9. PRETREATMENT AND PRIMARY TREATMENT

9.1 EQUALIZATION

It is used to minimize or control fluctuations in wastewater characteristics in order to provide optimum conditions for subsequent treatment

❖ The purpose of equalization for industrial wastewater treatment facilities is:

- For **dampening of organic fluctuations** to avoid shock loading on biological wastewater treatment system.

- To **minimize flow surges** to physical-chemical treatment systems.

- To **control pH or to minimize** the chemical requirements for neutralization.

- To **provide continuous feed** to biological systems over periods when the manufacturing plant is not operating.

- To **controlled discharge** of industrial waste to municipal sewers.

- To prevent high concentrations of toxic materials from entering the biological treatment plant.

Mixing is normally provided to ensure adequate equalization and to prevent settleable solids from depositing in the basin.

- Also oxidation of reduced compounds from wastewater or reduction of BOD by stripping may be achieved by mixing and aeration.

Methods used for mixing:

- Distribution of inlet flow and baffling.

- Turbine mixing/ mechanical aeration.

- Diffused air aeration.

Most commonly submerged or surface aerators with power level of approx. 0.003 to 0.004 kW/ m^3 are used. In diffused air mixing air requirement of 3.74 m^3/ m^3 is used.

Equalization basin may be designed as

- Variable volume: to provide constant effluent flow (used in industries).

- Constant volume: variable effluent flow (used in municipal discharge)

Equalization basin may be designed on line or off line.

- Equalization basin may be designed to equalize flow, concentration or both.

- For flow equalization cumulative flow is plotted verses time over equalization period i.e. 24 hr. The maximum volume with respect to constant discharge line is the equalization volume required.
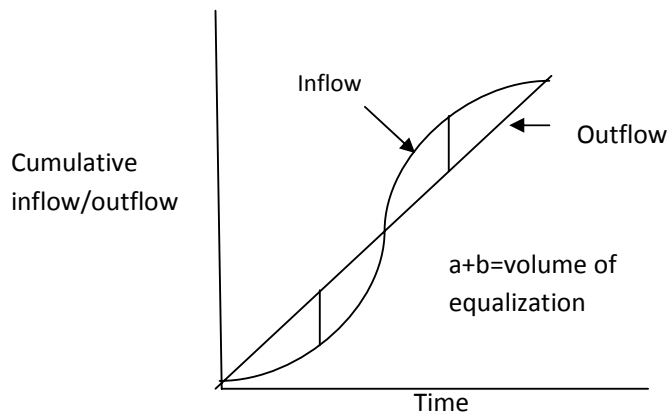
Example:

Design equalization basin for a constant outflow from the basin.

Table:

Given date		Cum.	Pumping	Cumulative	Cumulative
Time	Lit/min	m^3	Cumulative m^3	Samples	Deficit
8	50	3.0	8.05		5.05
9	92	8.5	16.11		7.61
10	230	22.3	24.16		1.86
11	310	40.9	32.22	8.68	
12	270	57.1	40.27	16.83	

1	140	65.5	48.32	17.18	**Capacity**
2	90	70.9	56.38	14.52	**45.44+7.61**
3	110	77.5	64.43	13.07	**=53.05 m³**
4	80	82.3	72.49	9.81	Provide 20% extra capacity to provide minimum volume in tank to protect mechanical aerators, if used or to provide some dilution without allowing tank to go empty.
5	150	91.3	80.54	10.76	
6	230	105.1	88.60	16.5	
7	305	123.4	96.65	26.75	
8	380	146.2	104.7	41.5	Provide power @ 0.004 kW/m³
9	200	158.2	112.76	45.44	
10	80	163.0	120.81	42.19	
11	60	166.6	128.87	37.33	
12	70	170.8	136.92	33.88	
1	55	174.1	144.98	29.12	
2	40	176.5	153.03	23.47	
3	70	180.7	161.08	19.62	
4	75	185.2	169.14	16.06	
5	45	187.9	177.19	10.71	
6	55	191.2	185.25	5.95	
7	35	193.3	193.3	0	

Total quantity of wastewater to be treated is 193.3 m³/d

Pumping rate =193.3/24=8.05

Example: *Design an equalization basin for a constant out flow from the basin for further biological treatment of industrial wastewater.*

Time	Volume of waste water	Cum m³	Pumping cumulative	Cumulative surplus	Cum deficit
8-11	22.3	22.3	24.1625		1.86
11-14	43.2	65.5	48.325	17.175	
14-17	16.8	82.3	72.49	9.81	

17-20	41.1	123.4	96.65	26,75
20-23	39.6	163	120.8125	42.187
23-2	11.1	174.1	144.897	29.125
2-5	11.1	185.2	169.137	16.063
5-8	8.1	193.3	193.3	0

Avg. pumping 193.3/24 =8.054 m³/h.

in three hours = 24.1625 m³.

