Aerobic Suspended Growth Treatment Processes

Main types

1) activated sludge
2) aerated lagoon
3) sequencing batch reactor
4) aerobic digestion
5) nitrification (later)

1) Activated sludge

Process

The activated sludge process consists of an aeration basin and a secondary clarifier. The waste flows into the aeration basin, is retained for a specific detention time and then flows into the secondary clarifier.

<u>Aeration basin</u>

The aeration basin is designed for the removal and transformation of soluble and particulate pollutants. The contents are known as mixed liquor.

The bacterial component known as mixed liquor suspended solids (MLSS) (or volatile solids). The microorganisms clump together in a floc. The soluble and suspended particles are removed by both adsorption onto the gel-like matrix of the floc and by metabolism by microorganisms. The microorganisms are recycled, so the population is enriched on the waste and degrades its substrates and grows very rapidly.

<u>Secondary clarifier</u>

The secondary clarifier is designed as a quiescent environment to allow sludge solids to separate by flocculation and gravity sedimentation.

The water goes over the top through a weir and is called the secondary effluent. The solids are removed from the bottom and is called return activated sludge.

The efficiency of the activated sludge process is effected by factors affecting biological oxidation and solids separation. When biological oxidation is affected, certain of the waste components may not be degraded. When solids separation is affected, the secondary effluent is not clear and organisms may wash out of the process leading eventually to complete failure.

Microbiology

The process is called activated sludge because some care is put into maintaining an active mass of microorganisms to degrade the waste. This is usually achieved through recycle of some of the sludge after it is settled from the wastewater. This sludge represents an acclimated population that are currently capable of degrading the waste in the water. We have already discussed most of the microbiology involved in this system. As a review we can list the genera of organisms involved in the process:

You will recall that there are several species of aerobes capable of degrading many compounds and that *Zooglea* is very important for maintaining a viable floc. The following figure (next page) is an example of the different numbers of microorganisms with time (or sludge age) in an activated sludge process.

I would like to spend a while on some of the problem microorganisms that are often found associated with process upsets and in most cases the type of organism is indicative of the problem with the process. This lecture is from the book "Manual of Causes and Control of Activated Sludge Bulking and Foaming". by David Jenkins, Michael G. Richard and Glen T. Daigger.

Solids separation problems

There are several problems associated with solids separation. These problems are named in terms of the effect observed, so are general in nature. (Table) (Figure)

Dispersed growth
viscous bulking (non-filamentous bulking) (slime formation)
Pinpoint floc
filamentous bulking
blanket rising
foaming/scum

There are several organisms involved in sludge bulking or foaming (Table). The type of organism is often of use as a diagnostic technique to help determine the cause of the problem (table).

<u>Control and Problem Solving</u>

BULKING - When filamentous organisms proliferate and upset settling of sludge. Usually caused by a nutritional imbalance in the activated sludge reactor.

<u>control</u>
addition of Chlorine and H_2O_2 to RAS
alteration of DO level in reactor
increase F/M ratio.
add N and P
mixing RAS with incoming water in anoxic tank (selector)

SBR and Plug flow have better settling characteristics and are less susceptible to this.

RISING SLUDGE - caused by denitrification, N_2 formed is trapped by sludge, making it float. Can also often see bubbles associated with floating sludge.

control

1 increasing RAS withdrawal rate from the clarifier to reduce the detention time in the clarifier
2. decreasing flow into the clarifier
3. increase speed of the sludge collecting system
4. increase sludge wasting rate

these all decrease the amount of time spent under possible anaerobic conditions, therefore the possibility of denitrification occurring.

NOCARDIA FOAM - caused by growth of *Nocardia* usually due to low F/M in aeration tanks, high MLSS due to insufficient sludge wasting, operation in the sludge reaeration mode.

