حرارة

تغيير عمليات الإنتاج   تركيب تقنيات تحكم فعالة   حلول عملية

- Pollution control can be achieved through common sense solutions such as the installation of effective control technology, changes in production processes, and the implementation of pollution prevention techniques.

شان تتوافق مع ISO   تطبيق تقنيات منع التلوث

- Compliance with emission standards and the successful attainment of air quality standards depends in large part on the application of appropriate stationary source control measures. Select proper controle units on Air sources emissions.

تطبيق تدابير مناسبة للتحكم في مصادر التلوث الثابتة

particulate matter.

PM Control Procedures

➢ Control procedures for stationary sources of pollution include: إجراءات التحكم في مصادر التلوث الثابتة ؟؟

dispersion شان انشر اقل   هذا ال standard العالمي ← 100m minimum مرتفعة   تستخدم مداخن طويلة

- the use of tall smokestacks,
- changes in plant operations, and   تغيير في عمليات التصنيع
- installation of effective control devices   تركيب الأجهزة التحكم الفعالة

➢ The control strategy required for an industrial environmental impact is a four step process:

حل المشكلة على المصدر
رنس بدها مصاريف
(1) elimination of the problem source or operation,   ازالة مصدر المشكلة او العملية
pipe او حل (2) modification of the source operation,   تعديلات على عملية المصدر
غير مكان المصدر (3) relocation of the source, and   نقل المصدر
(4) selection and application of the appropriate control technology.   cost   مع بعض اقل تكاليف

Don't mix the waste → liquid waste or solid wast
لأنه هيك بدك تدفع مصاري تفصلهم وتعالجهم
شي دائما نبين للستاندرد

 اختيار وتطبيق تكنولوجيا التحكم المناسبة

Condition unstable climate

Dispersion.
Disperses it

Exhaust Stacks

end of pipe

cleaner production

- Exhaust stacks do not reduce emissions from a stationary source; rather they reduce the local effects of the pollution by elevating the exhaust stream to a point where it can be more effectively dispersed.

Solution

- High exhaust stacks were an inexpensive solution in the absence of expensive control technology. For years elevated stacks were used with the nearby communities in mind. A belief was widely held that elevated stacks reduced the likelihood that pollutants would have any effect on neighboring populations.

emission process

- Utility and smelter operations have traditionally used tall stacks (200m to 400m) in order to reduce the amount of ground-level concentrations of sulfur dioxide (SO2). However, this did not always eliminate the problem, but instead simply transferred it to another location.

acid + Base + organic Matter

- This approach was used for many years, until concern arose over the regional and transboundary spread of harmful toxics. For example, there is great concern over the spread of acid rain from one region to another.

Persistance Carcinogenic pollutants.

Plant Operations

mass balance.

procedure ⇒ low cost or no cost

cost precautionary measure

- Compliance with emission standard may require the use of control technology, but many industrial operations have reduced emissions by **changing operational methods**.

- Some of these changes include **pre-treating process materials**, fuel or material substitution, and changes in the manufacturing process. As an example of how pre-treating raw materials can be an inexpensive solution to pollution control, industry has discovered that significant reductions in particulate matter and sulfur emissions can be achieved by a technique called coal washing. Pre-treating raw materials in this manner not only reduces the amount of fly ash released from coal, but it also reduces the amount of inorganic sulfur released as well.

- Another way to comply with emission standards is to **substitute cleaner fuels** during the refining process. Natural gas and low-sulfur fuel oil are just two examples of fuels that emit less pollution during combustion. However, cleaner fuels can be more expensive and can increase national reliance on foreign fuel sources.

maintenance losses Fugitiv sources

not effective.

الصيانة الدورية تقلل من احتمالية وقوع حوادث الانسكاب من خلال اكتشاف الاعطال في المعدات قبل حدوثها.

- Reduction in emissions from stationary sources can also be accomplished through increased attention to **plant maintenance**. معالجة المصنع

Plants that release significant quantities of pollutants into the environment frequently do so as the result of improperly maintained equipment. This is especially true of combustion equipment.

ISO requirment

- **Adequately scheduled maintenance** must be performed to reduce both the exhaust and amount of fugitive emissions released from vats, valves, and transmission lines. **Periodic maintenance** also reduces the likelihood of spill-related accidents by discovering faulty equipment before problems occur.

Adsorption = هو عبارة عن solid material تعمل capturing لل pollutant الموجودة في الهواء سواء كان غاز او solid particle باستخدام solid media وهي بشكل discrete media او fixed bed داخل في مراحل

Absorption = هو عبارة عن عملية تتم فيها capturing لل solid particle او gases باستخدام liquid يكون عنا نازل من فوق و gas طالع من bottom Exhaust gas يلتقوا مع بعض ويسحب منه pollutant سواء كانت dust او ال particle size

Control Technology

- A final way to reduce emissions from stationary sources is through the use of advanced, add-on control technology. استخدام تقنيات التحكم المتقدمة والاضافية

- Control devices can destroy or recover gaseous compounds or particulate matter for proper disposal or re-use. → اعادة استخدام

- The pollution control operations used to destroy or capture gases include combustion, adsorption, absorption, and condensation. → gas → liquid
  - solid material
  - Heat exchanger

- Control devices that implement these processes include thermal incinerators, catalytic incinerators, flares, boilers, process heaters, carbon absorbers, spray towers, and surface condensers.
  - حارقات حرارية
  - activate carbon استخدام

The most important process parameters for selecting air pollution control equipment are **the exhaust gas characteristics** obtained from emissions tests and **process or site characteristics** obtained from a field survey

Control Devices for Particulate Emissions

- Technologies used to control particulate matter focus on removing particles from the effluent gas stream. تيار الغازات السائلة.

مهم عشان نعرف كيف اختار الجهاز المناسب

- Many factors (such as particle size and chemical characteristics) determine the appropriate particulate control device for a process.
- Devices most commonly used devices to control particulate emissions include:
  - Gravity settlers (often referred to as settling chambers)
  - Mechanical collectors (cyclones)
  - Electrostatic precipitators (ESPs)
  - Scrubbers (Absorption)
  - Fabric filters فلاتر مصنعة من القماش
  - Hybrid systems

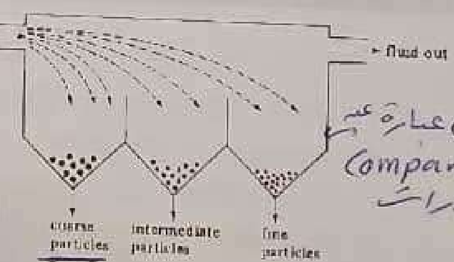
عند استخدام كل جدول ب series
عشان نحصل efficiency اعلى

- In many cases, a combination of multiple devices yields the best collection efficiency. For example, a settling chamber can be used to remove large particles from the exhaust stream before it enters an electrostatic precipitator where smaller particles are removed.