Therefore, balancing capacity for basin=42.1875+1.86=44.04

Provide 20% extra for min volume for conc. dampening & protecting mixture=

Total volume= 53.0 m³

Provide mixer of 0.004kW/ m³

Power requirement = 53.2× 4 W = 212.8 ≈ 250 W

Design of equalization basin for concentration dampening

The equalization basin may be designed to keep the maximum concentration of BOD or COD under control for wastewater.

For **near-constant wastewater flow** and normal statistical distribution of wastewater composite analyses the required equalization retention time

$$t = \frac{\Delta t (Si^2)}{2(Se^2)}$$

Where, Δt = time interval over which samples where composited, hr

   t = equalization detention time, h

   Si^2 = variance of the influent wastewater con. (SD²).

   Se^2 = variance of the effluent concentration at a specified probability (e.g. 99%)

When completely mixed basin is used for treatment, (e.g. ASP, aerated lagoon) this volume can be considered as part of equalization volume. E.g. completely mix aeration tank dt = 8 hr, and retention time for equalization is 16 hr, then equalization basin only needs to have a retention time of 8 hr.

Refer example from Eckenfelder

Equalizing both volume and strength

For the wastewater when both the flow and strength vary randomly the equalization requirements can be worked out from material balance (Patterson & Menez).

$$CiQT + CoV = C_2QT + C_2V$$

Where, Ci = Concentration entering the equalization basin over sampling interval T.

T= Sampling interval, i.e. 1hr.

Q = Avg. flow rate over sampling interval.

C_0 = Conc. in the equalization basin at start of sampling interval.

V = volume of equalization basin

C_2 = Concentration leaving the equalization basin at end of sampling interval.

It is assumed that the effluent concentration is constant during time interval.

Hence, effluent conc. after each time interval

$$C_2 = \frac{Ci\,T + Co\,V/Q}{T + V/Q}$$

Refer example 3.3 Eckenfelder

Neutralization

Where wastewater is acidic or alkaline, neutralization is required prior to discharge to receiving waters or prior to chemical or biological treatment.

Types of processes

(a) Mixing acidic and alkaline waste streams: This requires sufficient equalization capacity to effect neutralization.

(b) Acid waste neutralization through limestone beds:

- Can be down flow or up flow.
- Max hydraulic load for down flow system 2.5 m^3/m^2.hr to ensure sufficient retention time.
- H_2SO_4 conc. should be limited to 0.6% to avoid coating of limestone with nonreactive $CaSO_4$ and excessive CO_2 evaluation, which limits neutralization.
- Effective for wastewater where relative acidity is fairly constant.
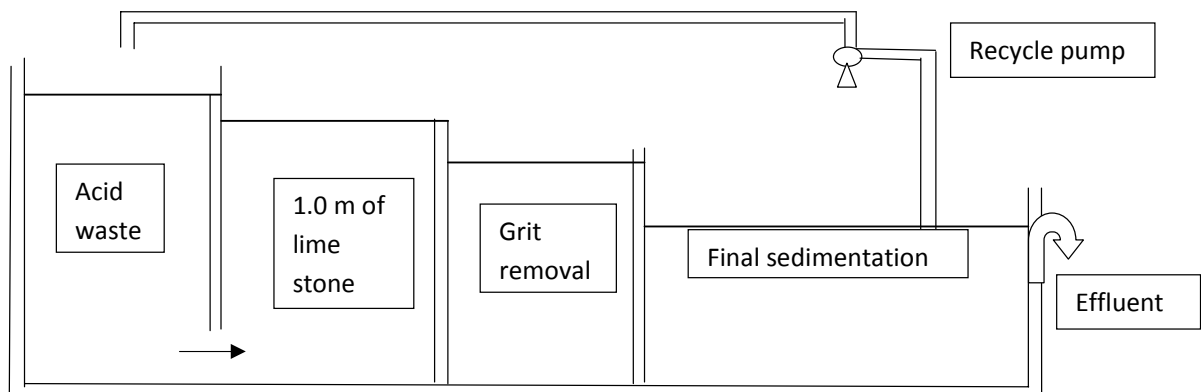- Not very effective where flow and conc. varies with time.

