ACTIVATED SLUDGE PLANT GENERAL DESIGN INFORMATION

INTRODUCTION

The Sanitaire Activated Sludge Plant is custom engineered for each job with "flexibility of operation" as a foundation for the design. Since each project has a set of conditions (waste flow, flow variations, waste concentration, waste characteristics, etc.) that is different from all other projects, each Activated Sludge Plant should be designed to fit those conditions. There should be sufficient flexibility to meet all feasible variations in waste load and fluctuations in biological process.

This "design information", is not an "off the shelf" standard. It is intended as a guide to allow selection of appropriate components to meet specific requirements of each project. The discussion and "Design Example" that follow will assist in the design of an Activated Sludge Plant. The example that follows covers many, but certainly not all, factors that need to be addressed in a complete system design. We would encourage you to contact Sanitaire directly for design design assistance as well as specifications for other equipment that may be necessary within the facility.

PROCESS REQUIREMENTS

The first step in an Activated Sludge Plant design is to determine what the facility has to accomplish or "goals" that have to be met. Federal, state or local regulatory agencies has already selected many of these "goals" for you. These "goals" always involve effluent limitations and in most cases include some "process requirements". Whatever design is selected, these "process requirements" and effluent limitations must be taken into account. Effluent limitations usually involve TSS, BOD and NH_3-N concentrations but may also involve NO_3, phosphorous, COD, D.O., coliform concentrations and pH, as well as requirements on waste solids handling and disposal. "Process requirements" vary widely but could include one or more of the following:

1. Flow equalization
2. Initial screening
3. Grit collection
4. Primary treatment
5. Secondary treatment
    - A. BOD loading rate
    - B. Aeration basin detection time
    - C. Oxygen requirements
    - D. Mixing requirements
6. Clarification
    - A. Hydraulic loading rate
    - B. Solids loading rate
    - C. Side water depth
    - D. Weir length per flow
    - E. Sludge rake drive torque requirements
    - F. Scum collection
7. Tertiary treatment/nutrient removal
8. Post aeration
9. Disinfection
10. pH adjustment

Working within these "requirements", one can select the overall process that will determine the basis of design for the Activated Sludge Plant facility.

FLEXIBILITY

As stated earlier, "designed in" flexibility is the foundation of the Activated Sludge Plant facility, which makes it unique. A properly designed Activated Sludge Plant can use any "activated sludge" process in conjunction with either the plug flow or complete mix modes. This provides a high degree of flexibility and allows the optimum operating flow scheme to be selected at a specific time in the life of the wastewater treatment facility. Taking into account the fact that the waste flow and waste concentration will vary significantly over the life of virtually every wastewater treatment facility, flexibility is a strong asset of the Activated Sludge Plant.

Assistance from Sanitaire is available to provide design concepts that have been used successfully in facilities now in operation.

MECHANICAL REQUIREMENTS

The components of the Activated Sludge Plant that involve mechanical design are 1) the blower (providing air for oxygen transfer, mixing and/or airlift pumping) and 2) the clarifier sludge rake drive unit. Sanitaire can approximate design and sizing of the blower for the MARK IV package plant. The clarifier sludge rake drive design is covered in the clarifier section of this catalog.

PROCESS SELECTION

As previously discussed, the activated sludge process can operate in a variety of modes. Each variation of the activated sludge process is designed to remove varying degrees of suspended solids and reduce the carbonaceous and/or nitrogenous concentrations of the wastewater. The process selection is dependent on a number of factors including:

1. Degree of treatment as required by local and federal regulatory agencies
2. Flow variations (daily, weekly, seasonal)
3. Consistency of treatment required
4. Type of waste to be treated
5. Land constraints
6. Operator experience and knowledge

It is the Consulting Engineer's responsibility to select the proper activated sludge process for the treatment plant design in question.

Table 1 summarizes some typical design parameters for a variety of activated sludge processes. These parameters are listed for average flow and loading conditions.