EQUIPMENT

physical System (mechanical) don't need pumps, heating cooling, no need any electric power.

Gravity settlers (often referred to as *settling* chambers) بنحكي عن parts بالـ density عالية
بنحكي عن velocity profile



جدول عبارة عن Compartment 3 تقسيمات

- Gravity settlers, or gravity settling chambers, are used industrially for the removal of solid and liquid waste materials from gaseous streams.
- Advantages accounting for their use are simple construction, low initial cost and maintenance, low pressure losses, and simple disposal of waste materials.

Flow gas have ممكن يكون high Temperature

Mechanical collectors (cyclones)

hydrocyclones ⇒ liquid عبارة عن

- Centrifugal separators, commonly referred to as *cyclones,* are widely used in industry for the removal of solid and liquid particles (or particulates) from gas streams. gravity ⇒ particle تنزل بسبب

 بسبب دوران لتقت شار الهواء يطلع لفوق

Fabric filters (bag houses) cloth

مكنسة الكهرباء.

بتكون Vacuum or high pressure ، compartment (الحجرة) وهاي فيها فلاتر مصنعة من الـ media بتكون مصنعة من لشوادر او بكتان

- Filtration process may be conducted in many different types of fabric filters. Differences may be related to:

  مختلفة عن بعض

  The Temprature should be modarate. حتى احافظ على fabric material الموجودة في هذا الـ filter

  - Type of fabric
  - Cleaning mechanism
  - Equipment
  - Mode of operation

- Gases to be cleaned can be either "pushed" (دفع) or "pulled" (سحب) through the bag house.
- In the pressure system (push through) (دفع) the gases may enter through the cleanout (فتحة لتنظيف الـ القادوس), hopper in the bottom or through the top of the bags. (للاتجاه سفلي)
- In the suction type (pull through) the dirty (ملوث) gases are usually forced through the inside of the bag and exit through the outside.

Baghouse Filter

مونفس الـ Vacuum اللي بنستخدمه في البيت

- similar to conventional home vacuum cleaner داخل efficiency عالي
- Efficiency:
  - efficieny عالي >99.5% for <1 µm diameter
  - maintance بده عالي >99.8% for >5 µm diameter

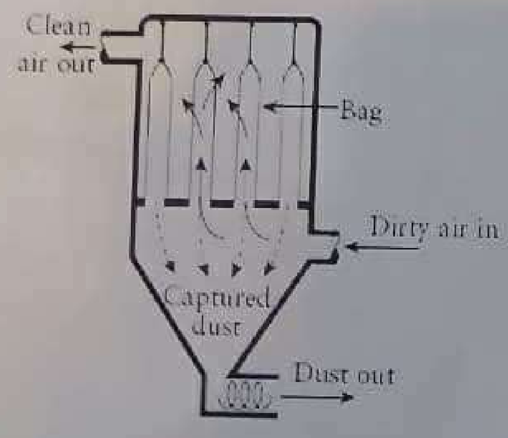
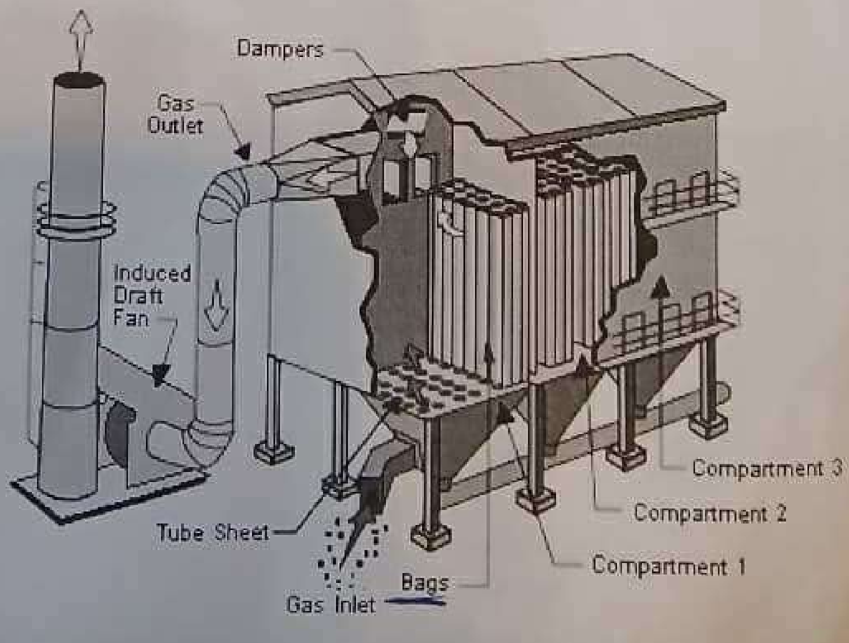


Figure 13. Reverse Air Fabric Filter



- ***Hybrid systems*** are defined as those types of control devices that involve combinations of control mechanisms-for example, fabric filtration combined with electrostatic precipitation. wet electrostatic precipitation.

- Four of the major hybrid systems found in practice today include:
  - Wet electrostatic precipitators,
  - Ionizing wet scrubbers, have electrical feild.
  - Dry scrubbers, and
  - Electrostatically augmented fabric filtration.