Fig 9.2: Simplified flow diagram of limestone neutralization

(C) Mixing acid waste with lime slurries

- Depends on the type of lime used.
- Magnesium fraction of lime is most reactive below pH of 4.2.
- The reactions can be accelerated by heat and agitation.
- Reaction is complete within 5 to 10 min.

- Quicklime (CaO) is used as 8 to 15 % lime slurry

- Neutralization can also be accomplished by NaOH, Na_2CO_3, and NH_4OH.

- Lime slurries pose practical difficulties due to variation in quality of lime received.

(D) <u>Alkaline waste:</u>

- Strong acids are used. H_2SO_4 is preferred for economy. HCl can also be used.

- Reactions are instantaneous.

- Flue gases containing 14% CO_2 can be used.

    Either gases are bubbled or spray tower with countercurrent can be used.

System for neutralization:

- Usually stepwise addition is preferred for all above for better results with two or even three stages.

- Batch treatment is used up to flows of 380 m^3/d.

- Air is used for mixing (min. rate 0.3 to 0.9 m^3/m^2.min at depth of 2.7m).

- When mechanical mixers are used, 0.04 to 0.08 kW/ m^3 is required power.

<u>Control of process</u>

 The pH control is troublesome for the following reasons:

1. For strong acid-strong base **neutralization is highly nonlinear**, particularly when close to neutral.

2. The influent pH change can be fast per pH unit per min.

3. Variation in wastewater incoming flow

4. <u>Small amount of reagent</u> must be thoroughly mixed with larger liquid volume in short time.

5. Hence for biological treatment bicarbonate addition is preferred to maintain neutral pH.
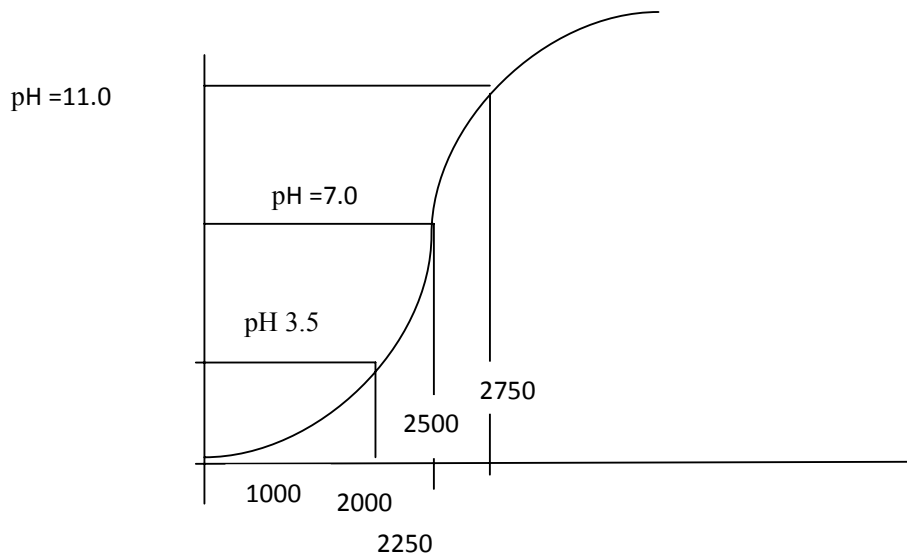
Fig: Lime waste titration curve for strong acid

Hence, stepwise addition is advantageous:

e.g. Tank 1- pH 3 to 4

Tank 2-pH 5 to 6

Tank 3- further correction to desired pH (neutral).

Example: A highly acidic wastewater with flow 0.38 m³/min is to be neutralized to pH of 7.0 using lime. The titration curve for the wastewater is shown in above fig, from which a two stage control neutralization system will be used with a total lime consumption of 2250 mg/L. The first stage requires 2000 mg/L and the second stage 250 mg/l. Design the tanks.