TABLE 1

Various Activated Sludge Processes Based On General Regulatory "Allowable Design Criteria"*

Process Name	ADF Carbonaceous Load (#BOD/d/1000 cu. ft.)	MLSS (mg/l) (ave.)	Carbonaceous Load $\#O_2/\#BOD$ Required	RAS Rate (% of influent)	Volatile Sludge Yield Y (#VSS/#BOD)	(4) Nitrification	Peak Clarifier Overflow (gpd/ft.^{2})	Clarifier Solids Loading (#/d/ft.^{2})
Extended Aeration	10-20	2000-5000	1.1-1.5	50-150	0.3-0.5	Yes	1000	50
Conventional Nitrification	20-30	2000-4000	0.9-1.2	50-150	0.4-0.6	Probably	1000	50
Conventional Carbonaceous	30-40	1000-4000	0.7-1.1	30-100	0.5-0.7	Maybe	1200	50
Contact C Stabilization S	40-50	2000-4000(2)	0.7-1.0 0.3-0.6	50-150	0.5-0.7	No / Maybe	1200	50
High Rate Aeration	>50	2000-5000	0.6-1.0	15-75	0.8-1.2	No	2000(3)	75(3)
Single Stage Nitrification	N/A (1)	1000-3000	1.0	50-200	(5)	Yes	800	50

(1) Dependant on upstream carbonaceous treatment method (normal assumption – 30 ppm influent to nitrification tank(s)
(2) Dependant on RAS flow rates
(3) Range of values is highly variable. Midpoint value is indicated.
(4) Nitrification should consider 4.6 $\#O_2/\#NH_3$ applied to aeration
(5) 0.5 #VSS/BOD plus 0.15 $\#VSS/\#NH_3$
*Consult state or local codes for specific governing design requirements

SLUDGE PRODUCTION AND DIGESTION SIZING

When calculating the quantity of sludge produced that requires aerobic digestion for further stabilization, it is important to consider a variety of factors including

suspended solids removal upstream of the package plant.

Typically, package treatment plants, like the SANITAIRE MARK IV, serve as a stand-alone unit. There are no separate primary treatment units such as grit chambers, bar screens or primary clarifiers upstream of the plant. If primary settling tanks are present, this should be taken into account when calculating non-volatile suspended solids (NVSS) concentrations in the influent flow of the plant. A 50% reduction in NVSS and a 30% reduction in BOD in the primary clarifiers are typical. The remaining load of NVSS is passed through the activated sludge process and is settled out in the final clarifier. Sludge is recycled or wasted to the aerobic digester.

In addition to NVSS loadings, careful consideration should be given to sludge loadings due to mixed liquor volatile suspended solids (MLVSS) generated from BOD conversions. MLVSS loadings to the digester can be estimated using the following equation:

MLVSS loading, (#/day) = BOD x 8.34 x Q x Y
Where:
BOD = BOD loading to aeration basin, ppm
Q = influent flow to plant, MGD
Y = VSS fraction wasted to digester #VSS/#BOD in the influent obtained from Table 1.

Non-volatile suspended solids loading can be calculated as follows:

NVSS loading (#/day) = TSS x 8.34 x Q x f
Where:
TSS = total suspended solids present in wastewater, ppm
Q = influent flow to plant, MGD
f = fraction of TSS removed with primary treatment expressed as a decimal (no primary treatment f = 1.0, primary treatment f = 0.5)

By adding the NVSS and MLVSS loadings, an estimate can be made of the sludge production delivered to aerobic digester and/or sludge holding tank.

DIGESTER OR SLUDGE HOLDING TANK SIZING

To determine the volume required for the aerobic digester or sludge holding tank, assumptions should be made about expected sludge concentrations and detention times.

Table 2 presents general guidelines for expected sludge concentrations for a variety of aeration processes.