مشبوع

معزز

Cyclones

physical system.

cyclonal inlet اللي بطلع من cyclone الذي بدخل على الخارج

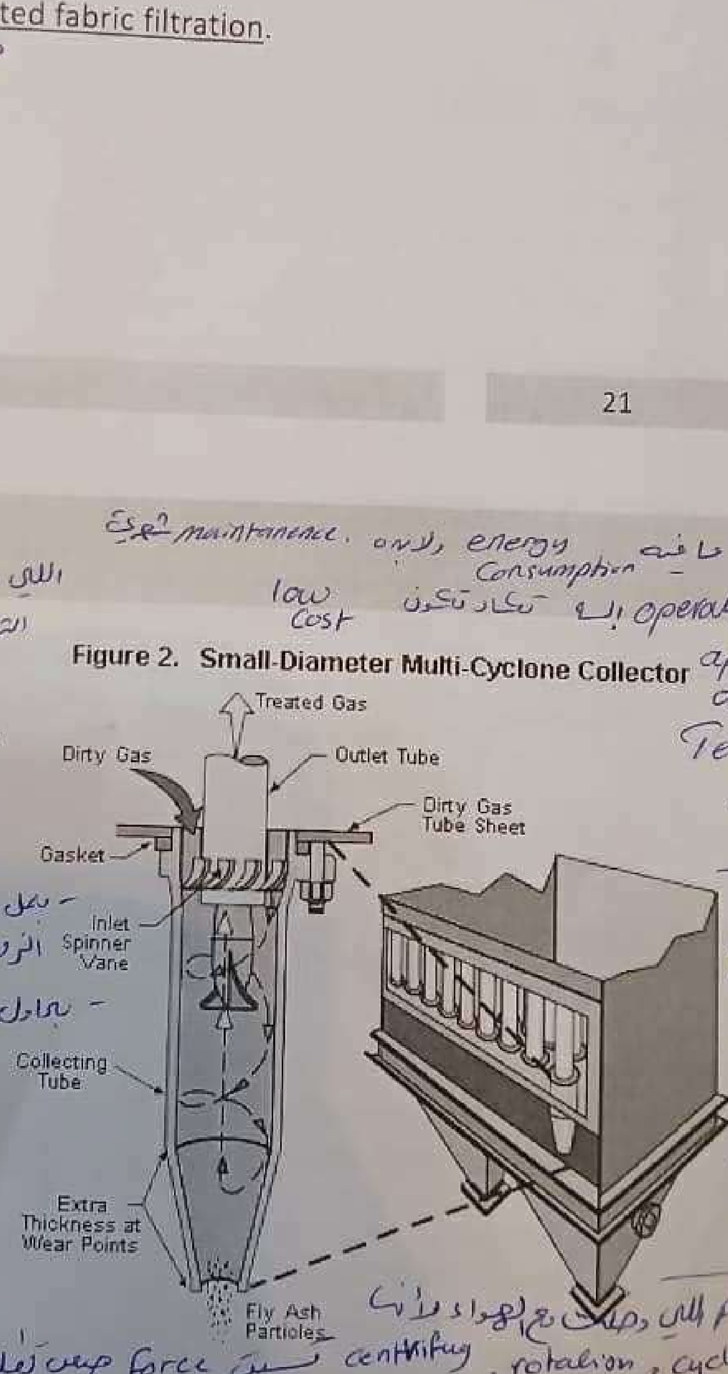
particle بعيد الى rotation and Centrifuge.

صيانة maintenance اقل ، و energy Consumption

low cost تكاد تكون operating cost -

applicable of high Temprature < 600°C

Figure 2. Small-Diameter Multi-Cyclone Collector



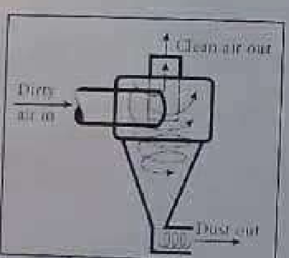
✓ can be used for 50-100 μm size particles and down to 10 μm

✓ simple economical unit:

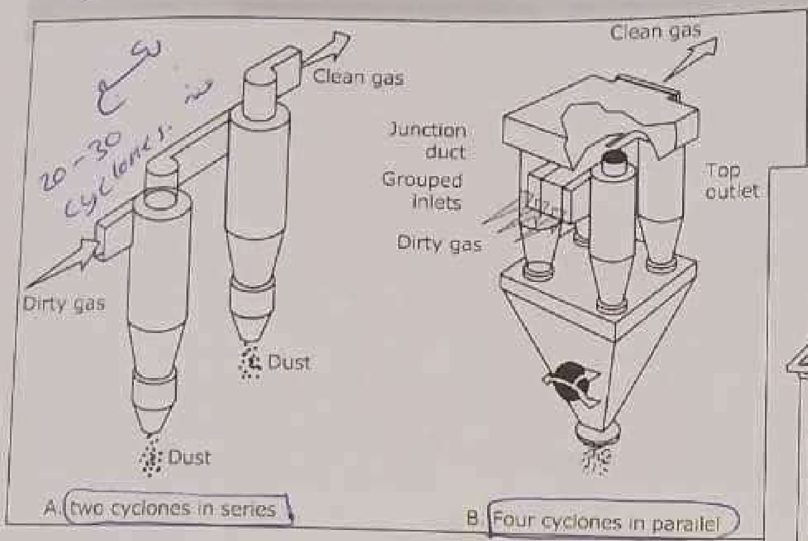
- no moving parts - بعمل زي المروحة
- relies on inertial effects - بحاول يغير اتجاهه للأقل مقاومة

يعتمد بالكامل على القصور الذاتي

مع نقصان diameter Bottom في الهواء رح يحاول يغير ضده مكان آخر من خلال الفتحة Top.



عند cyclone, rotation, centrifug بسبب force صعب تطلع مع الهواء من top فتكمل حركتها الدولبية وتنزل من Bottom
الـ particle اللي دخلت مع الهواء ولأنها



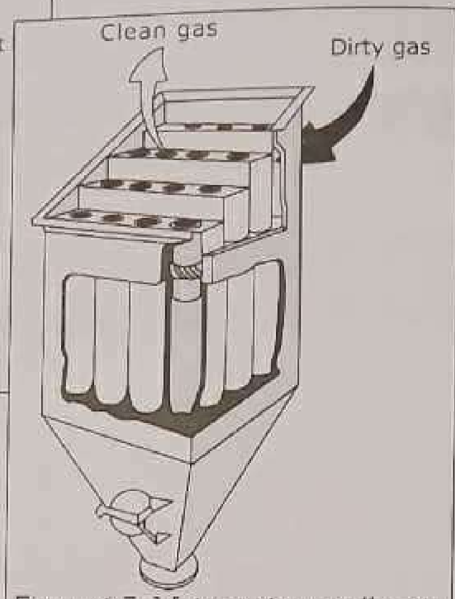


Figure 6-7. Multi-cyclone collector

For particle sizes greater than about 10 μm in diameter, the collector of choice is the cyclone

المعادلة هاي تستخدم حتى احاول عليها سؤال كم $d_{0.5}$ اللي لازم يكون حسب الـ geometry الموجود عندي انا للـ Cyclone design بحيث يعطيني removal بـ efficiency معينة.

