ADVANCED WASTEWATER MATH

Sidney Innerebner, PhD, PE
Principal / Owner
INDIGO WATER GROUP
626 West Davies Way
Littleton, Colorado 80120
Sidney@indigowatergroup.com 303-489-9226

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Math Problem Solving Strategy

1. Read the question carefully and underline what they are asking you to find.
2. Write down the formula you need to solve the problem. Look in the front of the test booklet if necessary.
3. Fill in everything you know. Sometimes filling in what you know might require you to find something else first like area or volume.
4. Check your units! Make sure they are correct for the formula and agree with each other.
5. Convert units where needed.
6. Put the new units into the formula.
7. Solve.
8. Check the units of your answer. Are they what the question asked for?
9. Convert units if necessary.

ABC Formula/Conversion Table
for Wastewater Treatment, Industrial, Collection and Laboratory Exams

Alkalinity, as mg $CaCO_3$/L $= \dfrac{(\text{Titrant Volume, mL})(\text{Acid Normality})(50{,}000)}{\text{Sample Volume, mL}}$

Amps $= \dfrac{\text{Volts}}{\text{Ohms}}$

Area of Circle $= (0.785)(\text{Diameter}^2)$ or $(\Pi)(\text{Radius}^2)$

Area of Cone (lateral area) $= (\Pi)(\text{Radius})\sqrt{\text{Radius}^2 + \text{Height}^2}$

Area of Cone (total surface area) $= (\Pi)(\text{Radius})\left(\text{Radius} + \sqrt{\text{Radius}^2 + \text{Height}^2}\right)$

Area of Cylinder (total outside surface area) $=$ [Surface Area of End #1] + [Surface Area of End #2] + [(Π) (Diameter) (Height or Depth)]

Area of Rectangle = (Length) (Width)

Area of a Right Triangle $= \dfrac{(\text{Base})(\text{Height})}{2}$

Average (arithmetic mean) $= \dfrac{\text{Sum of All Terms}}{\text{Number of Terms}}$

Average (geometric mean) $= [(X_1)(X_2)(X_3)(X_4)(X_n)]^{1/n}$ The *n*th root of the product of *n* numbers

Biochemical Oxygen Demand (unseeded), in mg/L $= \dfrac{(\text{Initial DO, mg/L}) - (\text{Final DO, mg/L})}{\dfrac{\text{Sample Volume, mL}}{\text{Final Diluted Volume, mL}}}$

Chemical Feed Pump Setting, % Stroke $= \dfrac{(\text{Desired Flow})(100\%)}{\text{Maximum Flow}}$

Chemical Feed Pump Setting, mL/min $= \dfrac{(\text{Flow, MGD})(\text{Dose, mg/L})(3.785\ \text{L/gal})(1{,}000{,}000\ \text{gal/MG})}{(\text{Liquid, mg/mL})(24\ \text{hr/day})(60\ \text{min/hr})}$

Circumference of Circle $= (\Pi)(\text{Diameter})$

Composite Sample Single Portion $= \dfrac{(\text{Instantaneous Flow})(\text{Total Sample Volume})}{(\text{Number of Portions})(\text{Average Flow})}$

Cycle Time, min. $= \dfrac{\text{Storage Volume, gal}}{\text{Pump Capacity, gpm - Wet Well Inflow, gpm}}$

Degrees Celsius $= (\text{Degrees Fahrenheit} - 32)(^5/_9)$ or $\dfrac{(^\circ\text{F} - 32)}{1.8}$

Degrees Fahrenheit $= [(\text{Degrees Celsius})(^9/_5) + 32]$ or $[(\text{Degrees Celsius})(1.8) + 32]$

Detention Time $= \dfrac{\text{Volume}}{\text{Flow}}$ Note: Units must be compatible.

