Lecture 11: CVL100: 05 September 2017

Prof B. Alappat : Minor 2 (today onwards) (1-2 case studies)

TOPIC 1: TREATMENT OF DISTILLERY SPENT WASH

Topics covered:

- where does H_2O come from?
- H_2O supply to campus — ground H_2O / surface H_2O by river
- Hardness in H_2O
- 2 pipes that run in campus: water supply pipe above the sewage pipe (so that in case of leakage, no H_2O enters supply pipe) (sewage pipe requires slope)
- org matter (especially in sewage) —Anaerobic respiration→ $CH_4 + H_2S + CO$ (POISONOUS)

• Most imp pollutant in sewage water

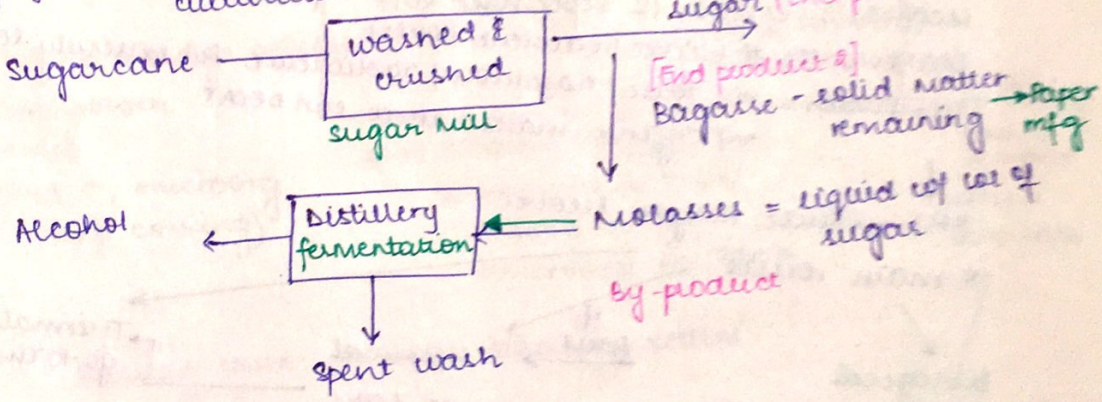
- Heavy metal pollutants in H_2O are As, Fluoride
- Most important pollutants in H_2O are microorganisms/pathogens - since they multiply very fast ∴ reason for the last unit to be disinfection.

We deal with wastewater here:- main pollutants are organic matter.

Generation of spent wash.

Sugar cane industry - Maharashtra, UP (most prominent)

cultivation - India, Cuba



Bagasse - fuel (also)

- paper (Most imp use -) because has lot of cellulose

dilution, pH adjustment, fermenter (for fermentation of molasses all sugar → alcohol)

Centrifuger → residual/extra yeast that is re-circulated

↓ Beer

↓ via stripping column → stillage/slop/vanasse (main source of spent wash)

cooling H_2O keeps on going thru' column giving aldenyde / 93% alcohol

2nd column: low temp

1st column: high temp

3rd column: alcohol comes from the top
2nd column: Aldehyde from the top
3rd column: alcohol cooled to give 93% alcohol

# not toxic, infectious, poisonous
Problem = org matter : BOD measure of org matter's presence
Domestic sewage : 315 mg/L
vs
org matter — 60K-80K mg/L
- sugar - fats/lipid
- carbohydrates
COD ~ 100K mg/L
BOD
biodegradable portion of org matter
eg kitchen waste.
pH and colour - issue.

COD
total org matter present.

1L of alcohol (industrial use) accompanied by 8L / 15L } spent wash

Interesting fact : how much pollution load spent wash has.
= high strength org matter w/ low pH and colour.

lecture 12 : CVL100 : - Missed
lecture 13 : CVL100 : 12 September 2017 (Next week : Tue + Wed)
Starts with # Waste Treatment Routes
Spentwash = not toxic / hazardous / radioactive but extremely loaded w/ organic matter that can DECAY

↓

3RS → Reuse, Recycle, Recover
5 main routes

Biological
more eco friendly, end products more acceptable to nature
= first CHOICE!
less expensive

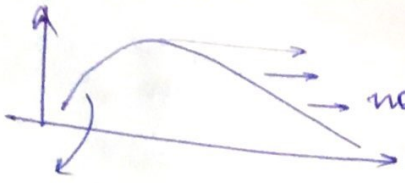
if fails → chemical
not easy → Thermal
go to this

aerobic | anaerobic

aerobic
gases released to atm
Biomass ↑↑
(cell growth/mass/bacterial)
$= CO_2$

anaerobic
$= CH_4 + CO_2 + H_2S$
(rotten eggs)

Reactor:-



Batch:- one batch processed / treated
best eg:- compost!
eg vermicomposting

sys = continuous
↳ keep on giving food & remove bacteria ctsly
= non-stop
log phase! eg: most plants