TABLE 2

Process	Digester Solids Concentration (%)	Sludge Holding Tank Solids Concentration (%)
High Rate Aeration	2.5	3.5
Conventional Aeration	1.5	2.5
Extended Aeration	1.0	2.0

Normally, 15 days of detention time should be provided for sludge storage in digestion. However, many plants may require between 45 days to 6 months of storage. Consult the regulatory agency for local requirements.

The volume requirements of the aerobic digester or sludge holding tank can be obtained by using the following equation:

$V_0 = (S \times DT)/(SC \times 8.34)$
Where:
- V_0 = digester volume, million gallons
- DT = desired sludge detention time, days
- SC = desired sludge solids concentration, ppm
- S = total MLVSS & NVSS loading to digester, #solids/day

AERATION BASIN SIZING

The aeration basin size can be calculated based on the aeration process selected and the influent BOD loading. A simplified calculation is as follows:

$V_A = (BOD \times Q \times 8.34)/BLF$
Where:
- V_A = volume of aeration basin, 1000 ft^3
- BOD = BOD loading to aeration basins in ppm
- Q = influent flow to plant, MGD
- BLF = BOD loading factor obtained from Table 1, #BOD/day/1000 ft^3

For a contact stabilization process, a typical volume split of 30% / 70% between the contact chamber and stabilization chamber, respectively, is often used.

CHLORINE CONTACT CHAMBER SIZING

Typically, the chlorine contact chamber (if required) is designed for a 15 minute detention time at peak flow. Consult local regulatory agencies for specific design requirements. A calculation for sizing the chamber is as follows:

$V_{CC} = (Q \times DT)/7.48$
Where:
- Q = plant Peak Flow in GPM
- DT = detention time at peak flow, assume 15 minutes
- V_{CC} = chlorine contact chamber volume in ft^3

CLARIFIER SIZING

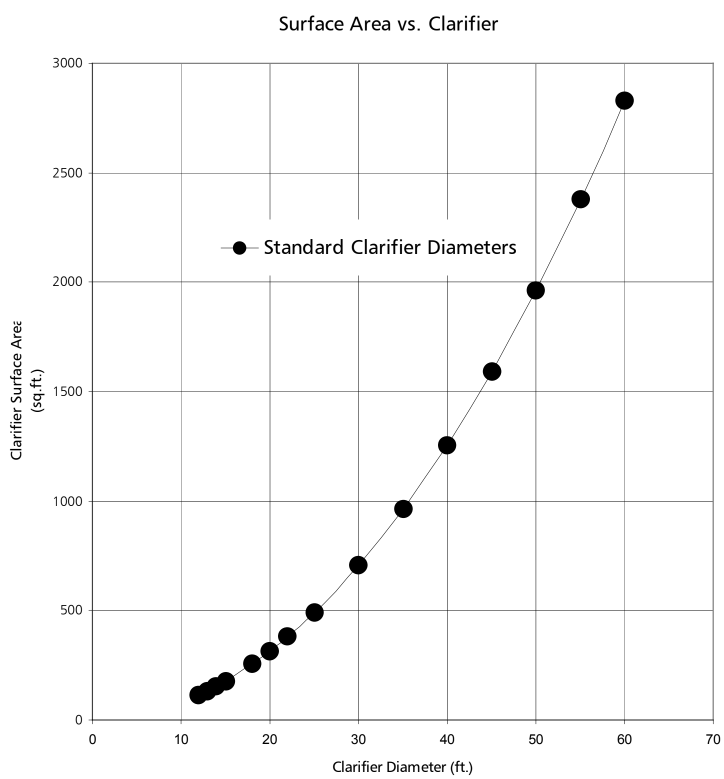
When considering the sizing of the final clarifier, hydraulic overflow rate and solids loading rate should be taken into account. Table 1 lists approximate sizing factors for various activated sludge processes. Clarifier sizing should be evaluated based on both factors. Typically, the most conservative sizing governs, however, an average size based on both results may be used.