Electromotive Force (E.M.F), volts = (Current, amps) (Resistance, ohms) or E =IR

Feed Rate, lbs/day = $\frac{\text{(Dosage,mg/L)(Capacity,MGD)(8.34 lbs/gal)}}{\text{(Purity,decimal percentage)}}$

Filter Backwash Rate, gpm/sq ft = $\frac{\text{Flow, gpm}}{\text{Filter Area, sq ft}}$

Filter Backwash Rise Rate, in/minute =($\frac{\text{Backwash Rate, GPM/sq ft) (12 in/ft)}}{\text{(7.48 gal/cu ft)}}$

Filter Yield, lbs/hr/sq ft = $\frac{\text{(Solids Loading, lbs/day)(Recovery, \% / 100\%)}}{\text{(Filter Operation, hr/day) (Area, sq ft)}}$

Flow Rate, cfs = (Area, sq ft) (Velocity, ft/sec) or Q = AV where: Q = flow rate, A = area, V= velocity

Food/Microorganism Ratio = $\frac{\text{BOD}_5\text{, lbs/day}}{\text{MLVSS, lbs}}$

Force, pounds = (Pressure, psi) (Area, sq in)

Gallons/Capita/Day = $\frac{\text{Volume of Wastewater Produced, gpd}}{\text{Population}}$

Hardness, as mg $CaCO_3$/L = $\frac{\text{(Titrant Volume, mL) (1,000)}}{\text{Sample Volume, mL}}$ Only when the titration factor is 1.00 of EDTA

Horsepower, Brake (bhp) = $\frac{\text{(Flow, gpm) (Head, ft)}}{\text{(3,960) (Decimal Pump Efficiency)}}$

Horsepower, Motor (mhp) = $\frac{\text{(Flow, gpm) (Head, ft)}}{\text{(3,960) (Decimal Pump Efficiency) (Decimal Motor Efficiency)}}$

Horsepower, Water (whp) = $\frac{\text{(Flow, gpm) (Head, ft)}}{\text{3,960}}$

Hydraulic Loading Rate, gpd/sq ft = $\frac{\text{Total Flow Applied, gpd}}{\text{Area, sq ft}}$

Leakage, gpd = $\frac{\text{Volume, gallons}}{\text{Time, days}}$

Mass, lbs = (Volume, MG) (Concentration, mg/L) (8.34 lbs/gal)

Mass Flux, lbs/day = (Flow, MGD) (Concentration, mg/L) (8.34 lbs/gal)

Mean Cell Residence Time (MCRT) or Solids Retention Time (SRT), days = $\frac{\text{Aeration Tank TSS, lbs + Clarifier TSS, lbs}}{\text{TSS Wasted, lbs/day + Effluent TSS, lb/day}}$

Molarity = $\frac{\text{Moles of Solute}}{\text{Liters of Solution}}$

$$\text{Normality} = \frac{\text{Number of Equivalent Weights of Solute}}{\text{Liters of Solution}}$$

$$\text{Number of Equivalent Weights} = \frac{\text{Total Weight}}{\text{Equivalent Weight}}$$

$$\text{Number of Moles} = \frac{\text{Total Weight}}{\text{Molecular Weight}}$$

$$\text{Organic Loading Rate} = \frac{\text{Organic Load, lbs BOD}_5\text{/day}}{\text{Volume}}$$

$$\text{Organic Loading Rate-RBC, lbs BOD}_5\text{/day/1,000 sq ft} = \frac{\text{Organic Load, lbs BOD}_5\text{/day}}{\text{Surface Area of Media, 1,000 sq ft}}$$

$$\text{Organic Loading Rate-Trickling Filter, lbs BOD}_5\text{/day/1,000 cu ft} = \frac{\text{Organic Load, lbs BOD}_5\text{/day}}{\text{Volume, 1,000 cu ft}}$$

$$\text{Oxygen Uptake Rate/Oxygen Consumption Rate, mg/L/minute} = \frac{\text{Oxygen Usage, mg/L}}{\text{Time, minute}}$$

$$\text{Population Equivalent, Organic} = \frac{\text{(Flow, MGD) (BOD, mg/L) (8.34 lbs/gal)}}{\text{lbs BOD/day/person}}$$