الـ rectangle بالمثلث و استخدم بالمعادلة عند الان فيه friction عالي
شكل الكل design.

The particle size collected with 50% efficiency, termed the cut diameter:

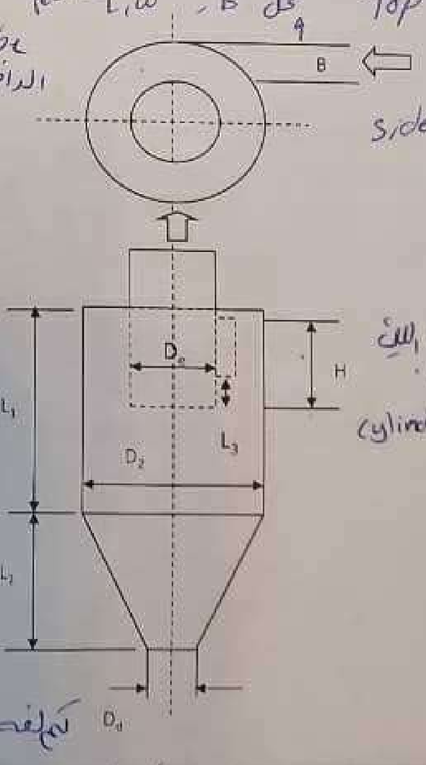
Diameter of inlet tube
الداخل outer wall

سؤال فاينل

$$d_{0.5} = \left[\frac{9\mu B^2 H}{\rho_p Q_g \theta}\right]^{1/2}$$

hight of cylindrical shape — hight of conical shape

$$\theta = \frac{\pi}{H}(2L_1 + L_2)$$



كم طول الـ tube اللي يلف فيه الهواء و كم داخل جوا الـ cylinder

- $d_{0.5}$ = cut diameter at 50% removal
- μ = dynamic viscosity of gas, Pa-s
- B = width, m
- H = height, m
- ρ_p = particle density, kg/m3
- Q_g = gas flow rate, m3/s
- θ = effective number of turns → كم لفة بلف فيه

→ number of rotation. قديش بيلف الـ particle جوا الـ cylindrical part

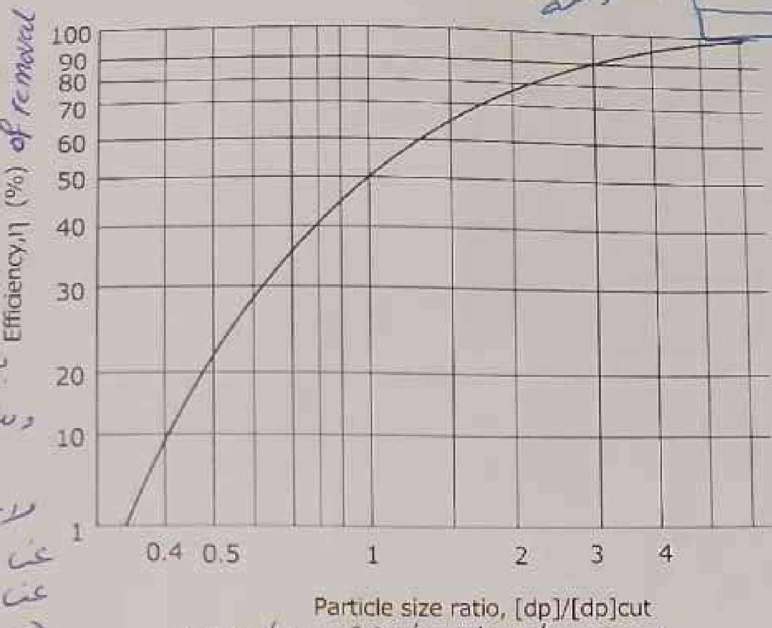
سؤال فاينل هاد chart

مع

المهتمين بدارستة

d_p	d_p/d_p	η
10		75
20		30
		70

مع معطيات بالسؤال لحساب $d_{0.5}$



عندهم بكيلك 90% هي efficiency of

$\frac{d_p}{d_0}$ من

$3 = \frac{d_p}{d_{0.5}}$

$3 = \frac{10 \text{ micr}}{?x}$ هو معطيني اياه

برجع على المعادلة ونحط $d_{0.5}$ وبشتغل train and error

H, L_1, L_2 لازم اعرفهم ولكنه بعت عن Dahn Boss عن standard ويعطي.

diameter اللي انا مهتم فيه وطالع من flow gas. مهتم اعلى removal.

→ $d_{0.5}$. اللي بعطيني اياه بالمعادلة

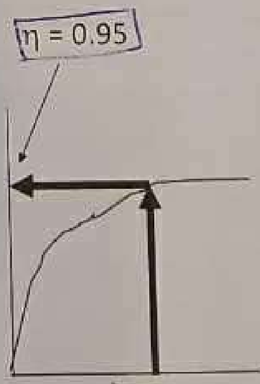
Example

Given:
$D_2 = 0.5$ m
$Q_g = 4$ m^3/s
T = 25 °C
$\rho_p = 800$ kg/m^3

For standard Cyclone:
$B = 0.25\ D_2 = 0.13$ m
$H = 0.5\ D_2 = 0.25$ m
$L_1 = L_2 = 2\ D_2 = 1$ m

$$\theta = \frac{\pi}{0.25}(2(1)+1) = 37.7$$

Q = What is the removal efficiency for particles with ave diameter of 10 µm?



$$d_{0.5} = \left[\frac{9(18.5x10^{-6})(0.13)^2(0.25)}{(800)(4)(37.7)}\right]^{0.5} = 2.41x10^{-6}$$

$$= 2.41(\mu m)$$

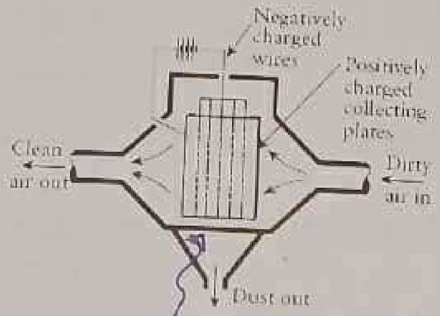
@ d =10 µm particle اللي هو المهتمين $\frac{d}{d_{0.5}} = \frac{10}{2.41} = \boxed{4.15}$