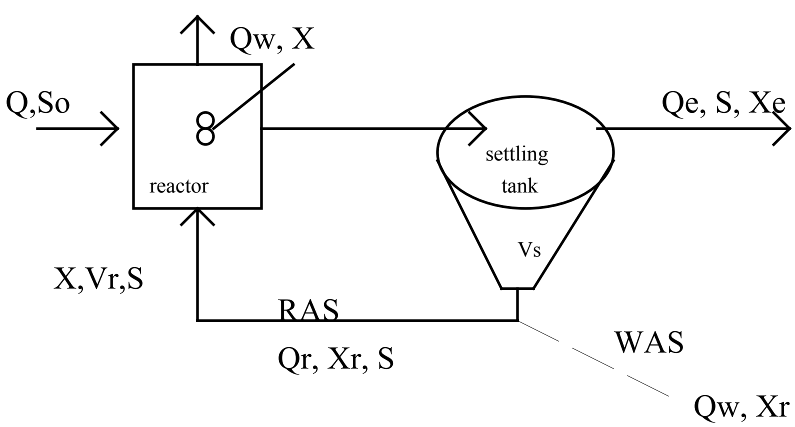
control

1. reducing sludge age (most common)
2. reduce air flow rate
3. adding a selector compartment (see above)
4. injecting mutant bacterial additive
5. chlorinating the RAS
6. chlorinate the foam directly
7. reduce pH of mixed liquor.

Expect a wait of at least 3 mean cell retention times (MCRT's) for the sludge to return to a settleable state. In some cases even longer times may be required.

Flow Scheme

Many different flow schemes can exist. Depending on various design and space considerations the simplest flows are diagrammed below.



New terms

Q_w = waste flow
Qe = effluent flow = (Q-Q_w)
Q_r = sludge return flow
X_r = microorganism concentration in return sludge flow line
X_e = microorganism concentration in effluent
RAS = return activated sludge
WAS = waste activated sludge

The mixing and aeration are usually accomplished in one step. The pressure of the air input also mixes the system. The cells settle out of the MLSS in the settling tank where some of them are wasted (biological sludge) and some are recycled back into the reactor to maintain a good population of cells in the reactor.

In order to develop design or control parameters for this type of process we have to develop a model that provides the information we need to do the tasks.

Model

In order to model this type of systems we have to make some assumptions:

1. complete mixing is achieved
2. no microorganisms in the influent
3. waste stabilization occurs only in the reactor (conservative)
4. volume used to calculate mean cell residence time includes only the volume of the reactor.

The model for hydraulic detention time for the whole system is

$$\theta_s = \frac{V_T}{Q} = \frac{V_r + V_s}{Q}$$

while that for the reactor is

$$\theta = \frac{V_r}{Q}$$

The mean cell residence time can be given by the equations below for

1. waste from the reactor

$$\theta_c = \frac{V_r X}{Q_w X + Q_e X_e}$$

2. Waste from the return line

$$\theta_c = \frac{V_r X}{Q'_w X_r + Q_e X_e}$$

The overall mass balance is

$$\frac{dX}{dT}V_r = QX_0 - \left[Q_w X + Q_e X_e\right] + V_r\left(r'_q\right)$$

This depends on where you waste if you waste from recycle the $Q_w X_r$ is used instead of $Q_w X$.

After some manipulation as discussed in the text we end up with a substrate utilization rate.

$$r_{su} = -\frac{Q}{V_r}\left(S_0 - S\right) = -\frac{S_0 - S}{\theta}$$

where $(S_0\text{-}S)$ = mass concentration of substrate utilized
S_0 = substrate concentration in influent
S = substrate concentration in effluent
θ = hydraulic detention time

To determine the mass concentration of microorganisms the equation below is used.

$$X = \frac{\theta_c}{\theta}\frac{Y\left(S_0 - S\right)}{\left(1 + k_d\theta_c\right)}$$

While effluent substrate concentration can be represented as

$$S = \frac{K_s\left(1 + \theta_c k_d\right)}{\theta_c\left(Yk - k_d\right) - 1}$$

The observed yield can be determined by

$$Y_{obs} = \frac{Y}{1 + k_d\theta_c}$$

Although the above equations are the basis for CFSTR systems they involve a lot of constants and are bulky to use for design criteria. Some simpler relationships have evolved for these purposes.

The reactor volume can be determined using the equation.

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

Another useful relationship arisies from defining the term $-\frac{r_{su}}{X}$ as the specific utilization rate U. This can be calculated as follows

$$U = \frac{S_0 - S}{\theta X} = \frac{Q}{V_r}\frac{S_0 - S}{X}$$

When the term U is substituted into the equation for mean cell residence time then we have

$$\frac{1}{\theta_c} = YU - k_d$$

Therefore U is directly related to $1/\theta_c$

To determine U you must know the substrate utilized and the mass of organisms effective in this utilization.