Hydraulic Equation:
$SA = Q/OR$
Where:
- SA = clarifier surface area, ft^2
- Q = peak hourly influent flow, gpd
- OR = overflow rate from Table 1, gpd/ft^2

Solids Loading Equation:
$SA_C = SL/SLR$
Where:
- SA_C = clarifier surface area, ft^2
- SL = solids loading rate to clarifier, #/day
- SLR = surface loading rate, #/day/ft^2

Once a clarifier surface area has been selected, refer to Table 3 for the corresponding tank diameter and most common clarifier sizes available from Sanitaire.

TABLE 3



CLARIFIER RAKE DRIVE UNIT

The clarifier rake drive unit is used to move settled solids on the floor of the circular clarifier to a center sump by means of dual rake arms attached to the rotating torque tube. The torque tube is in turn attached to the drive unit. The sizing of the drive unit is based on calculating the torque necessary to rotate the rake arms. The equation used to determine necessary torque is as follows:

TORQUE (T) = WR^2
Where:
W – sludge load on rake arm (lbs./ft. of rake arm)
R – radius of clarifier (ft.)

R is determined when the diameter of the clarifier is selected based on hydraulic and/or solids loading requirements. W is selected based on the type of solids being handled within the clarifier. Since the application of a clarifier varies widely, so will the characteristics of the solids handled.

Typical values of W for corresponding solids generally seen in clarifier applications are as follows:

	W (lbs./ft.)
Primary sludge	6 - 12
Secondary "activated sludge"	4 - 6
Thickened "activated sludge"	10 - 20
Primary paper mill waste	15 - 25
Alum sludge (water conditioning)	2 - 6
River silt (flocculated with coagulant)	20 - 30
Primary grit or sand	20 - 50
Fly ash (power plant waste)	60 - 120

The "design operating" torque calculated should then be inserted into the specifications for the clarifier rake drive unit. If complete specifications for the drive unit are, needed please contact Sanitaire and they will be provided.

DETERMINING OVERALL PLANT SIZE

Once the individual compartment volumes are calculated, the overall plant size can be determined by following these steps:

1. Convert all compartment volumes to projected surface areas using the standard compartment depths listed in the "Engineering Data" sheets in this section.

2. Add the projected surface area for concrete clarifier walls and compartment divider walls to the total surface area. The projected surface of steel walls is minor and can be neglected.

3. Calculate the theoretical plant inside diameter using the total projected surface area requirement.
   Plant inside diameter, ft. =

   $$\sqrt{\frac{4A}{\pi}}$$

   Where:
   A = total projected surface area required, ft^2

   Typically, plant inside diameters can be rounded off to the nearest one-foot increment or for larger plants rounded off to the nearest five-foot increment without any significant changes in performance.

4. Calculate the position of the individual compartment walls by partitioning the outer annulus based on relative volume requirements.

   Compartment size in degrees =
   $(A_{comp}/A_T) \times 360$
   Where:
   A_{comp} = area of the specific compartment
   A_T = total area of the outer annulus (total surface area of the plant less the clarifier and divider wall projected surface areas)

Note: Be aware that smaller plants may yield unusually small compartments. Consult Sanitaire regarding minimum compartment size requirements to accommodate mechanical equipment and the ability to construct.

5. After actual compartment volumes have been calculated, finalize the loading rates to each process. The final loading rates are usually very close to the original assumptions.

DETERMINING AIR REQUIREMENTS

For determining aeration compartment air requirements, please refer to the section entitled "Aeration Design".

For digester aeration requirements, an estimate should be made regarding oxygen requirements due to biological loading. A typical value used for total oxygen requirements throughout the system (including aeration and digestion) is 1.8 $\#O_2/\#BOD$. Part of this demand will be satisfied in the aeration compartment, however, the balance should be taken into account in the digester and/or sludge holding tank. Consult local regulatory agencies for specific design requirements.

Due to the high solids concentrations typically found in aerobic digesters and especially sludge holding basins, a minimum air rate of 20-30 SCFM/1000 ft^3 for mixing is recommended.