Bio reactors:

Bacteria → or attached eg: to media RBCs.
↓
suspended growth microorg suspended.
eg: ASP

(def^n's in slide)

Biggest sewage plant in Asia : Okhla

Very imp:-

waste water ctsly →→ reactor (++Biomass) use up O_2 Tank w/ aeration → Settling tank clarifier sedimentation tank → Treated effluent (missing in slide)

$\uparrow CO_2$ removed

↑ diffusers (eg used in aquariums) can be surface aerators
air / O_2

•> continuous reactor

org + O_2 → CO_2 + H_2O + Biomass GROWTH (to be removed) + turbulence

activated sludge process (ASP)
in log growth phase
(food ↑, microorg keep coming)

Sludge some removed → Settled biomass

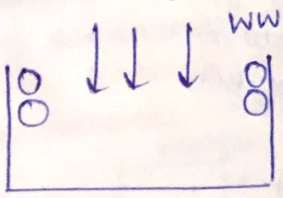
← treated sludge to maintain good supply of microorg in tank

Settling tank: so that bacteria settles

Settled biomass → dry (in drying tanks) → can be used for manure etc ← not very good but nevertheless.

eg of suspended growth systems.

Attached growth:- pebbles + growth 'attached' to pebbles.



Aerobic & Anaerobic egs.

Types → Cts or batch
Types → Aerobic vs Anaerobic
Types ↓ Suspended vs Attached

a) Bio / Chem :-
b) Bio → Aerobic vs An
c) Cts or batch
d) Sus or att

How to decide which reactor to choose?

Comparisons :- Aerobic

- no recovery of gas
- sludge produc° very high - mngment reqd
+ rel faster & smaller
+ no foul smell
- energy intensive

Anaerobic:

- smell issues (H_2S)

Which reactor to choose?

BOD → O_2 reqd by microorg to treat aerobic → biodegradable!
COD → represents org matter

$\frac{BOD}{COD}$ >= 0.5 : Biological treatment

BOD ∈ (40K, 60-70K)
COD ∈ (60K, 100K)

Step 1: Biological treatment
Step 2: BOD = huge :- Anaerobic

Reasons:
- generates lot of CH_4
- can you supply that much oxygen to meet BOD given O_2 solubility acc to Henry's Law?

DO = 14.5 mg/L max

so high strength WW = distillery spent wash.

Low strength WW: domestic WW / sewage

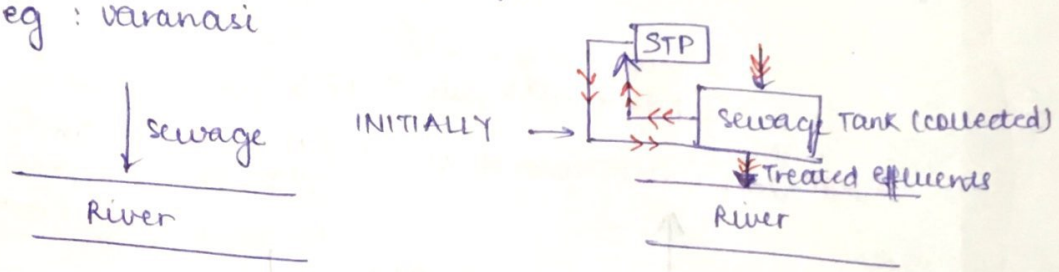
BOD ∈ (100, 350)] Biological
COD ∈ (300, 500)]

use Aerobic now :- a) can supply O_2 even w/ solubility
b) CH_4: not commercially useful
- can't use if you choose anaerobic + huge reactors.

↘ Low strength :- few 100s – 1000s : of BOD
STP: Sewage treatment plant (domestic)
ETP: Effluent treatment plant (industrial)

Aside: sewage = main pollutant of Ganga.
⇒ BOD + aero
→ used ASP till now
Recently proposed: to use anaerobic (UASB) reactors
- failed!
UASB became a breeding point for microorg
=∴ effluents o/p = dark & more hazardous.
{absence of oxygen}

eg: Varanasi



O_2 mixes due to turbulence
→ biodegradation!! - self purification
→ downstream, this prop degrades.

High strength ww 45K → +CH4 (fuel) 3K-4K
can't be disposed to river / surface body
Disposal std = 30 mg/L
can't be done for high strength.
↓
~ low strength w/w
colour rem.
↓
Aerobic septic colour
⇒ darker! output

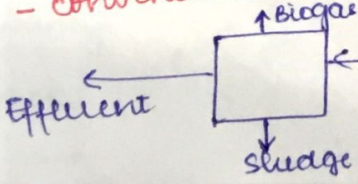
45K
↓
USK
can't be brought down in one go

Adsorption tower (activated c) ← for this - colour persists ← < 30 mg/L ← imparts

adsorbs BOD & colour (org matter)
~ charcoal
can't dilute for colours ∴ large volumes reqd.
↓
BOD ✓
no colour

Lecture 14: CVL100: 13 September 2017

People have tried nearly all types of anaerobic treatment methods. however all have failed.
Acceptable value ≃ 30 mg/L - which can't be achieved by only using an anaerobic reactor.
Types of Anaerobic reactors:
- conventional: ~ Biogas Plant (even within IIT)



• if conc spent wash
→ PROBLEM: all things/ processes happen within the same chamber,
∴ = very low.