The substrate utilized is determined from the difference in the influent COD or BOD_5. The evaluation of the effective mass of microorganisms is more difficult and makes this impractical as a control parameter.

θ_c on the other hand is a valuable control parameter because you don't need to determine either the mass of effective organisms or the mass of substrate consumed. The use of this parameter relies on knowing the percentage of cell mass that must be wasted each day that is required to maintain the desired growth rate.

When wasting from the recycle line with a proper clarifier, the concentration of microorganisms in the effluent is minimal so we can use the equation below to determine θ_c

$$\theta_c \approx \frac{V_r X}{Q'_w X_r}$$

To do this you must know the concentration of microorganisms in the mixed liquor and the recycle line.

Another term which is used to approximate the specific utilization rate is the food to microorganism ratio F/M. This is used quite frequently in process description and is an important control variable.

$$F/M = \frac{S_0}{\theta X}$$

Typical values for this found in the literature vary from 0.5 to 1. It is important to keep your F/M ratios in a good range in order to ensure a good floc. (Table)

You can relate U and F/M by the process efficiency as follows

$$U = \frac{(F/M)E}{100}$$

$$E = \frac{S_0 - S}{S_0} \times 100$$

Application Example 8-1 in text. Next three pages.
Another Example

CFSTR with recycle
$Q = 1650\ m^3/d$
r =0.6
$S_o = 200$ mg/L COD
S = 34 mg/L COD
$X_e = 15$ mg/L VSS
$X_r = 5{,}000$ mg/L
θ = 8 h = 0.33 d

fits Monod kinetics Rate constants as follows
k = 0.95 mgCOD/mg VSS/d $K_s = 85$ mg/L COD
Y = 0.48 mg VSS/mg COD $K_d = 0.07\ d^{-1}$

Determine
1. Total COD in effluent
2. Waste flow from underflow
3. Sludge age
4. MLVSS (X)

1. Total COD in effluent
34 mg/L + 15(1.42 mg COD/mf VSS) = 55 mg/L

4. $X = \frac{\theta_c}{\theta}\frac{Y(S_o - S)}{1 + K_d\theta_c}$ we need a θ_c for this
or we can use

$$X = \frac{(S\ \ - S)(K_s + S)}{\theta k S} = \frac{(200\text{ mg/L} - 34\text{ mg/L})(85\text{ mg/L} + 34\text{ mg/L})}{(0.33\text{ d}^{-1})(0.95\text{ d}^{-1})(34\text{ mg/L})} = 1835\text{ mg/L}$$

3. Sludge age
$= 1/\theta_c$
There are lots of ways to calculate θ_c, the easiest for this purpose is:

$$\frac{1}{\theta_c} = \frac{\text{YkS}}{\text{K}+\text{S}} - k_d = \frac{(0.48)(0.95\text{ d}^{-1})(34\text{ mg/L})}{85\text{ mg/L} + (34\text{ mg/L})} - 0.07\text{ d}^{-1} = 16.6\text{ d}$$

2. Q_w Again there are many ways. Here is one way:

$$\theta_c = \frac{\text{VX}}{\text{Q}_\text{w}\text{X}_\text{r} + \text{Q}_\text{e}\text{X}_\text{e}}$$ define Q = Q-Q_w and rewrite this $$\theta_c = \frac{\text{VX}}{\text{Q}_\text{w}\text{X}_\text{r} + (Q - \text{Q}_\text{w})\text{X}_\text{e}}$$

rewrite again
$\theta_c\ (Q_wX_r + (Q\text{-}Q_w)Xe) = VX$

Calculate V = Qθ = 1650 m^3/d (0.33 d)= 550 m^3

$(16.6\ d)\ (Q_w)(5{,}000\ mg/L) + 16.6\ d\ (1650\text{-}Q_w)15 = 550\ m^3 \times 1850\ mg/L$

$Q_w = 7.33\ m^3/d$

Read about process stability in your text, it is fairly straight forward.

Figure 8.15 in text. Overhead.

θ_c^M = minimum mean cell residence time

below this value waste stabilization fails and cell washout occurs.

For design a good rule of thumb is to use θ_c= 2 to 20 times θ_c^M.

