Calculations used in daily operations of a typical Wastewater Treatment Plant

The calculations provided in this booklet are tools, much like the equipment utilized, that will enable the operator to manage and run a wastewater treatment facility as efficiently and smoothly as possible.

Operating a treatment facility can be challenging, yet very rewarding. These plants are designed using parameters that take into account various hydraulic and organic loadings, and with equipment that will allow for efficient operation. However, running the equipment alone is not enough to ensure a smooth operation. The operator must use the calculations provided to operate the plant in an effective manner. While the operator can choose which calculations to use, it is imperative that the facility is run following operational guidelines.

We hope you find this guide helpful.

Contents

Calculations Used in the Daily Operation of a Wastewater Treatment Facility

Several basic equations are used in calculations to determine things such as Weir Overflow Rate, Detention Time, SRT, etc. The formulas for area and volume appear below, along with examples.

AREA

Area	Formula	Example
Rectangle	(Length) x (Width)	(35' L) x (12' W) = 420 sq. ft.
Circle	(0.785) x (Dia. sq.)	(0.785) x (55') x (55') = 2,375 sq. ft.

VOLUME

Volume	Formula	Example
Rectangle	L x W x H	80'L x 25'W x 10"H = 20,000 cu. ft.
Cylinder	(0.785) x (Dia. sq.) x (H)	(0.785) x (55') x (55') x (25') = 59,366 cu. ft.

Raw Influent Calculations

Plant Influent Loadings

Determines the influent loadings of pounds (BOD, TSS, etc.) to a wastewater treatment facility.

Plant Influent Loadings:
mg/l x mgd x 8.34 = lbs./day

Example (using TSS):

Plant Conditions:

TSS Influent = 135 mg/l

Influent flow = 1.5 mgd

To determine pounds into the plant, use the following calculation:

mg/l x mgd x 8.34 = lbs/day

Example: 135 mg/l x 1.5 mgd x 8.34 = 1,688.85 lbs.

This reflects the pounds of TSS into the plant on that particular day.

Clarifier Capacity Calculations

Surface Loading Rate - RECTANGULAR Clarifier

Gallons of wastewater applied to each square foot of the clarifier area. This affects the settleable solids and BOD removal efficiency in the sedimentation process.

Surface Loading Rate (RECTANGULAR CLARIFIER):

$$\frac{\textbf{gpd}}{\textbf{sq. ft. of clarifier}}$$

Example:

Clarifier:

Length = 75 feet
Width = 12 feet
Influent flow = 1.2 mgd (1,200,000 gpd)

The square footage of the clarifier is L x W:

75 x 12 = 900 sq. ft.

To determine the Surface Loading Rate of a **rectangular** clarifier, use the following calculation:

$$\frac{\textbf{gpd}}{\textbf{sq. ft. of clarifier}}$$

Example: $\frac{1{,}200{,}000 \text{ gpd}}{900 \text{ sq. ft.}} = 1{,}333$ gpd/sq. ft.

Clarifier Capacity Calculations

Surface Loading Rate - CIRCULAR Clarifier

Gallons of wastewater applied to each square foot of the clarifier area. This affects the settleable solids and BOD removal efficiency in the sedimentation process.

Surface Loading Rate (CIRCULAR CLARIFIER):

$$\frac{\textbf{gpd}}{\textbf{sq. ft. of clarifier}}$$

Example:

Clarifier:

Diameter = 60 feet
Influent flow = 2,200,000 gpd

The square footage of the clarifier is .785 x Dia. sq.

.785 x 60' x 60' = 2,826 sq. ft.

To determine the Surface Loading Rate of a **circular** clarifier, use the following calculation:

$$\frac{\textbf{gpd}}{\textbf{sq. ft. of clarifier}}$$

Example: $\frac{2{,}200{,}000 \text{ gpd}}{2{,}826 \text{ sq. ft.}} = 778.48$ gpd/sq. ft.

Clarifier Capacity Calculations

Detention Time

Period of time that a particle remains in a tank.

Detention Time:

$$\frac{\textbf{tank volume x 24 hours}}{\textbf{Influent flow}}$$

*Example (**rectangular** clarifier):*

Clarifier:

Length = 75 feet
Width = 30 feet
Depth = 10 feet
Influent flow = 2,850,000 gpd

The volume of the clarifier is L x W x H x 7.48

70' x 25' x 10' x 7.48 = 130,900 gals.

To determine the Detention Time of a **rectangular** clarifier, use the following calculation:

$$\frac{\textbf{tank volume x 24 hours}}{\textbf{Influent flow}}$$

Example: $\frac{\text{130,900 gals x 24}}{\text{2,850,000}}$ = 1.10 hours

Clarifier Capacity Calculations

Weir Overflow Rate

Volume of water flowing over foot length of weir per day.