$$\text{Recirculation Ratio-Trickling Filter} = \frac{\text{Recirculated Flow}}{\text{Primary Effluent Flow}}$$

$$\text{Reduction in Flow, \%} = \frac{\text{(Original Flow - Reduced Flow) (100\%)}}{\text{Original Flow}}$$

$$\text{Reduction of Volatile Solids, \%} = \frac{\text{(In - Out)(100\%)}}{\text{In} - (\text{In} \times \text{Out})}$$ All information (In and Out) must be in decimal form

$$\text{Removal, \%} = \frac{\text{(In} - \text{Out) (100)}}{\text{In}}$$

$$\text{Return Rate, \%} = \frac{\text{(Return Flow Rate) (100\%)}}{\text{Influent Flow Rate}}$$

$$\text{Return Sludge Rate-Solids Balance} = \frac{\text{(MLSS) (Flow Rate)}}{\text{Return Activated Sludge Suspended Solids} - \text{MLSS}}$$

$$\text{Slope, \%} = \frac{\text{Drop or Rise}}{\text{Distance}} \text{ x } 100$$

$$\text{Sludge Density Index} = \frac{100}{\text{SVI}}$$

Sludge Volume Index, mL/g = $\dfrac{(\text{SSV}_{30}\text{, mL/L})\ (1{,}000\ \text{mg/g})}{\text{MLSS, mg/L}}$

Solids, mg/L = $\dfrac{(\text{Dry Solids, grams})\ (1{,}000{,}000)}{\text{Sample Volume, mL}}$

Solids Concentration, mg/L = $\dfrac{\text{Weight, mg}}{\text{Volume, L}}$

Solids Loading Rate, lbs/day/sq ft = $\dfrac{\text{Solids Applied, lbs/day}}{\text{Surface Area, sq ft}}$

Solids Retention Time (SRT): *see* Mean Cell Residence Time (MCRT)

Specific Gravity = $\dfrac{\text{Specific Weight of Substance, lbs/gal}}{\text{Specific Weight of Water, lbs/gal}}$

Specific Oxygen Uptake Rate/Respiration Rate, (mg/g)/hr = $\dfrac{\text{OUR, mg/L/min (60 min)}}{\text{MLVSS, g/L (1 hr)}}$

Surface Loading Rate or Surface Overflow Rate, gpd/sq ft = $\dfrac{\text{Flow, gpd}}{\text{Area, sq ft}}$

Three Normal Equation = $(N_1 \times V_1) + (N_2 \times V_2) = (N_3 \times V_3)$, where $V_1 + V_2 = V_3$

Two Normal Equation = $N1 \times V_1 = N_2 \times V_2$, where N = concentration (normality), V = volume or flow

Velocity, ft/second = $\dfrac{\text{Flow Rate, cu ft / sec}}{\text{Area, sq ft}}$ or $\dfrac{\text{Distance, ft}}{\text{Time, second}}$

Volatile Solids, % = $\dfrac{(\text{Dry Solids, g} - \text{Fixed Solids, g})\ (100)}{\text{Dry Solids, g}}$

Volume of Cone = (1/3) (0.785) (Diameter^2) (Height)

Volume of Cylinder = (0.785) (Diameter^2) (Height)

Volume of Rectangular Tank = (Length) (Width) (Height)

Waste Milliequivalent = (mL) (Normality)

Watts (DC circuit) = (Volts) (Amps)

Watts (AC circuit) = (Volts) (Amps) (Power Factor)

Weir Overflow Rate, gpd/ft = $\dfrac{\text{Flow, gpd}}{\text{Weir Length, ft}}$

Wire-to-Water Efficiency, % = $\dfrac{\text{Water Horsepower, HP}}{\text{Power Input, HP or Motor HP}} \times 100$

Wire-to-Water Efficiency, % = $\dfrac{(\text{Flow, gpm})\ (\text{Total Dynamic Head, ft})\ (0.746\ \text{kw/hp})\ (100)}{(3{,}960)\ (\text{Electrical Demand, kilowatts})}$