Sludge Volume Index

This is a measure of the settleability and compactability of sludge. It is measured by a standard lab test in which mixed liquor is placed in a 1- or 2-L cylinder and allowed to settle for 30 min (usually). At the end of the settling period, the volume of sludge solids on the bottom of the cylinder is measured. The calculation relies on knowing the original density of the total suspended solids and the volume.

e.g. $\text{SVI} = \dfrac{y}{X_T V_c}(1{,}000\ mg/g)$.

SVI = sludge volume index (mL/g)
y = volume of sludge after settling (mL)
X_T = TSS content of mixed liquor (mg/L)
V_c = Volume of cylinder (L)

A low SVI indicates that the sludge settles well.

This can be used to estimate the concentrations of the VSS and TSS in the recycle line if the ratio of VSS to TSS is known (X_V/X_T typical 0.75 - 0.8)

The following relationships exist.

$X_{Tr} = 10^6/\text{SVI}$ where X_{Tr} = total solids in the recycle line

and

$X_{Vr} = (X_{Vr}/X_{Tr})\ X_{tr}$ where X_{Vr} = volatile solids in the recycle line

Recycle ratio

The recycling of sludge can be related to measurable parameters by the following eqn.

$$r = \frac{1 - \frac{\theta}{\theta_c}}{\frac{X_{Vr}}{X} - 1}$$

Where r = the recycle ratio

θ = hydraulic detention time

θ_c = mean cell detention time

X_{Vr} = VSS in recycle line

X = VSS in reactor

New examples (handwritten)

Return Sludge Control

The control of the RAS is very important

pumps - should have the capability to pump 50 - 100% of the wastewater flow rate (150 for small plants)

flow rate calculations

1) settleability

RAS pumping rate is set to the percentage ratio of the volume occupied by the settleable solids from the aeration tank to the volume of the clarified liquid

e.g. 275 mL settleable solids in 1L = 275/725 = 38% therefore want to return 38% of total flow.

never go less than 15%

2)sludge-blanket control level

maintain optimum blanket of sludge in clarifiers

based on experience (0.3 to 0.9 m)

requires considerable operator attention

3) secondary clarifier mass balance (solids in must = solids out)

difference in concentrations accounts for differences in volumes or pumpimg rates

4) aeration tank mass balance

return enough solids to maintain constant concentration in aeration tank.

5) sludge quality

sludge settleability curves are generated and used as guidelines to determine return rates

Aeration

An important consideration in aerobic treatment systems such as the activated sludge system is the requirement for oxygen of the system. For plug flow this is very difficult at the head or beginning of the reactor, due to the high requirements of oxygen to metabolize the high concentrations of substrate and subsequent high growth of microorganisms.

Oxygen demands.

$$\text{lb } O_2 \text{ / day } = \begin{pmatrix}\text{total mass of BOD} \\ \text{Utilized, lb / d}\end{pmatrix} - 1.42\begin{pmatrix}\text{mass of organisms} \\ \text{wasted, lb / day}\end{pmatrix}$$

or

$$\text{lb } O_2 \text{ / d } = \frac{Q(S_0 - S) \times 8.34}{f} - 1.42(P_x)$$

where

f = conversion factor for converting BOD_5 to BOD_U.

$P_x = Y_{obs}Q(S_o\text{-}S) \times 8.34$ = net waste activated sludge.

8.34 = conversion factor

if Nitrogenous oxygen consumption is to included then you must use

$$\text{lb } O_2 \text{ / d } = \frac{Q(S_o - S) \times 8.34}{f} - 1.42(P_x) + 4.57Q(N_o - N) \times 8.34$$

where

N_o = influent nitrogen concentration, mg/L total Kjeldahl nitrogen (TKN)

N = effluent nitrogen concentration

4.57 = conversion factor for the amount of oxygen required to oxidize TKN

Air supply must be adequate to

1. satisfy the BOD of the waste
2. satisfy endogenous respiration
3. provide adequate mixing
4. maintain a minimum DO of 1 to 2 mg/L throughout the aeration tank.