Weir Overflow Rate:

$$\frac{\textbf{gpd flow}}{\textbf{Total feet of weir}}$$

Example:

Plant Conditions:

Weir length = 100 feet
Flow rate = 1,500,000 gpd

To determine the Weir Overflow Rate, use the following calculation:

$$\frac{\textbf{gpd flow}}{\textbf{Total feet of weir}}$$

Example: $\frac{\text{1,500,000 gpd}}{\text{100 feet of weir}}$ = 15,000 gpd/ft.

Activated Sludge Calculations

Sludge Age

Average time a particle of suspended solids remains in the activated sludge system. Sludge age is used to maintain the proper amount of activated sludge in the aeration system.

To determine sludge age, you must calculate both the daily amount of suspended solids and the total amount of solids in the aerator.

Sludge Age:

$$\frac{\text{Total lbs. of MLSS in aerator}}{\text{Daily lbs. of MLSS in aerator}}$$

Sludge Age - Plants with Primary Clarifier

Example:

Suspended solids of primary effluent = 110 mg/l
Influent flow = 2.5 mgd
Aeration tank volume = .5 mg
MLSS concentration = 2,200 mg/l

The plant influent loading = **mg/l x mgd x 8.34**
Example:
110 x 2.5 x 8.34 = 2,293.5 lbs. **daily** of SS (lbs of MLSS in aerator)
2,200 x .5 x 8.34 = 9,174 lbs. **total** of MLSS in aerator

With these calculations, you can determine Slude Age:

$$\frac{\text{Total lbs. of MLSS in aerator}}{\text{Daily lbs. of MLSS in aerator}} = \text{Days Sludge Age}$$

Example:

$$\frac{\text{9,174 lbs. total of MLSS in aerator}}{\text{2,293.5 lbs. daily of MLSS in aerator}} = \text{4 Days Sludge Age}$$

Sludge Age - Plants without Primary Clarifier

Example:

Influent suspended solids = 250 mg/l
Influent flow = 2.5 mgd
Aeration tank volume = .5 mg
MLSS concentration = 2,200 mg/l

The plant influent loading = **mg/l x mgd x 8.34**
Example:
250 x 2.5 x 8.34 = 5,213 lbs. **daily** of SS (lbs of MLSS in aerator)
2,200 x .5 x 8.34 = 9,174 lbs. **total** of MLSS in aerator

With these calculations, you can determine Slude Age:

$$\frac{\text{Total lbs. of MLSS in aerator}}{\text{Daily lbs. of MLSS in aerator}} = \text{Days Sludge Age}$$

Example:

$$\frac{\text{9,174 lbs. total of MLSS in aerator}}{\text{5,213 lbs. daily of MLSS in aerator}} = \text{1.76 Days Sludge Age}$$

Activated Sludge Calculations

Solids Retention Time (SRT)

Average time a given unit of cell mass stays in the activated sludge system. SRT is based on solids leaving the Activated Sludge process, and includes solids in the clarifiers. Also called MCRT (Mean Cell Residence Time).

Solids Retention Time (SRT):

$$\text{SRT days} = \frac{\text{lbs./day of SS in system}}{\text{lbs./day of SS leaving system}}$$

Factors in determining SRT:

1. Solids leaving the system (wasted)
2. Solids leaving the system (SS in the final effluent)
3. Solids in the system (aeration basins and clarifiers)

Example:

Tank volumes:	Aeration volume = 1.6 mg Final Clarifer volume = .10 mg
SS Concentration:	Final effluent = 20 mg/l Waste sludge SS = 7,250 mg/l Aeration Tank MLSS = 2,500 mg/l
Flows:	Influent flow = 4.3 mgd Waste sludge flow = 0.08 mgd (24-hour period)

Using these figures, calculate the amount of suspended solids leaving the system:

Example:

(7,250 mg/l waste sludge) x (.08 waste sludge flow) x (8.34 lbs.)
+ (20 mg/l SS final effluent) x (4.3 MGD influent flow) x (8.34 lbs.)
= 4,837.2 lbs. SS + 717.2 lbs. SS = 5,554.4 lbs. SS leaving system

For this example, the volume of the aeration tank and clarifier equals 1.7 mg.

Pounds of Aeration Tank MLSS =
Aeration Tank **mg/l MLSS x mg x 8.34**

Example:

2,500 mg/l MLSS x 1.7 mg volume x 8.34 lbs. = 35,445 lbs. MLSS

Solids Retention Time (SRT):

$$\text{SRT days} = \frac{\text{lbs./day of SS in system}}{\text{lbs./day of SS leaving system}}$$

Example:

$$\frac{\text{35,445 lbs. MLSS}}{\text{5,554.4 lbs. SS leaving system}} = 6.38 \text{ SRT}$$

Activated Sludge Calculations

F/M Ratio

Ratio of food (biochemical oxygen demand) entering the aeration tank to microorganisms in the tank.