Conversion Factors:

1 acre = 43,560 square feet
1 acre foot = 326,000 gallons
1 cubic foot = 7.48 gallons
1 cubic foot = 62.4 pounds
1 cubic foot per second = 0.646 MGD
1 foot = 0.305 meters
1 foot of water = 0.433 psi
1 gallon = 3.79 liters
1 gallon = 8.34 pounds
1 grain per gallon = 17.1 mg/L
Population Equivalent, hydraulic = 100 gallons/person/day
Population Equivalent = 0.17 lbs BOD/person/day

1 horsepower = 0.746 kW or 746 watts or 33,000 ft. lbs./min.
1 million gallons per day = 694 gallons per minute
1 million gallons per day = 1.55 cubic feet per second
1 mile = 5,280 feet
1 pound = 0.454 kilograms
1 pound per square inch = 2.31 feet of water
1 ton = 2,000 pounds
1% = 10,000 mg/L
Π or pi = 3.14

Abbreviations:

BOD	biochemical oxygen demand
CBOD	carbonaceous biochemical oxygen demand
cfs	cubic feet per second
COD	chemical oxygen demand
DO	dissolved oxygen
ft	feet
F/M ratio	food to microorganism ratio
g	grams
gpd	gallons per day
gpg	grains per gallon
gpm	gallons per minute
in	inches
kW	kilowatt
lbs	pounds
mg/L	milligrams per liter
MCRT	mean cell residence time
MGD	million gallons per day
mL	milliliter
MLSS	mixed liquor suspended solids
MLVSS	mixed liquor volatile suspended solid
OCR	oxygen consumption rate
ORP	oxygen reduction potential
OUR	oxygen uptake rate
ppb	parts per billion
ppm	parts per million
psi	pounds per square inch
PE	population equivalent
Q	flow
RAS	return activated sludge
RBC	rotating biological contactor
SDI	sludge density index
SRT	solids retention time
SS	settleable solids
SSV_{30}	settled sludge volume 30 minute
SVI	sludge volume index
TOC	total organic carbon
TS	total solids
TSS	total suspended solids
VS	volatile solids
WAS	waste activated sludge

Activated Sludge Math Problems

Without a lot of pesky conversions and tank volume calculations

Influent Flow = 20 MGD
BOD5 = 250 mg/L
NH3-N = 30 mg/L
Effluent TSS = 5 mg/L

A-basin = 6 MG
MLSS = 3,000 mg/L
Clarifier = 2 mg
Core TSS = 600 mg/L
WAS = 7,500 mg/L
WAS pump = 110 gpm

1. Calculate the hydraulic detention time of the aeration basin. Then, calculate the hydraulic retention time of the clarieifier. Express your answer in hours.

2. Find F:M

3. Calculate the Sludge Age

4. If the target MCRT is 10 days, should wasting be increased or decreased? How much?

5. Assume that a total of four aeration basins make up the 6 MG of volume. If one basin is taken off-line and the MLSS concentration does not change, what will the new F:M be?

6. If there are two clarifiers and they are both 75 feet in diameter, what is the surface overflow rate?

7. Find the weir loading rate for the clarifiers.

8. An activated sludge plant receives a flow rate of 2 mgd with a BOD of 240 mg/L. If the desired F:M ratio is 0.4 and the primary clarifiers remove about 30% of the influent BOD, how many pounds of MLVSS should be maintained in the process?

9. In an aeration tank, the MLSS concentration is 2,500 mg/L. The settled sludge volume after 30 minutes is 230 mL. What is the sludge volume index?

1. Find the solids retention time for an aerobic digester that is 100 feet long by 40 feet wide by 12 feet deep. The digester is full and the solids in the digester are 2% total solids. The digester is decanted daily at a rate of 2,000 gallons per day. The decant liquid contains 400 mg/L of solids on average. Solids are removed from the digester for ultimate disposal at a rate of 4000 gallons per day.