Aeration Methods:

1. diffused-air aeration
2. mechanical aerators

1. diffusion-air aeration

blowers take in air through filter and blow through piping systems to diffusers submerged in the reactor.

diffusers - porous or fine pore

- non porous
- aerators

See Table 10-6 and figure 10-10 (OVERHEADS)

a, b, c **porous**,

Plates - costly to install and difficult to maintain

Must filter air so diffusers don't get clogged with grit and dust.

d, e, f **non-porous**.
Lower aeration efficiency, lower cost, less maintenance. don't have to filter air

g, h, i. **aerators** jet suited for deep tanks, U-tube good transfer because of pressures at great depth, good for high strength wastes.

Performance (Table 10-7) OVERHEAD

SOTE standard oxygen transfer efficiency
standard conditions are tap water, 68°F, at 14.7 $lb._f/in^2$, initial dissolved $O_2 = 0$.

increases with depth, values in table are for 15 ft.

Fouling - decrease in efficiency due to pore plugging and/or biological growth on diffusers
relates to how often maintenance must be performed.

Blowers - how the air gets in the pipes
Centrifugal - capacity >3,000 ft^3/min of free air, not too good below this
rotary lobe displacement - high pressure, capacity < 3,000 ft^3/min, good for variations in water level.

2. Mechanical aerators
1. vertical axis - impellers mounted on floats or fixed. Agitate water, thus entraining air.
2. horizontal axis - brushes rotated horizontally over the surface, or disks.

When these are on the surface they entrap atmospheric air. When submerged they disperse air bubbles pumped down to them.

<u>O_2.supply</u>
1. Atmospheric Oxygen from air.
2. High purity oxygen
    a) pressure swing adsorption
    b) cryogenic air separation
3. Dissolution of commercial oxygen
    a) down flow bubble contactor
    b) U-tube contactor
    c) conventional diffused aeration

<u>Typical requirements</u>
Course bubbles
F/M>0.3   500 to 900 ft^3/lb. (30 to 55 m^3/kg) of BOD_5 removed.
Fine bubbles
    400 to 600 ft^3/lb. of BOD_5 removed

F/M<0.3   1200 to 1800 ft^3/lb. of BOD_5 removed

Normal (10 State Standards)
1500 ft^3/lb. of BOD_5 removed for peak aeration tank loading

Design with a safety factor of at least two times the average BOD load. and design to leave a residual of 2 mg/L DO at the average load and 0.5 at peak

Ten State Standards
design to meet diurnal peak oxygen demand or 200 percent of the design average, whichever is larger.

Settling of Activated Sludge

This Material is from Chapter 6 section 6-5
Sedimentation – the process of separation of solids from water

Four types of settling occur in sedimentation basin
1. discrete particle settling (only for larger particles)
2. flocculant settling
3. Zone settling
4. Compression settling

1. discrete particle settling

this occurs in wters with relatively low concentrations of large particles. They settle as individual particles and do not have any significant interaction with each other.

2. Flocculant settling

The particles are present as a dilute suspension and coalesce to form larger particles with an increased mass. The particles then settle faster.

3. Zone or Hindered settling

The particles are present in suspension in intermediate concentrations. Interparticulate forces are important. These forces increase the hindrance of settling for neighboring particles. The result is that the mass usually settles as a unit. This settling results in the appearance of a solid liquid interface at the top.

4. Compression settling

The solids are now present in high concentration and the mass becomes structured. Only the compression of the structure will allow further settling.

Only zone and compressive settling are important in applications of settling for activated sludge. The flocs are usually concentrated enough that the first tow types of settling do not play important roles.

Design of sedimentation basins is based on the analysis of settling data from single batch tests or using the solids flux method.

Area requirement based on single batch results.

Factors
1. area needed for clarification
2. area needed fro thickening
3. rate of sludge withdrawal

1. area needed for clarification $A = Q_c/V$

Q_c = clarification rate
V = settling velocity
More in example

2. area required for thickening

column of height H_o filled with solid suspension concentration C_0
measure the position of the interface with time. graph the results (overhead)

important point C_2 height H_2, t_2
determined by extending tangents from flocculant and compressive settling and bisecting the angle

time t_u determined as follows:
the desired concentration of the solids is known (or directed by design of AS)
a horizontal line is drawn back to the height at which the desired concentration of solids would be achieved.
e.g. you want 10,000 mg/L
C_o = 5,000 mg/L (2 ft cylinder)

$H_U = C_oH_o/C_U = 5{,}000 \times 2\ \text{ft}/10{,}000 = 1$ ft.

make a tangent to C_2 (H_1 on graph) drop to t_u from where H_U crosses H_1.