4 steps :

macromolecules → monomers → acetyl causing/forming bacteria → if sulphur present, H_2S produced

] Broken down

] acid forming microorg perform

] acetogenèse

] methanogenèse

→ strong & systematic 4 broad processes.

→ very strong phase PH↓

→ very slow & delicate phase ↳ entire process suffers

① needs huge reactor
② pH = 4.54 :- slows down & gets stuck up.

⇒ soln: separate last phase & put 1 reactor for the first 3 = very fast + small reactor

2nd reactor
+ microorg also different

Diaphasic reactors

Diaphasic :- 2 + 2 (break-up)

Red reactor : small

fresh sludge picks heat → reactor → acid formation

$ ← (Heat exchange) ← wastes gained heat

Suspended growth

CH_4

Yellow reactor = big!

→ Digested sludge

Problem not solved.

UASB used in GAP
successful for high strength WW, failure otherwise.

Yellow :- grains of bacteria] Blanket of bacteria @ bottom.
- neither suspended nor attached } Blanket

Biomass themselves become blanket/ granules.

WW → Biogas → Effluent

trickles upwards thru' blanket] sludge blanket

Attached growth

○ : dark : pebbles → on which microorg grow

Pebbles = carriers on which bacteria grow

Problems w/ anaerobic : secondary trtment = aerobic
tertiary : colour

Why not thermal methods?

Thermal / Bio = cost ~ 2/3× atleast

less uncertainty ∵ do NOT rely on microorg

Thermal treatment :-

- Research on this prob
- Indian plan.

HHV :- Higher heat value - very high but has lot of H_2O.

→ dry it (-water) → same as coal.

Thick conc liquid :- can be burnt

raw spent wash :- can't be burnt → ∵ has H_2O

↓ concentrate

↓ dry

- Evaporation
- Volatilize
- Burns
- Final = Ash

Incineration :-

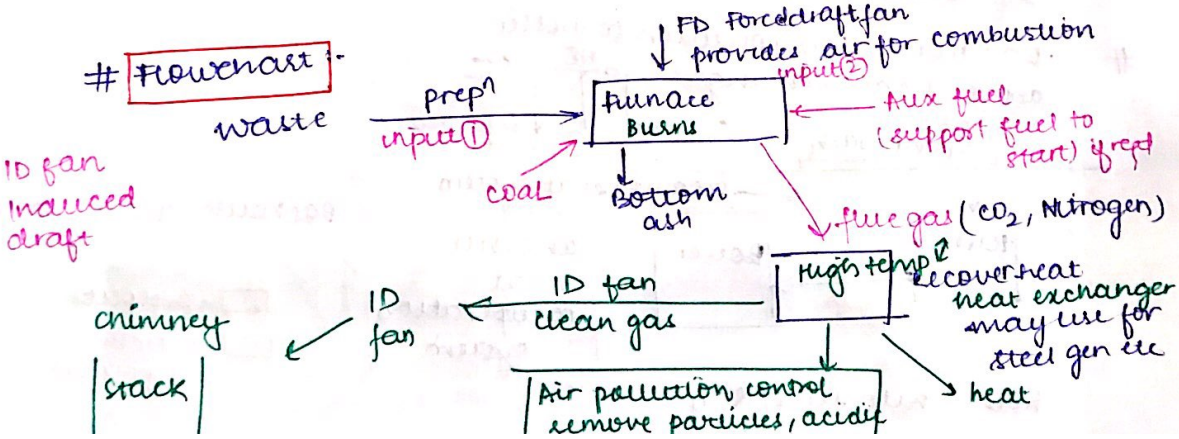
controlled burning to (sterile ash) w/o any pollution → water, air... etc

w/o volatile matter/ microorg

sys includes :-
furnace, heat recuperation, pollution controls

imp! last line = very imp! → waste destruction (most imp).
power gen = effect of this/ after..

Flowchart :-

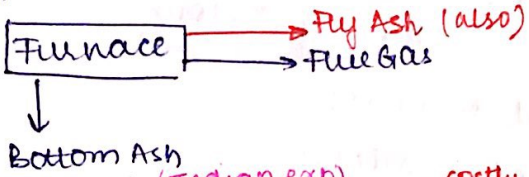


Lecture 15 : CVL100 : 19 September 2017

Anaerobic digesters cannot give treated effluent suitable for use. – Why thermal methods? – Since expensive, they were tried as last resort after trying biological methods.

