CIVE 3331 

Wastewater Treatment

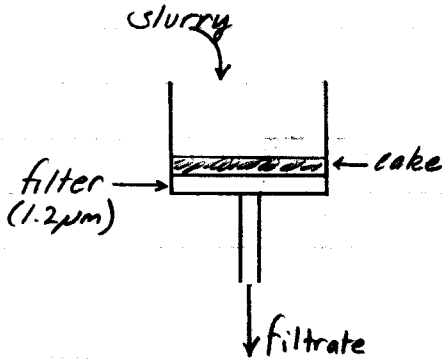
Goal is to remove pathogens, nutrients, BOD & solids before returning water to hydrologic cycle.

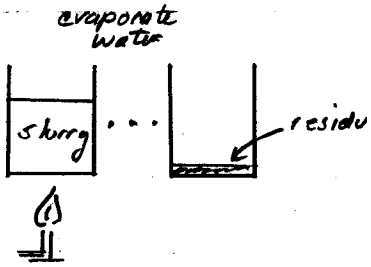
Methods are similar to drinking water treatment, but nutrient & BOD removal adds a step not normally used in drinking water

Solids

TS = TDS + TSS

TSS; filter known volume of slurry (ww) through 1.2μm filter. Mass cake/volume is TSS concentration




mass residue/volume is TS concentration

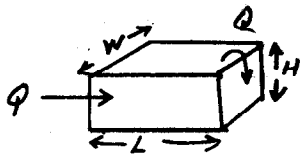
Primary, Secondary, Tertiary (advanced oxidization)

Primary treatment

- goal is to remove solids.
- screening (removes floatables > 2cm)
- grit removal (rapid settling – removes > 10mm)
- clarifier (settling – removes > 50μm)

grit removal

Settling –




hydraulic retention time

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

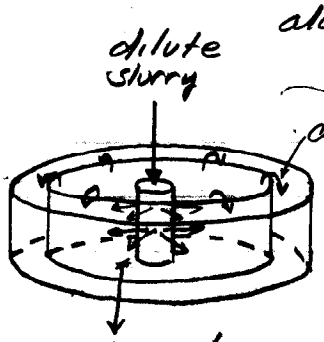
$V_c = \frac{H}{HRT} = \frac{HQ}{V}$ determines size of grit removed

if $V_p > V_c$ particle removed

hydrocyclones –

mechanical device (similar to cyclone on pg 387) that works with liquids – physical size of cyclone determines particle size rejected – ∴ to remove small particles need small (array) cyclone.

Clarifiers - similar to other settling concepts. Typically circular. Consist of 3 cylinders - concentric. Inner cylinder distributes flow. Middle cylinder is clarifier — clear water overflows along circumference. Sludge exits bottom (near inner cylinder). Outer cylinder is wet well (tail water) collector to collect clear water overflow to send to disinfection.




Typical loading rates
$SL_{rate} = 15\text{-}30\ m^3/d/m^2$
$WL_{rate} = 180\text{-}260\ m^3/d/m$
$HRT$ = at least 1 hr

Important parameters
depth - $H$
diameter - $d$
weir length - $\pi d$
surface area - $\pi d^2/4 = A$

volume $\frac{\pi d^2 H}{4} = \forall$
$HRT = \frac{\forall}{Q}$
$SL_{rate} = \frac{\forall}{A}$
$WL_{rate} = \frac{Q}{\pi d}$

Example

30,000 people, $0.5\ m^3/capita/d$ Circular clarifier to have $HRT = 2.5$ hr, $SL_{rate} = 20\ m^3/d/m^2$ Size clarifier. Estimate weir load. $Q = 15{,}000\ m^3/d$ Estimate critical particle size.

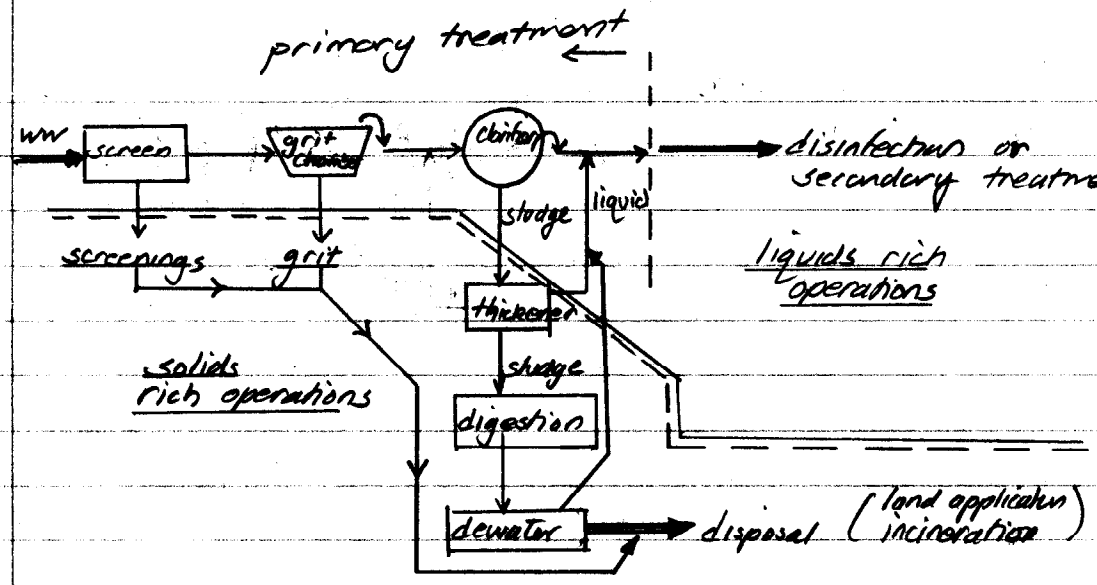
$SL_{rate} = \frac{\pi d^2/4}{Q} = 20\ m^3/d/m^2$ solve for $d$ $d \approx 31m$.