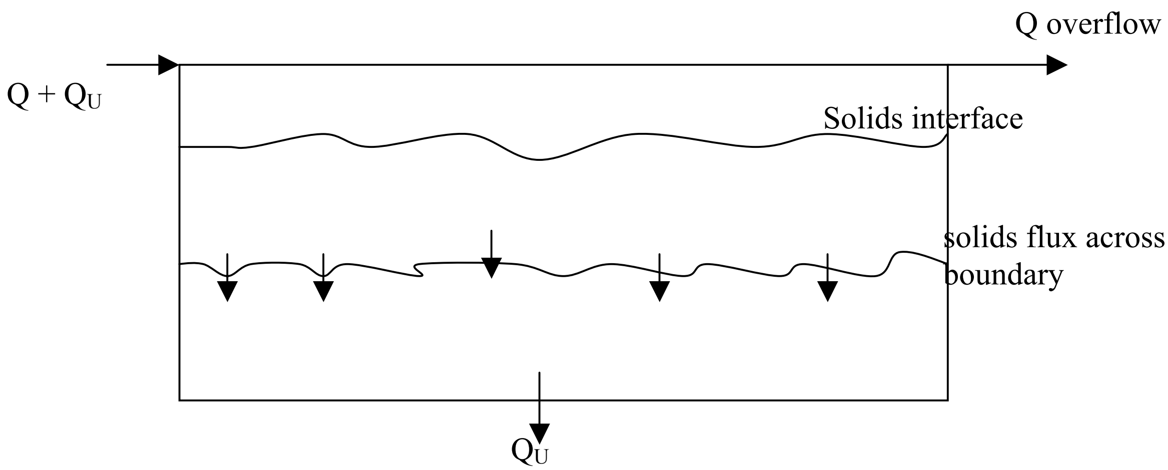
Area needed for clarification is $A\,(m^2) = \dfrac{Q\,(m^3/s)\,t_U(s)}{H_o}$ where

Q = flowrate
H_o = initial height
t_U = time to reach desired concentration

Example 6-5 (overhead)

Area requirement based on solids flux analysis

There is a constant flux of solids down the sedimentation basin caused by gravity settling and transport out of the clarifier.



SF_x = solids flux due to gravity

$SF_g = kC_iV_i$

$k = 1/16030$
C_i = solids concentration at point in question
V_i = settling velocity at concentration C_i
$SF_U = kC_iU_b$
U_b = bulk downward velocity

$SF_T = SF_g + SF_U = k(C_iV_i + C_iU_b)$

Procedures
Develop a solids flux settling curve (overhead Figure 6.17)
this is very similar to a microbial kinetic analysis
Take the initial slope as the velocity for the settling of different concentrations of solids.
Calculate V_iC_i plot vs C_1. This is solids flux due to gravity.
U_b =line with a slope that is a linear function of concentration

Total flux = Sum of these lines. (Overhead figure 6.18)
You will notice that an increase or decrease in the flow rate of the underflow will shift the total flux curve up or down.

Determination of area:

Two ways

One (Figure 6.18)
Draw an horizontal line tangent to the lowest point on the curve. The intersection of this with the y axis is the limiting flux (SF_L).
C_U = Underflow concentration at limiting flux. Drop a line from where the SF_L line crosses underflow line.

To make a thicker sludge reduce the slope of underflow flux, this reduces SF_L and increases area.

Two:
Figure 6.19
Draw line tangent to gravity flux curve passing through desired C_U
To make a thicker sludge choose a new C_U and draw a new line from C_U tangent to flux curve to Y axis – gives new SF_L

$$A = \frac{(Q + Q_U)C_o}{SF_L} \text{ x } 8.34 = \frac{(1+\alpha)QC_o}{SF_L} \text{ x } 8.34$$

$\alpha = Q_U/Q$
Q = flow over weir

See eacmple 6-6. (overhead)

Typical Design Information for 2nd Clarifier.

Table 10-12 in text.

	Overflow	Soilds	Depth
Activated sludge	400-800 gal/ft^2 d	0.8 – 1.2 lb/ft^2 h	12-20 ft

Extended aeration – more of the solids are removed so there is poorer settling. Need lower overflow rates for the same amount of water. Therefore a larger clarifier is required.