Solution:

Avg. lime dosage in first stage= $0.38 \text{ m}^3/\text{min} \times 2000 \text{ mg/l} \times 10^{-3} \times 60 \times 24 = 1094.4$ kg/d

Avg. lime dosage in second stage=$0.38 \times 250 \times 10^{-3} \times 60 \times 24 = 136.8$ kg/d

With this dosage each basin should be designed with detention time of 5 min.

Volume = $0.38 \text{ m}^3/\text{min} \times 5 = 1.9 \text{ m}^3$

Use two tanks with height 1.25 m and diameter 1.40 m.

To ensure proper mixing the power required is 0.04 to 0.08 kW/m³ say 0.05 kW/m³

Provide 100 W mixer in each reaction tank.

- Provide one or two standard wall baffles, 180° apart, 1/12 to 1/20 of the width of the tank diameter.

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Example: **Design of lime stone bed system for acid neutralization**: *A wastewater flow 0.38 m^3/min with 0.1N H_2SO_4 requires neutralization to a pH of 7.0 using a limestone bed. Assume limestone is 60% reactive. Hydraulic loadings to get pH of 7.0 with depth of lime stone bed are estimated from laboratory studies and results are furnished in the table below.*

Depth, m	0.152	0.305	0.61	0.915	1.22
Hydraulic loading m^3/m^2.hr	1.709	7.326	34.595	58.608	65.12

➢ Design neutralization system specifying.

a) Most economical bed depth of limestone (Bed will be economical which carries more flow per unit volume of bed).

b) Weight of acid per day to be neutralized

c) Limestone requirements on an annual basis.

Solution:

a) Most economical bed depth:

The flow rate per unit volume of bed

$$\frac{Q}{V} = \frac{Hydraulic\ loading}{depth}$$

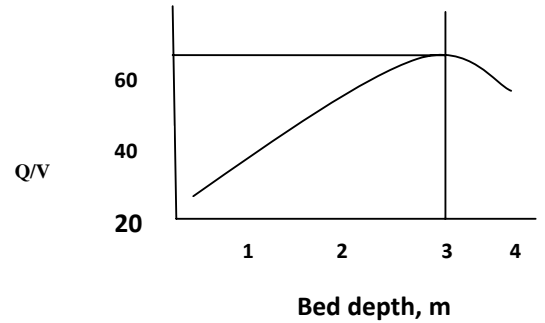| Depth, m	0.152	0.305	0.61	0.915	1.22
Q/V, m^3/m^3.hr	11.207	24.02	56.71	64.05	53.37

By plotting the flow rate per unit limestone volume against the limestone bed depth, the most economical bed depth is ≈ 0.91m.

This depth will give max flow per unit volume

b) Weight of acid per day to be neutralized.

$$0.38 \text{ m}^3/\text{min} \times 4900 \text{ mg H}_2\text{SO}_4/\text{L} \times 1440 \text{ min/day} \times 10^{-3} \frac{\text{kg/m}^3}{\text{mg/l}}$$

$$= 2681 \frac{\text{kg}}{\text{day}} \text{ of H}_2\text{SO}_4$$

Bed depth, m

c) Annual limestone requirements

$$= 2681 \times 365 \frac{\text{d}}{\text{yr}} \times \frac{1}{0.6} \times 50\text{g} \frac{\text{CaCO3}}{49\text{g H2SO4}}$$

$$= 1664400 \frac{\text{kg}}{\text{yr}} \text{ of lime.}$$

$\text{H}_2\text{SO}_4 = 2+32+64 = 98$

Equivalent wt = 49 g/l

$0.1 \text{ N H}_2\text{SO}_4 = 49 \times 0.1 \times 1000 = 4900 \text{ mg H}_2\text{SO}_4/\text{L}$
Similarly,
$\text{CaCO}_3 = 40+12+48 = 100$
Equivalent wt. = 50

Example: Find most economical bed depth for flow of 0.25 m³/min having 0.1 N H₂SO₄

Depth, m	0.15	0.3	0.6	0.9	1.2
Hydraulic loading m³/m²	1.7	7.3	34.6	58.6	65.1

Solution: most economical bed depth

$$\frac{Q}{V} = \frac{Hydraulic\ loading}{depth} \quad \text{to have max flow percent volumes.}$$

Depth, m	0.15	0.3	0.6	0.9	1.2
Hydraulic loading m³/m²	11.33	24.33	57.67	65.11	54.25

a) Economical bed depth ≈ 0.9m

b) Wt. of acid per day neutralized

$$= 0.25 \ m^3/min \times 4900mg \ H_2SO_4/l \times 1440 \ min/d \times 10^{-3}$$

$$= 1764 \ kg/day$$

c) Annual lime stone requirement

$$= 1764 \times 365 \times 1/0.6 \times 50g \ CaCO_3/49g \ H_2SO_4$$

$$= 10, 95,000 \ kg/yr.$$

Oil Separation

Plate separator

- Free oil is floated to the surface of a tank and skimmed off.