Spent wash = LIQUID = 80–85% water (HHV slide)

Flow (process):-



Thermal Plant (Indian exp) • costly • anaerobic not tried @ that time

→ First plant: Lucknow – 1960s.

Theory:

Raw Spent wash = ~~80–90%~~ 10–13% solids → evaporate H_2O & make 60% solids = this can be burnt w/o any support fuel

can't be burnt ∵ has lot of H_2O

→ then 1970s – 80s anaerobic tried however unsuccessful.

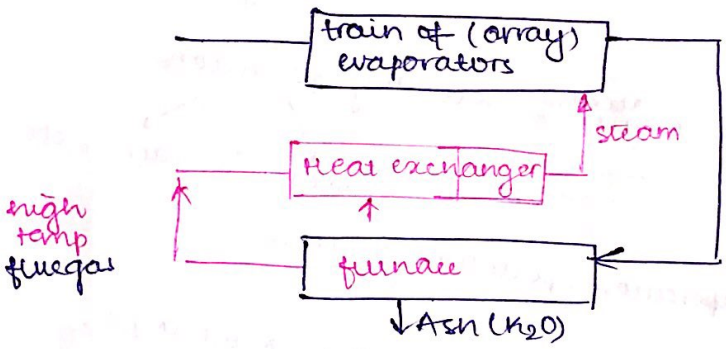
Destrotherm & Sprannihilator had opposing designs. rectified errors of Destrotherm.

1st Plant:

K_2O (last point) – very good fertilizer. = Ash!

picked up momentum later. ^ isolated expt.

Process :-



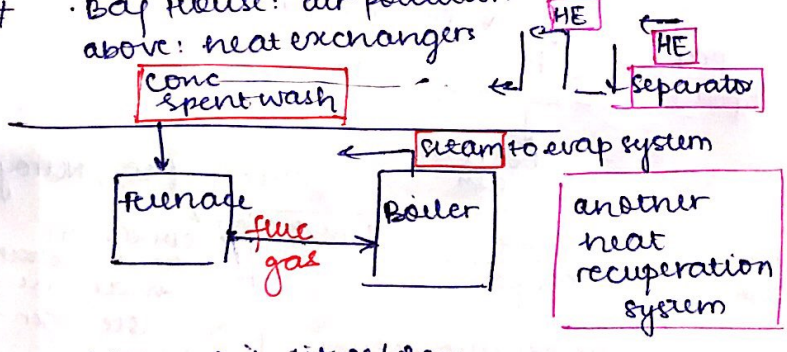
aux fuel ALWAYS to start plant

→ otherwise not to sustain

Excess steam = stored ∴ some steam for evaporating spent wash self sustainable

· Bag House: air pollution controller.

above: heat exchangers



Bag house | ID fan | Stack

□ : outputs

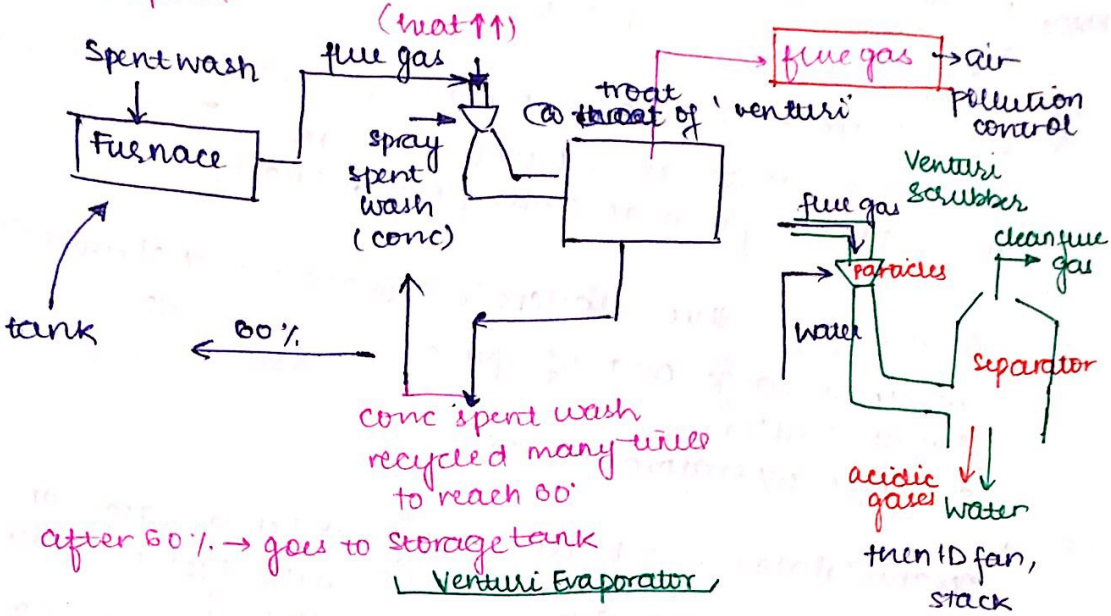
□ : blocks/systems

KLD : kilo litres/day

Sprannihilator :- simplified evaporating system.
steam/Boiler unit removed.
no excess heat gen - whatever heat gen ⟶ goes to burn spent wash.