F/M Ratio:

$$\frac{\text{lbs./BOD}}{\text{lbs. MLSS}}$$

Example:

lbs. of BOD entering plant daily = 4,340 lbs.
lbs. of MLSS in aerator = 8,201 lbs.

$$\frac{\text{lbs. BOD}}{\text{lbs. MLSS}} \text{ or } \frac{\text{4,340 lbs. of BOD entering plant daily}}{\text{8,201 lbs. of MLSS in aerator}} = .53 \text{ F/M}$$

MLSS Concentration in Pounds

Pounds of MLSS in the aeration system.

MLSS Concentration:
MLSS (mg/l) x volume of aeration tank x 8.34

Example:

MLSS in aeration tank = 2,500 mg/l
Aeration system volume = 1.4 mg

MLSS (mg/l) x volume of aeration tank x 8.34
2,500 mg/l x 1.4 x 8.34 = 29,190 lbs. of MLSS

Solids to be Wasted

Solids (measured in pounds) to be wasted over a set period of time (typically daily).

Solids to be Wasted:

Current inventory
- Desired inventory to achieve peak performance
= Pounds to be wasted

After calculating the MLSS Concentration (see above), use the following formula to determine the pounds of solids to be wasted.

Example:

Peak performance = 22,000 pounds of MLSS in aeration system
Current inventory = 25,000 pounds of MLSS in aeration system

25,000 pounds (current inventory)
- 22,000 pounds (desired inventory)
= 3,000 pounds to be wasted

Activated Sludge Calculations

Waste Sludge Pumping Rate

Rate at which to pump the sludge to be wasted from the system. Normally expressed in gallons per minute (gpm).

Example:

Plant Conditions:

lbs. of MLSS to be wasted = 1,400 lbs.

MLSS concentration = 5,900 mg/l

$$\frac{\textbf{lbs. to be wasted}}{\textbf{MLSS concentration x 8.34}} = \textbf{flow rate (mgd)}$$

Example:

$$\frac{\text{1,400 lbs. to be wasted}}{\text{5,900 mg/l x 8.34}} = \text{.0284 mgd wasting rate}$$

Convert million gallons per day to gallons per day:

mgd wasting rate x 1,000,000 = gpd wasting rate

Example: .0284 x 1,000,000 = 28,400 gpd

Convert gallons per day to gallons per minute (over 8 hours):

$$\frac{\textbf{gpd wasting rate}}{\textbf{480 minutes (8 hours)}}$$

Example:

$$\frac{\text{28,400 gpd}}{\text{480 minutes}} = \text{59.166 gpm}$$

Typical WWTP Operational Parameters

Process	BOD Loading, lb BOD/day per 1,000 ft. 3	MLSS, mg/l	F:M ratio, lb BOD/day per lb MLSS	Sludge Age, days	Aeration period, hr	RAS Rates, %	BOD Removal Efficiency %
Conventional	20-40	1,000-3,000	0.2 - 0.5	5 - 15	4.0 - 7.5	20 - 40	80 - 90
Step Aeration	40-60	1,500 -3,500	0.2 -0.5	5 - 15	4.0 - 7.0	30 - 50	80 - 90
Extended Aeration	10 - 20	2,000 - 8,000	0.05 - 0.2	> 20	20 - 30	50 - 100	85 - 95
High - purity oxygen	> 120	4,000 - 8,000	0.6 - 1.5	3 - 10	1.0 - 3.0	30 - 50	80 - 90

Metal Salt Addition for Phosphorus Removal

Using metal salt chemical data, theoretically calculate the amount of chemical salt solution to add in gallons per day to remove phosphorus.

* Values that need to be entered are shown in the gray boxes.

Step 1. Determine the amount of influent phosphorus to remove.

Influent flow in MGD		Influent P (mg/l)		lbs/gallon		lbs of P to remove
2	x	8	x	8.34	=	133

Step 2. Determine the pounds of metal salt in a gallon of solution knowing the specific gravity.

Specific gravity		lbs/gal		lbs metal salt/gal
1.4	x	8.34	=	11.7

Chemical	Specific Gravity
Alum	1.33
Ferric Chloride	1.441
Ferrous Chloride	1.23
Ferrous Sulfate	1.185

Step 3. Determine the pounds of actual metal in a gallon of metal salt solution with certain percentage metal content (provided by chemical supplier).

lbs metal salt/gal		% metal		lbs metal/gal metal salt solution
11.7	x	12.5	=	1.5

Step 4. Look up removal ratio for the metal salt being used.

Chemical	Removal Ratio
Alum	0.87 to1
Ferric Chloride	1.8 to 1
Ferrous Chloride	2.7 to 1
Ferrous Sulfate	2.7 to 1

Step 5. Determine the pounds of metal needed to remove the incoming pounds of phosphorus.

Removal ratio		Influent lbs of P		lbs of metal to add
1.8	x	133	=	240

Step 6. Determine the gallons of metal salt solution with a certain percentage metal content to thus add.

lbs of metal to add		lbs of metal/gal		gal/day of metal salt solution to add
240	÷	1.5	=	165

This estimate may be different than the value obtained from a calculator due to rounding differences.