بعطيك بالسؤال

ستكون ال removal

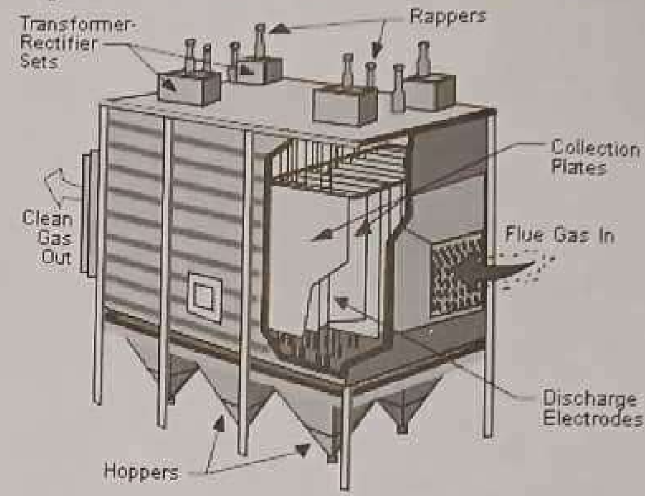
Electrostatic Precipitator (ESP)

- high efficiency, dry collector of particulates
- high electrical direct current potential (30-75 kV)



plates or rods

Figure 9. Conventional Electrostatic Precipitator



 يا نعمل Vibration عشان نتخلص منهم

او ندخل عليهم ضربات عشان كوش عشان يوقعوا

electrical feild

ندخل الهواء اللي فيه غبار في electrical feild فيه قضبان بيشحن دقائق

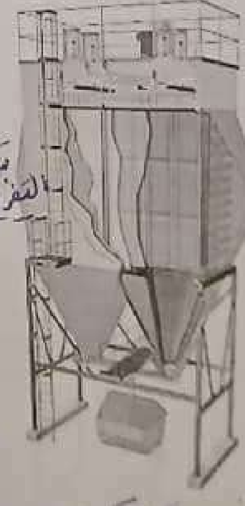
وتصبح تتراكم على الاقطاب حسب plates. high voltage

موجود في مصانع الفحم او الاسمنت

Electrostatic precipitators (ESPs)

بلجأ اله لما يكون عنا gas flow فيه high Temperature

- They are satisfactory (مرضية) devices for removing small particles from moving gas streams at high collection efficiencies. They have been used almost universally in power plants for removing fly ash (رماد متطاير) from the gases prior to discharge. (بين التفريغ)
- Two major types of high-voltage ESP configurations currently used are tubular and plate. Tubular precipitators consist of cylindrical collection tubes with discharge electrodes located on the axis of the cylinder. Vast majority of ESPs installed are of the plate type.
- Collected particles are usually removed by rapping. بالطرق



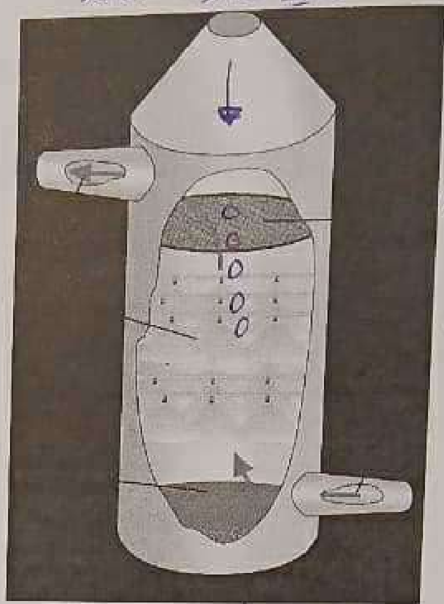
الترسيب الانبوبية تتكون من انابيب تجميع اسطوانية مزودة باقطاب تفريغ تقع على محور الاسطوانة ، الغالبية العظمى من ESP هي من نوع plate.

Scrubbers (venturi scrubbers)

liquid drop تعمل Capturing → dust, or particulat matter المعلقة بالهواء.

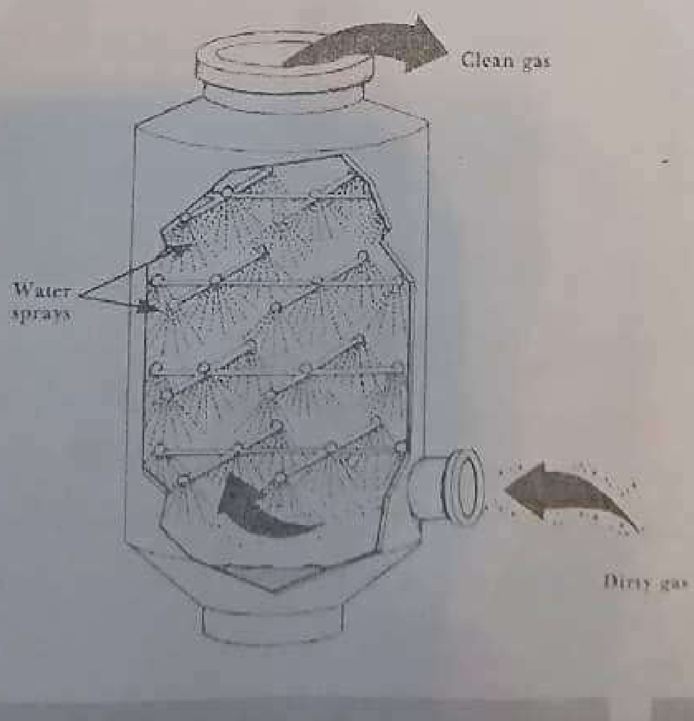
- Wet scrubbing involves the technique of bringing a contaminated gas stream into intimate contact with a liquid. بتلامس غاز ملوث مع سائل.
- Wet scrubbers include all the various types of gas absorption equipment.
- The term "scrubber" will be restricted (تقتصر) to those systems which utilize a liquid, usually water, to achieve or assist in the removal of particulate matter from a carrier gas stream. لازالة الجسيمات من تيار غاز ناقل او المساعدة في ذلك

هاد الجهاز كفاءته عالية وبعكس اللي الاخرين مالتقط particle المعلقة بالهواء لازم معلقة بالماء وبالتالي بدو Treatment عشان تشيل particles المعلقة من ال liquid المعلقة فيه او يرجع يعمل recycle وبعالجه مره اخرى.