★ idea is waste disposal

#



remove pollutants at stage flue gas

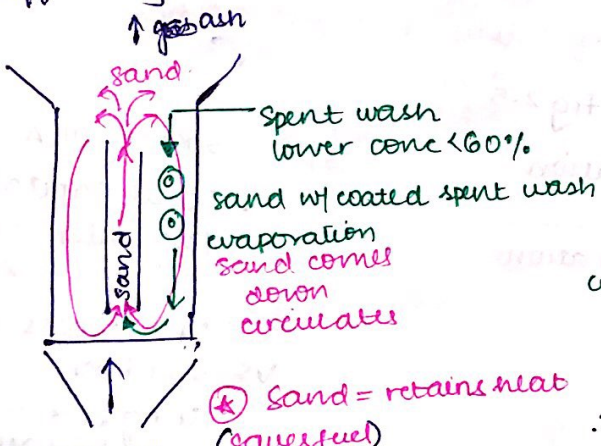
- particles
- acidic gases (SO_2)

velocities @ throat of venturi.

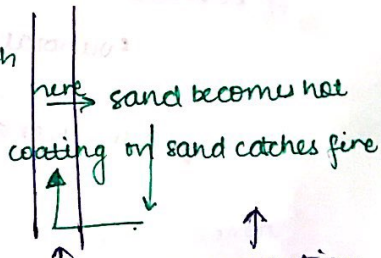
TRICKY waste:
Spent wash swells when you try to evaporate.
~5x volume. + STICKY

Why conc to 60% ?
some research/calc to figure out x% while burning also possible.
= RCFB : Recirculating Fluidized Bed Reactor

Theoretically $x < 60$ possible.
40% H_2O ⇒ evaporated before burning :- in same unit, which les efficiency. ∴ separate these processes & reduce x.



Sand gives heat for evaporation (down)
& gains heat when burning (up)



$x = 50 - 55\%$

Lecture 15: CVL100: 20 September 2017

1960s: management & disposal of spent wash was not s... a big issue. that's why did not pick up momentum

1980s: 3-4 units anaerobic digesters ⟶ Thermal Plants

DESIGN

(A) Destrotherm → Thermax. specializes in heat exchangers

Fuel gas :- that can be burnt CNG, LPG] IMPORTANT

Flue gas :- gas that comes from furnace.]

Steam prodn thru' boilers/evaporators = # of units ↑↑ ~10

occupies large amt of space + Excess steam

& very complex

& issues w/ evaporation design.

DESIGN

(B) Sprannihilator :- no boiler.. flue gas taken to evaporator "venturi type" evaporator.

no steam gen

Spent wash → 60% → Furnace → Fluegas → Evaporator

conc to 60%

60%

60% req = big for industry

Can it be decreased - even if to 55% or 50%?

Raw spent wash can never be burnt - 85% water.

∴ External evaporators required.

But x% (conc of spent wash reqd) can CHANGE.

Why 60%. :- 40% H_2O + 60% solid

evaporation + combustion → together in 1 chamber ↓ decreases

∴ separate chambers.

Was also in case of anaerobic digesters where separation of 1 slow & 3 fast steps.

Desrotherm Fig 2.5

Evaporation] (complex)

60% ↓ Incineration

SPRANNIHILATOR

- Total capital cost ↓ (no boiler, simple evaporator)
- no excess steam gen

Vs scrubber

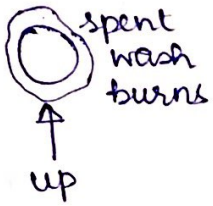
Fluegas + water (alkaline soln) → clean flue gas.

w/ evaporator.

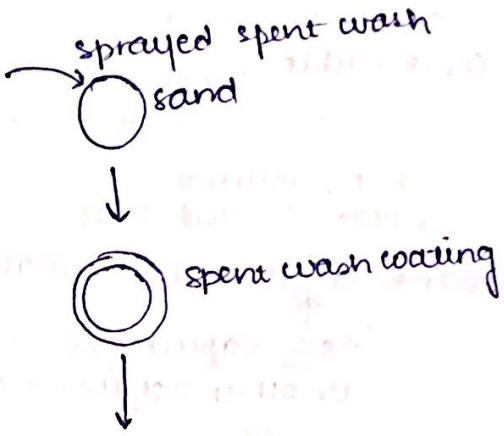
solution :- RCFB: (sand) → reservoir of heat
separate combustion & evaporation] sand gets heat gives heat

Question:

figure 1: Red = fire
1 sand grain



heat into sand
⇒ result/ o/p = hot sand
to receive another round of spray



central riser tube

we concentrate using heat. WHY NOT RO/membrane?

water purifiers = filters, membranes (nano etc), UV chambers
↳ v. fine particles → activated CO: filtration + adsorption
↳ microorg
↳ dissolved particles

water → activated CO
· bigger p: filtered
· adsorption
→ RO membrane

RO:- appy pressure
high conc → low conc.