Solids Separation Facilities

Circular or Rectangular tanks
Circular
- 30-140 ft (10-40 m) diameter
- radius should not exceed 5x the sidewater depth
- center feed or sidewall feed
- sludge removal by rotating a scraper on the bottom, directs sludge either to a central hopper or through suction orifices along the tank bottom.

Rectangular
- Maximum length not to exceed 10 to 15 x depth
- Width 20 to 80 ft. (6 to 24 m)
- Sludge collected with
  - traveling flights – a chain mechanism with buckets that scrape the bottom
  - traveling bridge – scraper or suction supported by overhead bridge

Trays, tubes and lamella

More modern ways to clarify, they cost more $$ but take less land.
They are used where using conventional systems is a problem usually due to space.
They are often added in retrofits when a plant must be expanded.

Modifications to Activated Sludge Process

Plug flow

Plug flow reactors are advantageous in some circumstances, due to the fact that faster rates can be obtained at higher substrate concentrations. Initially a fast rate of metabolism and growth is present. As the plug proceeds the rate of metabolism of substrate is limited by concentration, but high numbers of microorganisms are present, so the observed rate might not be affected too much. It is be beneficial to use plug flow when intermediates are produced that interfere with degradation of the parent compound or when diauxie is observed. This allows high concentrations of each substrate to be present initially. Cannot handle shock loads

McCarty's Model

$$\frac{1}{\theta_c} = \frac{Yk(S_o - S)}{(S_o - S) + (1+\alpha)K_s \ln(S_i / S)} - k_d$$

new terms
α = recycle ratio
S_I = influent concentration after dilution with recycle
= $(S_0 + \alpha S)/ (1 + \alpha)$

Tapered aeration (diagram on board)

modification of plug flow
air is added depending on oxygen demand
more at head and less towards effluent end
use diffuser spacing to achieve this

Step-feed aeration (diagram on board)

modification of plug flow in which wastewater is introduced at several points in the tank
equalizes F/M over reactor
has good flexibility of operation

Modified aeration

plug flow with shorter aeration times are used
higher F/M
Lower BOD removal efficiencies are obtained

Contact Stabilization (diagram on board)

plug flow
two tanks, one to stabilize and one to treat.
influent mixed with sludge (from stabilizer) in contact tank

goes into clarifier and then to stabilization tank
the return sludge is aerated while the rest is wasted unaerated
saves 50% on aeration volume requirements

Extended aeration

plug flow
low organic loading and a long aeration time.
good for small communities

High-rate aeration

CFSTR
high MLSS, high volumetric loading
high F/M and long mean cell residence times
short hydraulic detention times
mixing is very important

Kraus process

variation of step aeration plug flow
good for low N levels
digestor supernatant is added as a nutrient source to portion of return sludge designed to nitrify
resulting mixed liquor is then added to main plug flow reactor

High Purity Oxygen

Usually CFSTR in series
high purity O_2 is added to reactors instead of air
tanks must be covered so O_2 can be recovered and reused, some is wasted
can add 4x the amount of O_2 as when air is used

Oxidation ditch

plug flow
ring shaped channel with mechanical aerators
long detention times, long solids retention times
operate in extended aeration mode

Deep shaft

plug flow 400 to 500 ft deep
influent forced to go down and around metal annulus.
aeration occurs at about 1/2 way down.

2) Aerated Lagoons

long θ_c
reactor is an earthen basin (hole in the ground)

surface or diffused aerators for O_2
operated with or without settling and RAS
more newer ones operated with RAS therefore make these another version of activated sludge
large surface areas
modeled the same as activated sludge except use long $\theta_{c.}$
Example 10-4 from text.

3) Sequencing Batch Reactors

very popular these days
Intermittent flow stirred tank reactor
everything happens in one tank
add waste to sludge mix with air and is an STR, turn air off, things settle out, let water go, waste some sludge and add new waste to start off next cycle.
Usually run several of these so you can always handle the inflow. Stagger the flow so it goes from one to the next and then by the time you are back at number one it is ready again.

Example 10-3 from text.

4) Aerobic Digestion

used to treat sludge and get more BOD removal than possible with ACT sludge.
long retention times to allow fuller metabolism to occur
can use conventional or high purity oxygen
can be thermophilic