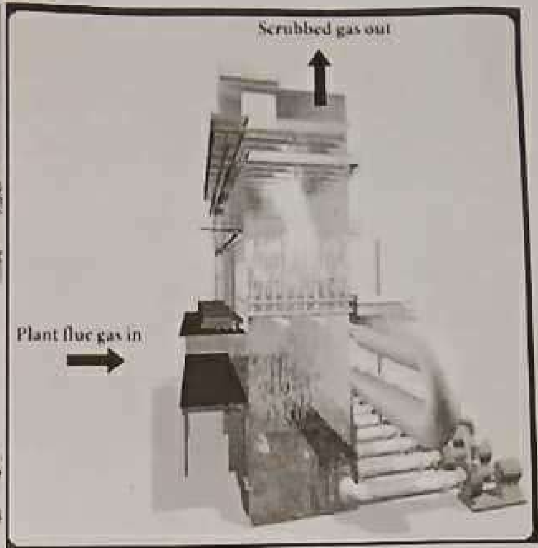


الهواء يدخل من Bottom ويطلع من Top

صارت داخل particles معلقة



Scrubbers Absorption system



إذا عنا Flow gas الحرارة moderate يعني اقل من 250°C والـ flow rate moderate بإمكاني اروح على الإرشاد للغرفة
واسعار متفاوتة وما بتقرب

Comparison of Air Pollution Control Devices

وبعد إذا عنا flow gas high Tem • 350 درجة ممنوع افكر ب scrubber system.

فشل شلال liquid ولا فاد

ولا تكون درجة الحرارة 600°F وأو فشل على filter bag لأنه بحرقها

لما تكون عندي درجات حرارة عالية corrosive و material لازم اروح electrostatic prec. و cyclones.

لأنه ارخص ويدخله بعد على electronic prec

وبعد استخدم settling tank

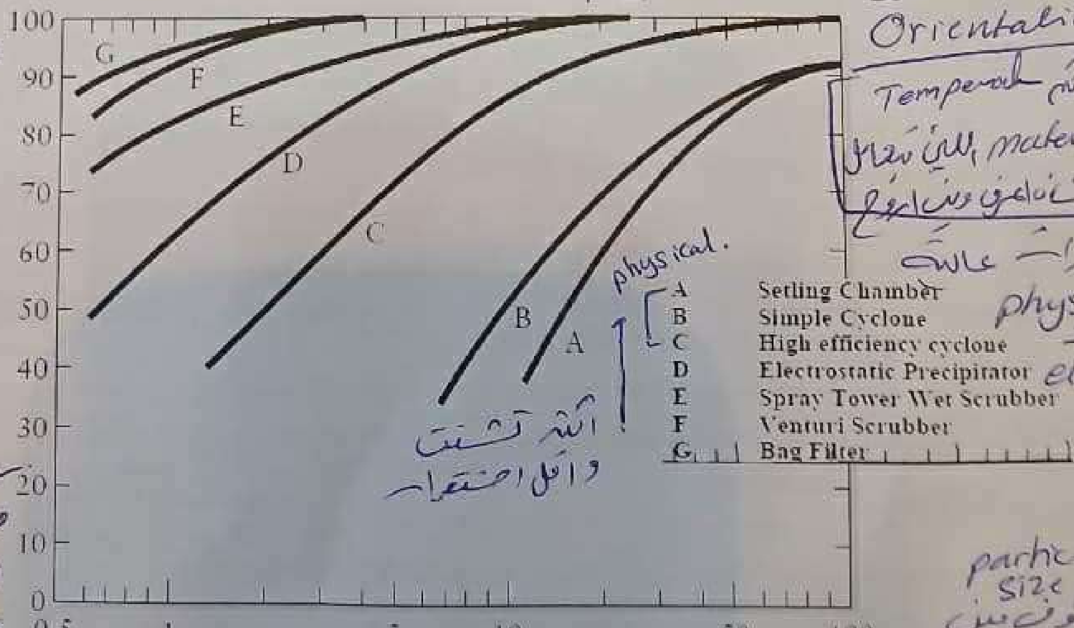
Qualitative or Orientation.

لازم اعرف ثم Temperature شو material اللي بتعامل معه حتى اعرف وين اروح

انا عندي حرارة عالية اروح physical + electrical

physical.

أكثر تشتت وأقل استقرار



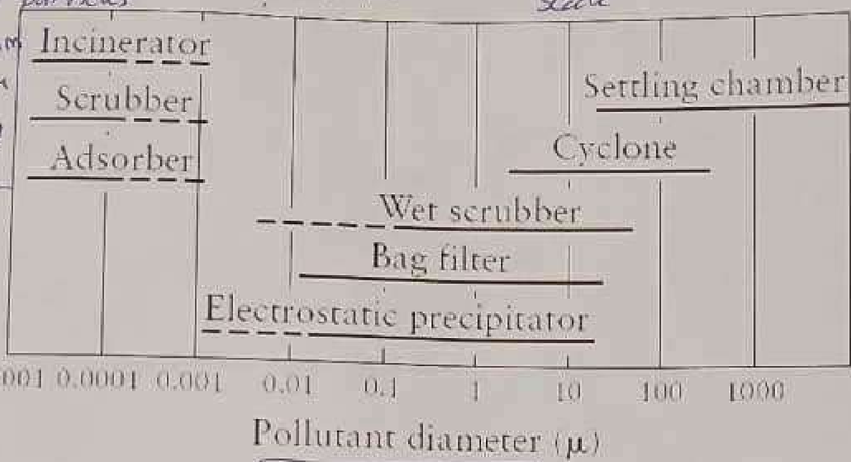
particle size بعدها مشان اشوف بين المنحنى اللي بيعطيني

nano scale ~~&~~ nano particle.
nano scale ⇒ 1×10^{-9} scale unit of length. 1×10^{-12} m | 1 x1000 μm
nano particle ⇒ particle in nano At nano scale نسبة حجم كرة قدم بالنسبة للكرة الأرضية

Effectiveness of Air Pollution Control Devices

nano particle اسمها nano scale لـ particle مشاكل
micro meter or particle اسمها micro scale لـ ، كل اسمها مشاكل ~~nano scale particle~~ مشاكل
الا اذا كانت nano particles اسميها ما بقدر 1-1000 nm من nano scale ← الـ particle لا تكون على

1-100 nm سميت nano particle
لازم ما يتعدا 100 nm



↗ another type of pollutant 3 Senario

Gaseous Emissions

1- incinration حرق إذا ما كانوا oxide فهي قابلة للحرق
2- recycle إذا كان gases جزء من reactant أو جزء من عملية تعتمد
3- To use it as fuel
الحرق الأول عشان اتخلص منه
والثالث عشان لاستخدام الحرارة لاستفيد منه من الهيت اللي فيه يعني نستفيد
to recove the heat