1980s:- costly, came from abroad, & membranes clogged easily + req changing
lose capability
treat / replace

now membranes used (India also makes)

conc to 60% - furnace strength intermediate
50% also - strong

important:
ZLD = zero liquid discharge :- by distilleries - needs to be followed :- requires MEE
Thermax :- raise ash : o/p ≠ ZLD
or put RO membrane :- water out to be used in distillery & left solid for ZLD

cement kilns = co-incineration = co-combustion = co-processing

long kilns :- instead of combustible fuel, use spent wash
* & ash becomes part of cement

USA : landfill
Europe, Japan : Burn co-incineration : municipal solid waste = MSW + biomedical waste = BMW (10-20% of can be replaced)

∴ MSW + BMW = co-incineration → abroad ✓ now India
80% 20%
Combustible ≠100%
low heat content

RDF : refused
~~RDF~~ : derived fuel

Cement (limestone) - alkaline
↑
+SO_2 capture especially or other acidic gases
∴ can be neutralized in kiln.

spent wash —Δ/burnt→ . SO_2
. particulate

2 ways to achieve ZLD : burn/cement kiln ≠ (b) follow bio route
(a) • conc thru' RO/MEE → ash used/produced = cost ↓es

(b) : already installed

effluent polished sludge → concentration

spent wash —Aerobic + activated CO filter→ effluent = H_2O (used in distillery) + sludge

[Anaer, aer, activated CO]

Biomass microorg

Distilleries should NOT discharge ANYTHING now.

clean H_2O useful

taken for conc/burnt off/ compost can be used for combustion

file:
disposal & drinking H_2O trends :- ocean, river.

DOMESTIC SEWAGE

CVLIDO: 25 September 2017

Document sent: Desirable &
- Total Hardness
- Fluorides
- STP and ETP (WWTP for industries) (domestic WW treatment)

⇒ COD and BOD both correspond to org matter.
- TOTAL org
- Biodegradable

⇒ TDS = Total Dissolved solids.

⇒ like STP, ETP → there exists CETP = common Effluent Treatment Plant.

STP (ONLY sewage) = Sewage Treatment Plant
- Who manages? = DJB
- Nearest STP: Okhla
- largest in Asia

ETP (industry) = Effluent Treatment Plant
- not every industry can afford
- govt makes common ETP all

Observation: All CETPs in Delhi able to meet ALL other standards, except TDS!

CETP (1 CETP = 200–300 industries)
⇒ lot of BOD, COD, heavy metals, Dissolved solids

TDS ≤ 2100 mg/L

Treatment
- Primary
- secondary
- Tertiary → does NOT work @ all

] works well for CETP

- screening, settling, gravity = NO reaction (not read for spent wash)
- Aerobic/Anaerobic reacn. BIOLOGICAL (spent wash)
- Only some specific pollutants (eg colour removal eg Adsorption)

Secondary: Alum + lime :- flocculation, coagulation AND/OR Biological reacn.
WORK WELL ⇒ conventional UNITS!

Tertiary: multimedia filter + activated C → reason: has a capacity. needs to be replaced ∵ after few months ⇐ clogged/ action not observed for activated C

dissolved SOLIDS!

sizes of particles

multimedia filterbeds

neither of them of use unless replaced.

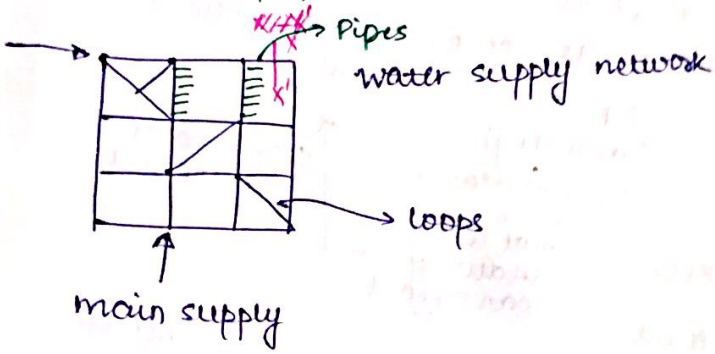
Age of plant ≃ ≤ 10 years.
Max duration of replacement - once in 1 year
ideal/optimal :- once in 6 months.