- Plate separators including parallel plates and corrugated plates (CPS) that can be used for separating oil droplets larger than 0.006 cm.

- This is capable to produce effluent less than 10 mg/L free non emulsified oil, when the influent oil content is less than 1%.

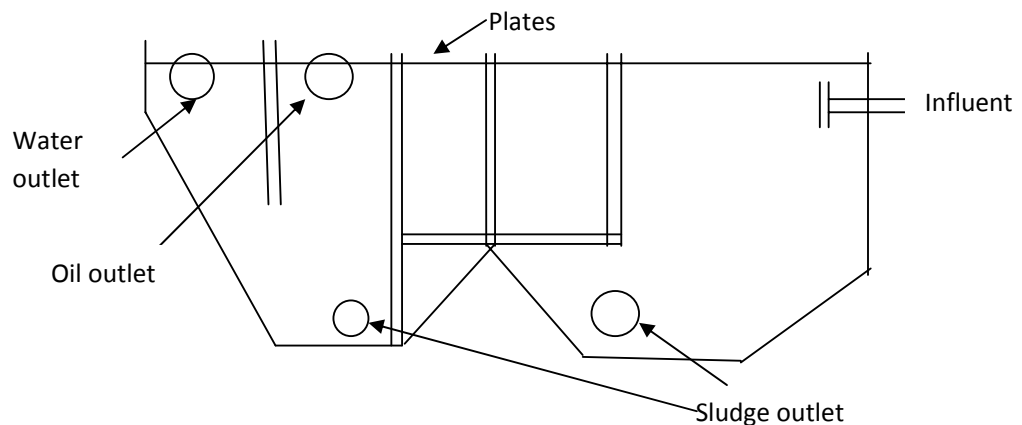- Efficiency reduces under high oil loading (due to shear of oil droplets and re-entrainment).

Fig: Cross

flow plate separation

- Plat angle 45° and 10 mm spacing is used.

- A hydraulic loading of 0.5 m^3/h. m^2 of actual plate area is used

- A safely factor of 50% is normally used in design

- Emulsified oily materials requires treatment, to break the emulsion to make free oily material.

- Emulsions can be broken by detergents, alum or iron salts, acidification, or emulsion-breaking polymers.

- Disadvantage of alum or iron salt is large sludge generation.

Flotation

- Used for the removal of suspended solids, oil & grease.

- Wastewater or clarified effluent is pressurized to 345 to 483 kPa or 3.4 to 4.8 atm pressure, in presence of sufficient air to approach saturation.

- When this pressurized air-liquid mixture is released to atmospheric pressure in floatation unit, fine air bubbles are released from solution.

- The sludge flocs, SS, oil globules are floated by these minute air bubbles.

- The air-solids mixture rises to the surface, where it is skimmed off.

- The clarified liquid is removed from the bottom of flotation unit.