- The preferred method for controlling gaseous pollutants is with add-on control devices used to destroy or recover the pollutant. Filter Carbon عبارة عن packed bed

Combustion as purpose
Heat Content من fuel أعلى Control Equipment for Gaseous Emissions:

- *Thermal Incinerators* عند حرارات عالية
- *Catalytic Incinerators* عشان حرارات متوسطة — عشان يحسن الأكسدة ما تكون حرقها
- *Flares* نظام الشعلة ← جميع الغازات القابلة للاشتعال ويكون كميته الحجم للغازات غير كافية للاستفادة منه
- *Boilers and Process Heaters* → Heat
- *Carbon Adsorbers* → solid layer عبر فراغات ← إذا ما بدي أتعامل Thermally ← برضهم ممكن عشان استفيد من
- *Absorbers* packed bed و layer في فراغات pollutant وهو عليه الـ flow gas يمر
- *Condensers* الـ flow gas تطلع pollutant تتوزع لا packed bed Adsorber والسوائل

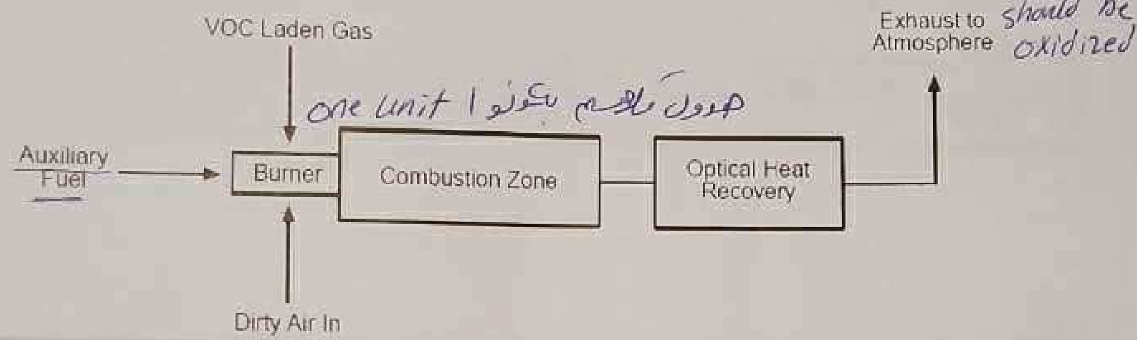
Adsorber بده solid matter شي للتقطيع | Absorber بده liquid material مثل الماء أو solvent اي نازل من الـ Top. active matter liquid.
active matter solid

Convert from gases To liquid.

Thermal Incinerator

نفس نظام Boiler

- Thermal incinerators are commonly used to destroy volatile organic compounds (VOCs). → aromatic gases. + organic gas
  معظمها بتكون قابلة للحرق
- In general, incineration involves the destruction of liquid, solid, or gaseous waste by a controlled burn at high temperatures. 99.9% volume reduction
  تم تدميره
- Incinerators are one of the most positive and proven methods for destroying VOC, with efficiencies up to 99.9% possible.
  اذا كان complete combustion

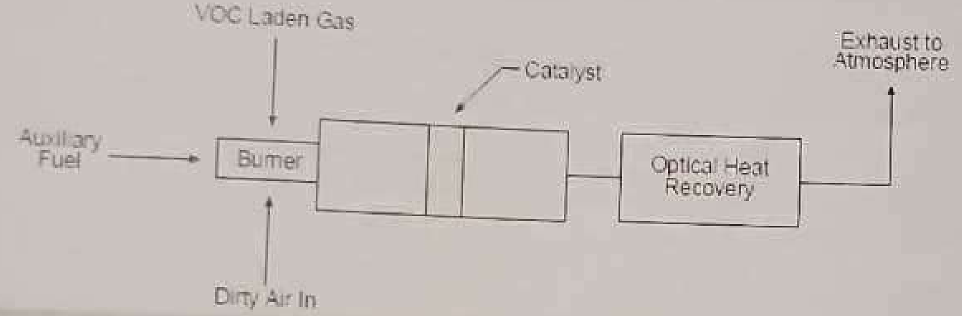


- **Applicable Pollutants:** Primarily volatile organic compounds (VOC). Some particulate matter (PM), commonly composed as soot (particles formed as a result of incomplete combustion of hydrocarbons (HC), coke, or carbon residue) will also be destroyed in various degrees.
  السخام
- VOC destruction efficiency depends upon design criteria (i.e., chamber temperature, residence time, inlet VOC concentration, compound type, and degree of mixing) (EPA, 1992).
  second or millisecond
  1000°C
  complete composition
  نوع المركب
- Most thermal units are designed to provide no more than 1 second of residence time to the waste gas with typical temperatures of 650° to 1100 °C (1200° to 2000 °F).
- Studies based on actual field test data, show that commercial incinerators should generally be run at 870°C (1600°F) with a nominal residence time of 0.75 seconds to ensure 98% destruction of non-halogenated organics (EPA, 1992).
  لا كلور ولا فلور ولا يود ولا بروم
  combustion
  اذا كان عنا halogenated organics
  persistent

There stable oxid — complete combustion — high Temperature — 2 shaped — NO_2, NO, CO_2, Co — fuel — oxide

Catalytic Incinerators

- Catalytic incinerators operate very similar to thermal incinerators. The primary difference is that the gas, after passing through the flame area, passes through a catalyst bed to destroy essentially any oxidizable compound in an air stream.
- The catalyst has the effect of increasing the oxidation reaction rate enabling conversion at lower reaction temperatures than in thermal incinerator units. Therefore, catalysts also allow for smaller incinerator size. Catalysts typically used for VOC incineration include platinum and palladium. Other formulations include metal oxides, which are used for gas streams containing chlorinated compounds EPA, 1998).



- The waste stream must be preheated to a temperature sufficiently high (usually from 300 to 900°F) to initiate the oxidation reactions.
- Catalyst Temperatures Required for Oxidizing 80% of Inlet VOC to CO_2, °F for Two Catalysts

Compound	Temperature, °F	
	CO_3O_4	Pt - Honeycomb
acrolein	382	294
n-butanol	413	440
n-propylamine	460	489
toluene	476 (1341)	373
n-butyric acid	517	451
1, 1, 1-trichloroethane	661	661
dimethyl sulfide	-	512

→ use for low recyclable value difficult to combust.