STP:-
∵ of SC rulings & NGT rulings, many STPs already.
But no connection b/w sewage & STP
(60-70% capacity - can't utilise ∵ doesn't receive other)

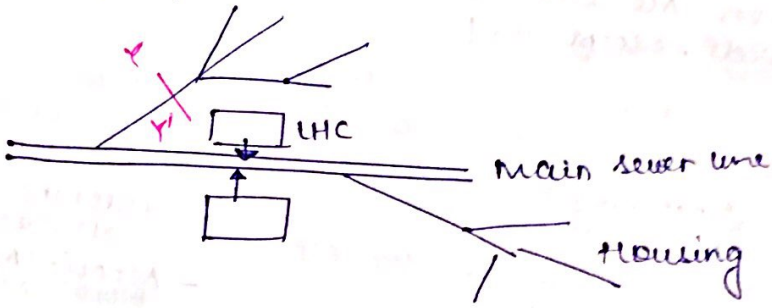
ONLY 70% sewage reaches STP, rest 30% WHERE?
eg Najafgarh drain

No sewerage connection

Design of plants → overdesigned capacity!



Sewerage system:



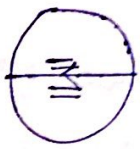
Q. List main difference b/w sewage pipes & water supply pipes?

water supply
Pressure pipes
dia ↓
no slope reqd

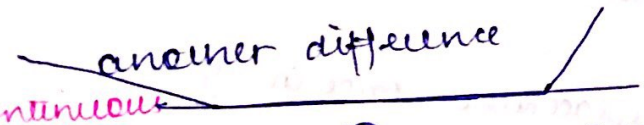
cross-section

closed networks to ensure pressure

sewerage
gravity flow
huge dia ≈ 3m
slope reqd



branches of tree - not closed
can have dead ends

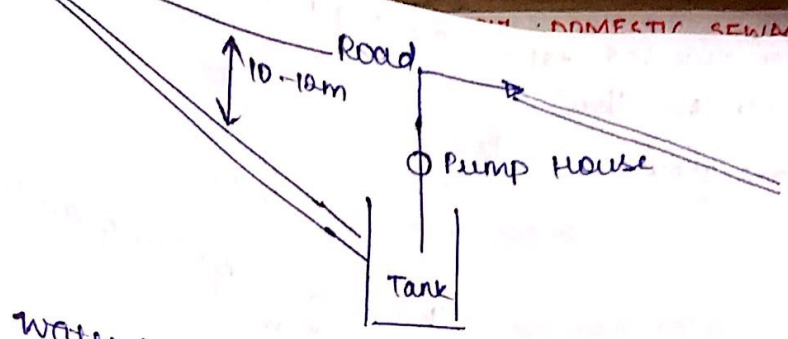


not continuous

2 supply pumping ⇐ in IITD, as here ∵ overhead tank!

water supply carry H_2O w/ pressure

Below supply pipe
a) leakage
b) slope



water supply does not req manholes, trunch/ trench

req manholes junc^n & changes, req trench vents reqd. to get rid of gases (H_2S = toxic CH_4 - explosive & carcinogenic)

lecture 18: CVL400 : 27 september 2017

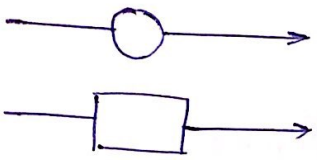
Domestic WW (sewage)

CH_4 = 5-15% of air :- explosive & carcinogenic → spark can cause fire. (CH_4, H_2S) done before

Methane Air exposing Mixture

manual cleaning - toxic

Flowsheet for STP (imp)



for operations

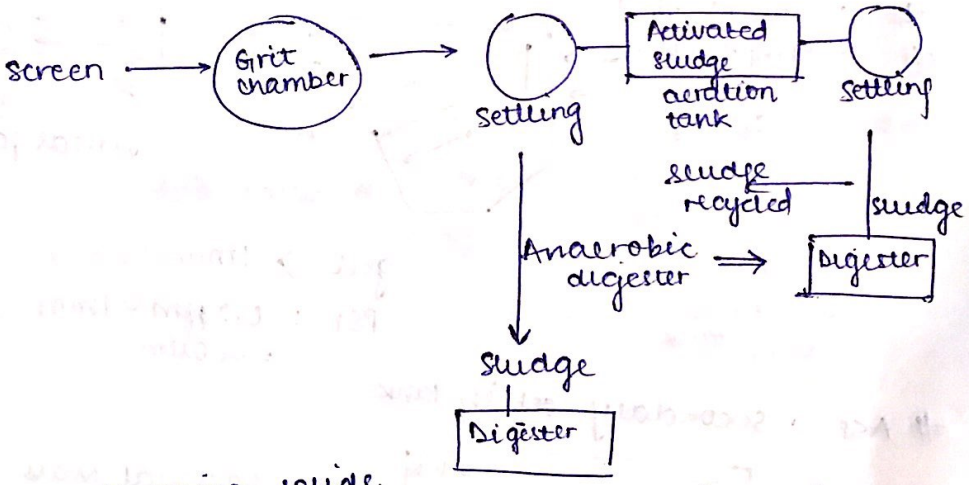
for processes

eg: primary treatment no reaction - gravity settling, screening, sedimentation, filtration.

reaction - chem, thermal, biological, nuclear

ANY CHANGE!

mistakes in flowsheet wrt notation



Primary

Screens: floating solids.