- Effluent may be recycled to yield a superior effluent quality.
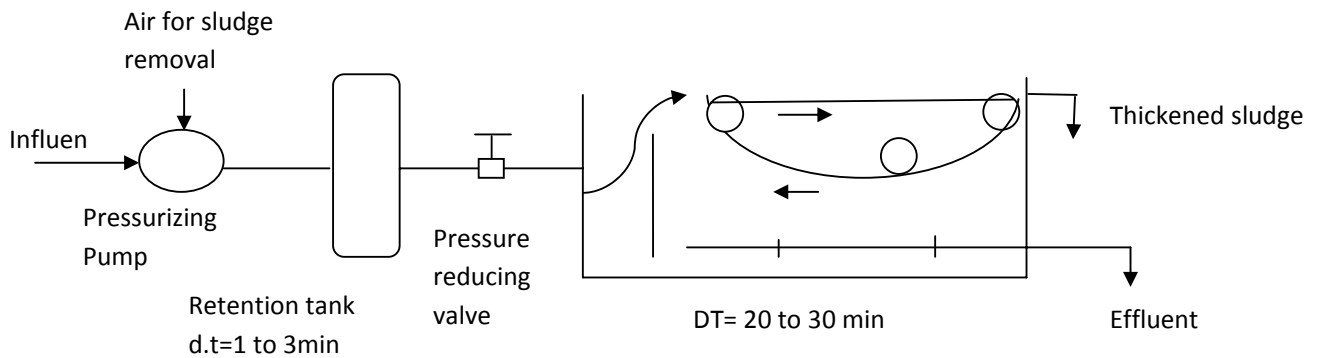
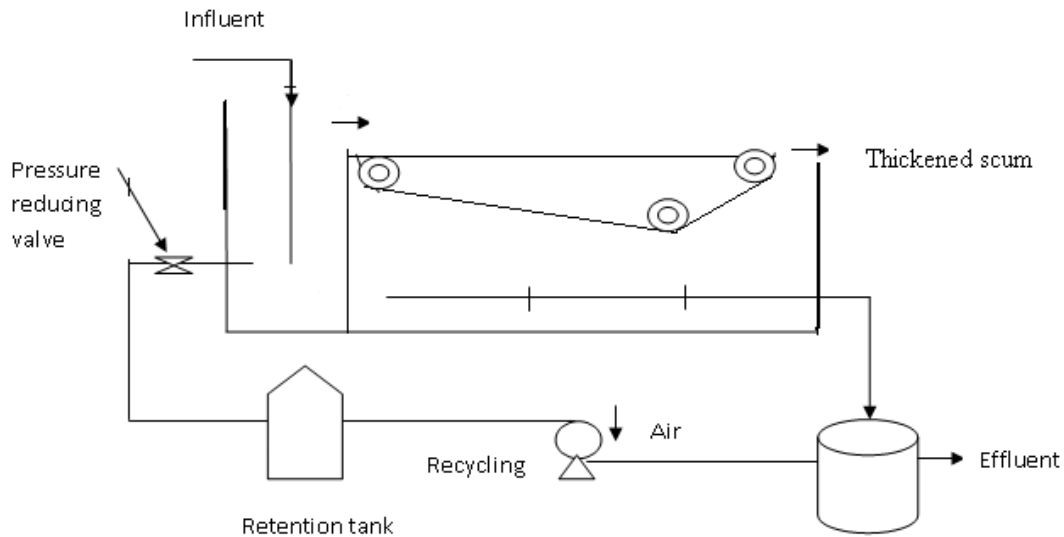**Flotation system without recirculation, bubble size=30 to 100 µm**

Fig: Flotation system with recirculation

Air solubility and Release

- Saturation of air in water is directly proportional to pressure and inversely proportional to temperature (Henry's Laws).

- In case of wastewater the relationship between pressure and solubility the slope of the curve varies as compared to unpolluted water depending on constituents of wastewater.

- The quantity of air that will be theoretically released from solution when pressure is reduced to 1 atm can be calculated as

$$S = Sa\frac{P}{Pa} - Sa$$

Where,

S = air released at atm pressure per volume at 100% saturation (cm^3/L)

Sa = air saturation at atm pressure, cm^3/L

P = absolute pressure

Pa = atm. pressure.

The actual quantity of air released will depend upon turbulent mixing conditions at the point of pressure reduction and on degree of saturation obtained in pressurizing system.

Solubility is less in wastewater than that in water; a correction may have to be applied. Retention tank will generally yield 85 to 90% saturation.

$$S = Sa\frac{f.P}{Pa} - 1$$

Where, f= fraction of saturation in retention tank.

- Presence of sufficient air bubbles to float all solids is important.

- Insufficient quantity of air will results only in partial floatation of solids and excessive air will result is no improvement.