Flares

ذو نسبة المواد اللي تبعث كـ (VOCs) شعلة محروقة (غير مجدية / مستفيد منها)

6 شعلة مهم

جاب سؤال على plume

- Flaring is a VOC combustion control process in which the VOCs are piped to a remote, usually elevated, location and burned in an open flame in the open air using a specially designed burner tip, auxiliary fuel, and steam or air to promote mixing for nearly complete (>98%) VOC destruction.

موقع بعيد عن موقع وجود الشعلة

- Flares are typically used as a last resort to dispose of gases that are of little recyclable value or are not easily combustible.

كحل اخير

للتخلص من الغازات قليلة القيمة القابلة لاعادة التدوير او التي يصعب احتراقها

- Gases flared from refineries, petroleum production, and the chemical industry are composed largely of low molecular weight VOC and have high heating values.

مصافي التكرير

- As in all combustion processes, an adequate air supply and good mixing are required to complete combustion and minimize smoke. The various flare designs differ primarily by their ability to mix air with the combustibles.

تحتاج امداد كافي من الهواء

الاختلافات بأنو عندهم حسب كل واحدة وقدرتها على خلط الهواء بالمواد اللي بدها تحترق

بدخل كل هاد المستم على compartment اي اشي فيه عالق كـ liquid (moisture) او solid. بدخله على unit ثانية (حوض فيه ماء) ويكون زي نظام شفونة الارجيلة بعمل bubbling

عشان احافظ على flow rate ثابت و pressure ثابت وحتى انظف VOCs من اي اشي عالق فيه (نظام فلترة)

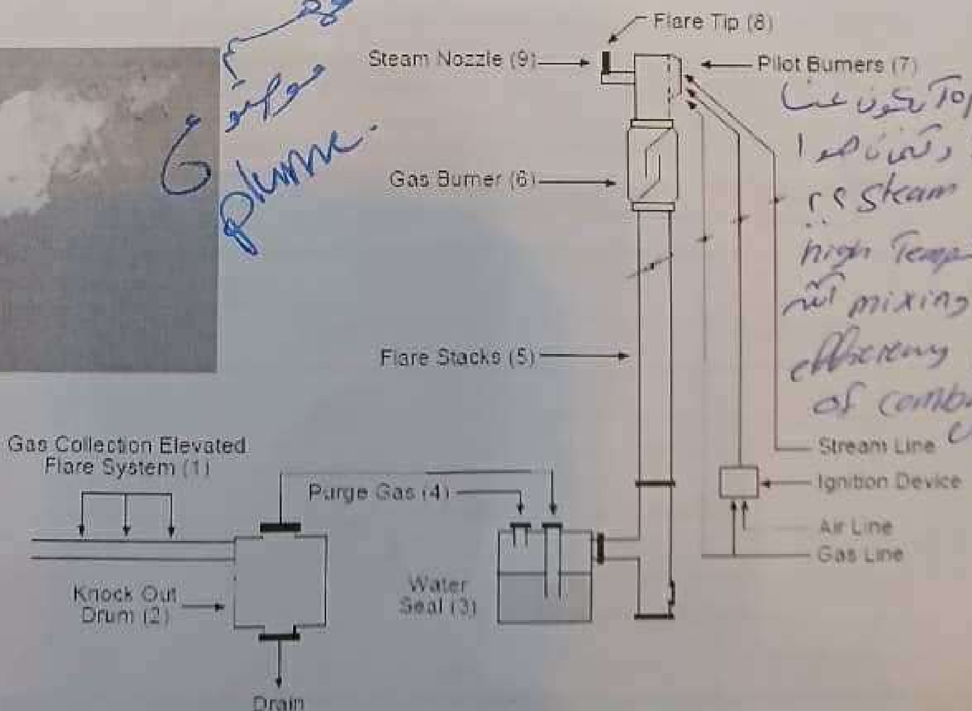
والغاز هاد عادة بكون fuel.

عشان الشعلة ما تنقطع بحطيش بحط بعض عشان هيك يكون مشوي

Steam-assisted Elevated Flare System

Bersion gas.

مهم موضوع 6 plume.



الهدف منه فلترة
- filtration
- To control pressure.
- fuel داخل

ادخال barsion gas عشان الشعلة تضل شغالة

VOCs بتكون قليلة ولازم ادخال barsion gas.

بال Top يكون عنا steam وتكون هوا ليش steam؟؟ اعطته high Temp وادخل mixing اكثر بالتالي efficiency of combustion very high

شعلة غير مساعدة

- The non-assisted flare consists of a flare tip without any auxiliary provision for enhancing the mixing of air into its flame. Its use is limited to gas streams that have low heat content and low carbon/hydrogen ratio that burn readily without producing smoke. These streams require less air for complete combustion have lower combustion temperatures.

تكون الشعلة غير المساعدة من طرف شعلة بدون اي تجهيزات اضافية لتعزيز خلط الهواء في لهبه يقتصر استخدامه على تيارات الغاز منخفضة الحرارة ونسبة الكربون إلى الهيدروجين والتي تحترق بسهولة دون اصدار الدخان . وتتطلب التيارات هواء اقل ~~الحترق~~ للاحتراق الكامل وتتميز بدرجات حرارة احتراق منخفضة

الهيدروجين السائل fuel للحرق

Boilers and Process Heaters

حديد مع مغنيسيا
السيد العبيد

- Boilers and process heaters are commonly used by production facilities to generate heat and power.

كلور مع بروم
العبيد السيد

المساهمة في عمليات التصنيع

- Although their primary purpose to contribute to plant operations, they can also be used quite effectively as a pollution control device by recycling the pollutant for fuel.

لاعادة تدوير الملوث كوقود

- However, the only pollutants that can be used for $\boxed{\text{fuel}}$ are those that do not affect the performance of the burner unit. For example, an exhaust stream can be used as supplementary fuel, but only if its fuel value is sufficient to maintain the combustion process. All volatile organic compounds (VOCs) have different heating values. If the $\boxed{\text{pollutant stream is large}}$ and the $\boxed{\text{heating value}}$ is high, the exhaust can be a primary source of fuel for the plant.

لكنه مشروط تكون قيمته الوقودية كافية لعملية الاحتراق الكامل.

يمكن ان يكون العادم مصدر رئيسي للوقود في المصنع .