Typically, airlift requirements are small, ranging from about 10 SCFM for small plants up to 150 SCFM for large plants. To calculate exact airlift air requirements, consult the section entitled "Airlifts".

DESIGN EXAMPLE

Wastewater comes from a seasonal resort facility. Flow characteristics are as follows:

	Winter	Summer
Average Daily Flow, MGD	0.5	2.0
Influent BOD_5, ppm	220	220
Influent NH_3, ppm	30	30
Influent Total Suspended Solids, ppm	200	200
Nitrification?	No	Yes
Peaking Factor	None	2:1

Other assumptions:

1. Selected activated sludge process is conventional nitrification loaded at 20# BOD/day/1000 ft^3 during summer months
2. No primary clarification
3. Influent TSS includes 50% NVSS
4. Digester only, no sludge holding tanks
5. Volatile sludge yield = 0.45 #VSS/#BOD
6. Digester sludge concentration = 2% (20,000 ppm)
7. Digester detention time = 14 days
8. Steel tank construction
9. Local regulatory agency requires 2 treatment units

1. AERATION BASIN SIZING CALCULATIONS

Summer:

V_A = [(220 ppm)(2.0 MGD)(8.34)]/(20 #BOD/day/1000ft^3)
= 183.48 1000 ft^3 = 183,480 ft^3
Surface area = 12,510 ft^2 @ 14'-8" SWD

Check winter operation:

$$\frac{(220\text{ ppm})(0.5\text{ MGD})(8.34)}{(183.48\ 1000\text{ ft.}^3)} = 5\#\text{ BOD/day/1000 ft.}^3$$

This loading rate is too low. A loading this low would result in high SRT and poor sludge setting. Consider designing winter loading at 30 #/day/1000ft^3. Partition a section of the aeration chamber for winter service only.

Winter:

V_A = [(220 ppm)(0.5 MGD)(8.34)]/(30 #BOD/day/1000ft^3)
= 30.58 1000ft^3 = 30,580 ft^3
Surface area required = 2085 ft^2

The aeration basin will therefore be divided into two compartments. The larger compartment will be 152,900 ft^3 for summer use only. The smaller compartment will be 30,580 ft^3 for summer and winter use. Mixed Liquor transfer will be accomplished through additional transfer pipes, multi-purpose launders or airlift pumps.

2. SLUDGE LOADING/DIGESTER SIZING CALCULATIONS

NVSS (#/day) = (200 ppm)(8.34)(2.0 MGD)(0.5)
= 1668 #NVSS/day
MLVSS (#/day) = (220 ppm)(8.34)(2.0 MGD)(0.45 #VSS/#BOD)
= 1651 #MLVSS/day
Total Solids Loading to Digester =
1668 #/day + 1651 #/day = 3319 #/day
V_D = [(3319 #/day)(14 days)]/[(20,000)(8.34)]
= .278 MG
= 37,237 ft^3
Surface Area = 2539 ft^2 @ 14'-8" SWD

3. CHLORINE CONTACT BASIN SIZING CALCULATIONS

Use 15 minutes of detention time at a peak flow of 4.0 MGD (2780 gpm)
V_{CC} = [(2780 gpm)(15 minutes)]/7.48
= 5575 ft^3
SA_{CC} = 423 ft^2 @ 13'-2" SWD
(SA_{CC} = surface area of chlorine contact basin)

4. CLARIFIER SIZING CALCULATIONS

Design based on solids loading rate. Assume 100% RAS flow @ 2.0 MGD influent flow and MLSS of 4000 ppm. Therefore, total average daily flow (ADF) to clarifier equals 4.0 MGD.