- The performance can be related to an air /solids (A/s) ratio, i.e. mass of air released per mass of solids (SS) in the influent wastewater

$$\frac{A}{S} = \frac{Sa}{Si}\frac{R}{Q}\left[\frac{f.P}{Pa} - 1\right]$$

Where Q = wastewater flow; R= Pressurized recycle

Si= influent oil and /or SS, A = Air released, S = Solids (SS) in wastewater

The shape of the curve will vary with nature of the solids in the feed.
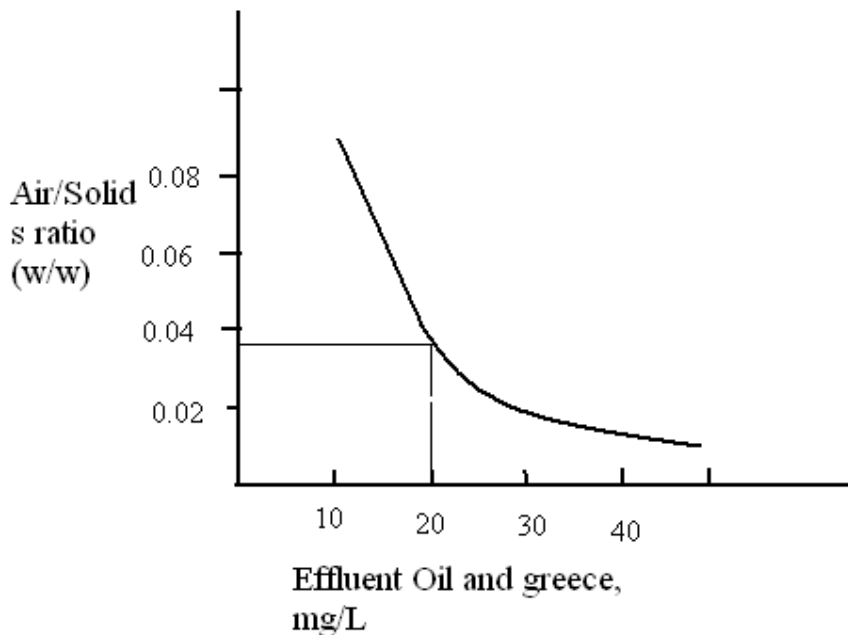
- Bubbles released after pressurization (1.36 to 3.4 atm) range in the size from 30 to 100 μm.

- The rise velocity of solid-air mixture varies from 2.56 to 12.7 cm/min (following stocks law).

- Rise velocity will increase with increase in air/solids ratio.

- Variables for floatation design are pressure, recycle ratio, feed solids conc. and retention period.

- With increase in detention period, effluent SS decreases.

- For clarification, detention period of 20 to 30 min is adequate.

- When thickening is desired, longer retention time is necessary.

Principal component of flotation system are:

➢ Pressurizing pump.

➢ Air injection facilities.

➢ Retention tank, (1 to 3 min d.t.)

➢ Back pressure regulating device,

➢ Flotation unit.

It is possible to estimate the flotation characteristics of waste by the use of a laboratory flotation cell (Fig. 3.39 Eckenfelder).

Dissolved Air Flotation design

Example:

A wastewater of 150 gal/ min (0.57 m³/min) at a temperature of 103°F (39.4 °C) contain significant quantities of nonemulsified oil and nonsettleable suspended solids. The concentration of oil is 120 mg/l. It is intended to reduce the oil to less than 20 mg/l using DAF. Laboratory studies showed the following results:

Alum dose = 50 mg/l

Pressure = 60 lb/in² (4.1 relative atm) = 515 kPa absolute

Sludge production = $0.64 \dfrac{mg}{mg \text{ of alum}}$

Sludge = 3% solids by wt.

Calculate:

    (a) The recycle rate

    (b) Surface area of the flotation unit.

    (c) Sludge quantities generated.

For effluent oil and grease of 20 mg/l, the A/S = 0.03 lb air/lb solids applied and required surface loading rate = 2.6 gal/min.ft^2 (0.11 m^3/min. m^2). At 103°F (39.4°C) the weight solubility of air is 18.6 mg/L. The value of f is assumed to be 0.85.
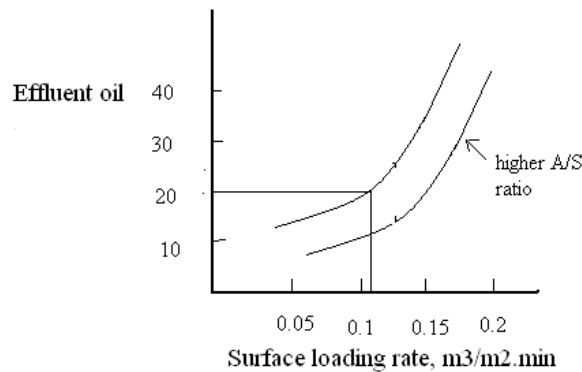
Solution:

    a) The recycle rate is

$$R = \frac{\left(\frac{A}{S}\right)Q.Si}{Sa(\frac{f.P}{Pa}-1)}$$

$$=\frac{0.03\times570\times120}{18.6[0.85\times\frac{515}{101.3}-1]}$$

$$= 33.11\frac{L}{min}$$

    b) The hydraulic loading for oil removal (from figure) is 0.11 m^3/m^2.min for an effluent oil and grease of 20 mg/l.