$HRT = \frac{\pi d^2 H}{4Q} = 2.5\ hr = \frac{750 m^2 H}{4(15{,}000)\frac{24\ hr}{d}} = 2.5\ hr$ solve for $H$ $H \approx 2.1m$

Weir load $\frac{15{,}000\ m^3/d}{\pi(31m)} = 154\ m^3/d/m$ (lower than typical)

$V_c \approx \frac{2.1m}{2.5hr} = 0.84 m/hr \cdot \frac{1hr}{60min} = 0.014 \frac{m}{min} \frac{1}{60} = 2.33 \cdot 10^{-4} m/sec$

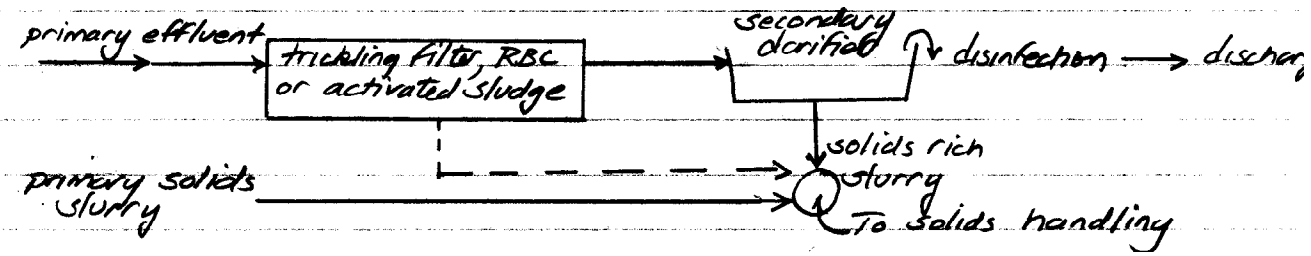
Assume particles are spheres, $\rho_p = 2\ g/ml$,
Check @ Stokes law $V_p = 2.3 \cdot 10^{-4}$ for $d_p = 0.06\ mm = 6.0 \cdot 10^{-5} m = \underbrace{60 \mu m}$
$Re = 0.015 < 1$ $\therefore$ Stokes law OK. silt/clay




primary treatment typically can achieve (on liquids side)
35% reduction in BOD
60% reduction in TSS
Still enough nutrients for eutrophication, BOD to cause fish kill. If disinfection is improper, lots of pathogens

secondary treatment
goal is BOD reduction by microbiological "oxidization" and additional solids removal.
- oxidation process
  - trickling filters
  - biological contactors
  - activated sludge process

common concept is aerobic decomposition of waste—
organic matter + $O_2$ $\xrightarrow{\text{microbes}}$ $CO_2 + H_2O$ + New Cells + By-Products ($NO_3$, $PO_4$, $SO_4$...
methods differ in how $O_2$ is supplied and how "fast" process is. In USA activated sludge is most common process for large volume plants.



solids handling – remove remaining liquid, inactivate pathogens reduce solids volume, sell dried solids. Municipal sludge (Class A dried) is agriculturally useful. Industrial solids are usually burned or landfilled for business-liability reasons.

removing the liquid
clarifiers, hydrocyclones, filtration, belt press, centrifuges.
typically a flocculant is added and then a clarifier is used to produce a "thick" slurry (8-10% solids).

inactivation of pathogens
thick slurry is "digested" anaerobically in a digester or oxidization pond. Extract remaining "energy" from waste by anaerobic decomposition.
organic matter $\xrightarrow{\text{microbes}}$ $CO_2 + H_2O$ + New cells + By Products ($H_2S$, $NH_3$, $CH_4$ ...)
↑ fuel
valuable nutrient (for soil, not water)
After digestion, slurry is further dewatered by filtration, filter press, centrifuge, drying beds
incineration (energy recovery)

oxidation ponds – easy to operate. Use a lot of real estate. may still need clarifier & disinfection for overflow. Flood & storm washout is a serious concern.

Nutrient removal
nitrification / denitrification
secondary effluent is still high in TKN (mostly as ammonia) and orthophosphate ($PO_4$).
Nitrification
$NH_4^+ + 2O_2 \xrightarrow{\text{microbes}} NO_3^- + 2H^+ + H_2O$ (requires days to reach this point)
$2NO_3^- + \text{organic} \xrightarrow[\text{No-air}]{\text{microbes}} N_2\uparrow + CO_2 + H_2O$ (anaerobic – sometimes requires addition of carbon source)

Phosphorous removal

Typically by flocculation & clarification or filtration

$Al_2(SO_4)_3 + 2PO_4^{3-} \rightarrow 2\,AlPO_4\downarrow + 3SO_4^{2-}$

Tertiary treatment

Includes nitrification/denitrification and any processes used to treat specific toxic compounds in waste stream.

Often avoided by pre-treatment (industrial pre-treatment) where upstream processes are modified so toxics never enter wastewater.