Solids loading (SL) = (4000 ppm)(4.0 MGD)(8.34)
= 133,440 #MLSS/day

At peak flow, assume 150% RAS based on ADF.
Peak flow = 4 + (2)(1.5) = 7.0 MGD
(SL) at peak flow = (4000 ppm)(7 MGD)(8.34)
= 233,520 #MLSS/day

From Table 1, select a clarifier loading rate of 50#/day/ft^2
The clarifier surface area is equal to:
SA_C = (233,520 #MLSS/day)(50#/day/ft^2)
= 4670 ft^2
Based on the use of two treatment units, two (2) 55' ∅ clarifiers will be required.

Check hydraulic loading rates at peak flow:

$$\text{Overflow Rate (OR)} = \frac{4.0 \times 10^6\text{ gpd}}{4750\text{ ft}^2}$$

= 842 gpd/ft^2
OK based on Table 1 Value

5. CALCULATE OVERALL PLANT SIZING

Total area per plant required:

Zone	Total Trial Area (ft^2)	Annulus Trial Area (ft^2)
Aeration*	6,255	6,255
Digester	1,270	1,270
Chlorine Contact	211	211
Clarifier (55′)	2,375	---
Total	10,111 ft^2	7,736 ft^2

*Total Winter/Summer

Overall plant diameter, ft. =

$$\sqrt{\frac{(4)(10,111)}{\pi}}$$

= 113.5 ft.

Round off to 115-ft. diameter

Compartment size can be calculated. For example, the angular space occupied by the aeration chamber will be:

$$\frac{6255\ ft.^2}{7736\ ft.^2} \times 360^\circ = 290^\circ \text{ (rounded off)}$$

Summer/winter use = 50°
Summer use only = 240°
Similarly,
Digester = 60°
Chlorine Contact = 10°

Final design loadings can then be recalculated, based on final volume calculations. Air requirements can be calculated by using the sections entitled "Aeration Design" and "Airlifts".

6. CALCULATE CLARIFIER RAKE DRIVE TORQUE & SIZING

The equation for Torque calculation is:
Running Torque (T) = WR^2
Where:
W = sludge load on rake arm (lbs./ft. of arm)
R = radius of clarifier (ft.)

For secondary "Activated Sludge":
W = 6 lbs./ft.
For a 55 ft. diameter clarifier: R = 27.5 ft^2
T (running) = $(6)(27.5)^2$ = 4,537.5 ft.-lbs.
Rated Torque of Drive* = 4,537.5 ft.-lbs.

*Torque of drive selected should be AGMA rated continuous running torque for 20 year or 1 million cycle life.

7. CALCULATE ACTUAL OXYGEN REQUIREMENTS

For determining actual oxygen requirements (AOR), an estimate must be made to determine the oxygen requirements for the biological loading. Typical combined aeration and digestion oxygen requirements are 1.8 lbs. O_2/lb. BOD and 4.6 lbs. O_2/lbs. NH_3. Nitrification may not be required, however conditions may cause its occurrence. Therefore, additional oxygen may be required to satisfy this demand. The calculation of AOR is as follows:

AOR (lbs./day) = (1.8)(lbs.BOD/day) + (4.6)(lbs. NH_3/day)
lbs. BOD/D = (BOD_5 Conc.)(Ave. Daily Flow, MGD)(8.34 lbs./gal)
lbs. NH_3/D = (NH_3 Conc.)(Ave. Daily Flow, MGD)(8.34 lbs./gal)
lbs./BOD/D (winter) = (220)(0.5)(8.34)
= 917
(summer) = (220)(2.0)(8.34)
= 3,669
lbs./NH_3/day (winter) = (30)(0.5)(8.34)
= 125
(summer) = (30)(20)(8.34)
= 500
AOR (winter) = (1.8)(917) + (4.6)(125)
= 2,226 lbs./day
(summer) = (1.8)(3669) + (4.6)(500)
= 8,904 lbs./day

To calculate the corresponding Standard Oxygen Requirements (SOR) and air requirements refer to the "Aeration Design Section". Selection of the type of air diffusion system is also discussed in this section.

DESIGN RESULTS

Two (2) package plants will be required with the configuration as shown on Drawing No. 99-523.