The required surface area is

$$A=\frac{Q+R}{loading}=\frac{570+33.11}{0.11}$$
$$=61ft^2 \ (5.7 \ m^2)$$

    c) Sludge quantities generated

Oil sludge=

$(120-20)$ mg/l $\times 0.57\frac{cu.m}{min} \times 1440\frac{min}{d} \times 10^{-3}$

$=82.08\frac{kg}{d}$

Alum sludge=

$0.64 \times 50\frac{mg}{l}$ alum $\times 0.57\frac{m3}{min} \times 1440\frac{min}{d} \times 10^{-3}$

$=0.64\times50\times0.57\frac{m^3}{min}\times1440\times10^{-3}) = 26$ kg/d

Total sludge = 82.08 + 26 = 108 $\frac{kg}{d}$

Total sludge volume=

108 kg of total sludge with con of 30 kg/m^3

Total volume of sludge produced per day $= \dfrac{108\frac{kg}{d}}{30\frac{kg}{m^3}}$ $=3.6 \frac{m^3}{d} = 2.5 \frac{L}{min}$

Questions

1. How the volume of equalization basin will be calculated for nearly constant wastewater flow and to keep COD conc of waste water under control?
2. Find out the lime requirement for lime slurry Neutralization of industrial wastewater which contain 0.1 N H_2SO_4 and flow rate of 600 m^3/day. Design two stage equalization with 90% lime addition in the first stage.

3. Design DAF for flow of 0.5 m^3/min, oil conc. of 140 mg/l, surface loading rate = 0.1 m^3/m^2.min

Solution:

a) $R = \dfrac{\left(\frac{A}{S}\right)Q.Si}{Sa(\frac{f.p}{Pa}-1)}$

$= \dfrac{0.03\times0.5\times140}{18.6(0.85\times\frac{515}{101.3}-1)}$

$= \dfrac{0.150}{61.77}$

$=0.034$ m^3/min

b) Required surface area= $\dfrac{Q+R}{\text{surface loading}} = \dfrac{0.5+0.034}{0.1} = 5.34\text{m}^2$

c) Sludge quantities

$$\text{Oil sludge= (140-20) }\times 0.5 \times 1440 \times 10^{-3} = 86.4\ \frac{\text{kg}}{\text{d}}$$

$$\text{Alum sludge= }0.64 \times 0.50 \times 50 \times 1440 \times 10^{-3} = 23.04\ \frac{\text{kg}}{\text{d}}$$

$$\text{Total=109.44}\ \frac{\text{kg}}{\text{d}}$$

$$\text{Hence with 3\% solids total=}\ \frac{109.44\frac{\text{kg}}{\text{d}}}{30\frac{\text{kg}}{\text{m}^3}} = 3.64\ \frac{\text{m}^3}{\text{day}}$$

4. **Example:** *Find the quantity of sludge generated in DAF for removal of oil from 80 mg/l to 20 mg/l alum added for emulsion breading at the rate of 40 mg/l, which generate 0.64 mg of sludge /mg of alum. What will be the volume of the sludge /mg of alum? What will be the volume of the sludge if it has 4% solids concentration? Flow of wastewater is $600\frac{m^3}{d}$.*

Solution:

Oil sludge= $60 \times 10^{-3} \times 600 = 36\ \dfrac{\text{kg}}{\text{d}}$

Alum sludge= $40 \times 10^{-3} \times 0.64 \times 600 = 15.35\ \dfrac{\text{kg}}{\text{d}}$

Total sludge= $36+15.36 = 51.36\dfrac{\text{kg}}{\text{d}}$

Volume of sludge 4%, i.e. $40\ \dfrac{\text{kg}}{\text{m}^3} = 51.36/40 = 1.284\ \dfrac{\text{m}^3}{\text{d}}$