Grit chamber: chamber for setting of big particles (dia 5 mm / 1 mm)

output ⇒ 3-4 mm dia big particles (coarse)

primary setting tank: dia = sand like fine + org matter can settle ≃ 0.5/1/2 mm

Activated sludge: dissolved org matter = surface aerators or air diffusers

BOD, COD removed

org matter digested for energy & growth → to Bacteria & take C/H for this.

→ Body mass grow
→ Energy

Dissolved org matter (C)
⟶ CO_2 (g) ↑
⟶ Fixed as body mass of bacteria (s)
(has higher specific gravity than H_2O)

Bacteria = 1.05
H_2O (4°C) = 1

removed via settling tank (FINAL) (sec treatment)
clarifier
∵ in secondary stage.

small amt of sludge reqd for bacteria re-growth.

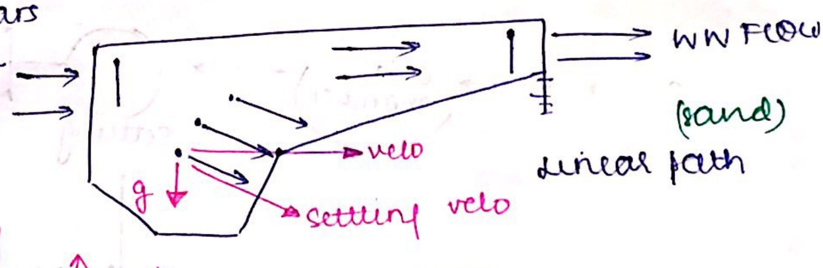
(log growth phase) cts ∵ food keeps on coming.

This is now High strength WW (⇒ anaerobic digesters)
resultant sludge = manure.

→ WW — — — — — → Treated effluent → [chlorination] → water supply
- KILL PATHOGENS
↓
sludge = Bacteria

Target pollutants:
Big floating matter
Coarse sand like
Fine sand like
Dissolved org matter
+ Pathogens (chlorination)

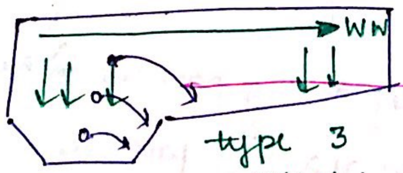
screening - bars
settling tank :-



discrete settling
linear path
GRIT CHAMBER
settling tank

grit > 1mm
PST : 0.2 mm - 1mm
= 200 μm

ASP : secondary settling tank



bacteria mass settles as a zone

here = bacterial mass settles

type 3 settling : zone settling

type 2 = coagulation + alum : flocculant settling

AGP.

Bacteria grows on stone

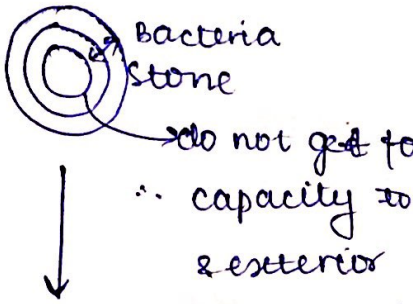
Trickling filter : water sprayed. Prev : suspended grown.

sludge not recycled

- some WW recycled : a) no clogging (trickling) b)

stone not taken out, but treated effluent. How come

O/P of clarifier = sludge?



do not get food & O_2 = inner layers. ⟹ die

∴ capacity to stick to stone ↓es & becomes 0

& exterior mass comes out

= SLOUGHING = breaking of bacterial layer

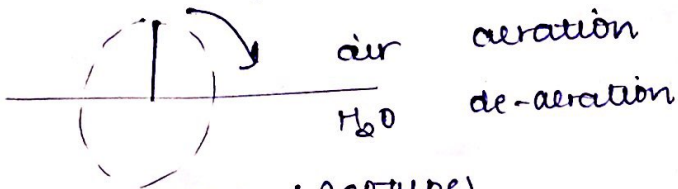
& then grows again.

Rotating Bio contactor :

- Disks rotate & bacteria grows on disk

when out in air: take O_2.

{during rotation}



SBR : Batch (ASP type)

Batch ds : aerated, settling, decantation, filling
(react) (not removed @ that time - after days)

all in same tank | in sequence

→ supernatant + H_2O filled taken out

Overall 4-5 tanks

3-4 batches (processes · diff @ same time)

makes 1 reactor CTS!