2. An anaerobic digester is maintained at 95 degrees Fahrenheit. If the SRT is 40 days, how many degree days are the biosolids digested?

3. MLSS is pumped to an aerobic digester. The MLSS is 3,000 mg/L and contains 80% volatile suspended solids. The digester contains solids at 1.82% total solids. Biosolids withdrawn from the digester are 67% volatile solids. What was the percent VSS reduction through the digestion process?

4. An activated sludge process has three aeration basins. Each basin is 100 feet long, 35 feet wide, and 12 feet deep. The MLSS concentration is 2800 mg/L. There are two clarifiers. Each clarifier is 35 feet in diameter and 12 feet deep. A clarifier core sample indicates that the solids concentration in the clarifier is equivalent to 500 mg/L. If the RAS/WAS concentration is 6,000 mg/L, find the WAS pumping rate in gallons per day to maintain a sludge age of 15 days.

5. If the WAS pump in problem #5 only operates for 15 minutes out of each hour, what should the pump rate be in gpm?

6. A water plant is fed by two wells. Water from the first well has an arsenic concentration of 60 ug/L. Water from the second well has an arsenic concentration of 3 ug/L. If the total water production desired is 60,000 gpd, what is the maximum pumping rate that can be allowed for the first well if the arsenic concentration in the finished water needs to be 25 ug/L or less?

7. The liquid train for a 4.0 mgd WWTP consists of screening, grit removal, primary clarification, activated sludge, secondary clarifiers, and disinfection. The influent contains 350 mg/L of BOD. If the primary clarifiers remove 47% of the BOD, what is the load to the secondary process?

8. If the treatment plant in problem #7 has two aeration basins with a combined volume of 1.25 mgd, what should the MLSS concentration be to maintain an F:M ratio of 0.10?

9. A WWTP produces 240 dry tons of biosolids per year. The biosolids are land applied to a quarter section (160 acres). Lab results indicate that the concentration of Cadmium in the biosolids is 22 mg/kg. What is the annual cadmium loading rate to the site? Express your answer as lbs Cd/acre.

10. Estimate the sludge pumping time in minutes per day for a primary sludge pump removing 100 gpm of sludge at 5% total solids from a primary tank receiving a flow of 5.0 mgd. Primary influent contains 200 mg/L of TSS and the primary effluent contains 70 mg/L of TSS.

11. Calculate the volatile solids loading rate in lbs/day/cf for a conical bottomed, cylindrical anaerobic digester receiving 13,000 gpd of sludge that is 5% solids. Assume the solids are 75% volatile. The digester is 40 feet in diameter. The cylindrical portion of the digester has a liquid depth of 25 feet. The cone is 10 feet deep at its deepest point.

12. Find the motor horsepower for a pump discharging 5.0 mgd against a total head of 15 feet. Assume that the pump is 70 percent efficient and the motor is 90 percent efficient.

13. A belt filter press receives a feed sludge at 3% total solids and produces a cake that is 20% total solids. If the influent flow rate to the press is 50 gpm, what will the volume of cake produced be if the press runs for 8 hours?

14. A treatment plant has 4 grit basins operated in parallel. Each grit basin is 2.5 feet wide, 2 feet deep, and 10 feet long. The influent flow is 4.0 mgd. What is the minimum number of grit basins that should be in service to maintain a velocity less than 1.0 fps?

15. A single-piston reciprocating pump has a 6-inch diameter piston and a 12-inch stroke. The pump makes 22 strokes per minute. What is the pumping rate in gpm?

16. A 25 hp pump is used to dewater a lake. If the pump runs for 8 hours a day, seven days a week, how much will is cost to run the pump for six weeks? Assume energy costs of $0.07 per kilowatt hour.

17. How many gallons of sodium hypchlorite (bleach) is required to obtain a residual of 100 mg/L in a well? The casing diameter is 18-inches and the length of the water filled casing is 180 feet. Sodium hypochlorite contains 5.25% available chlorine. Assume a demand of 15 mg/L.

18. A treatment plant uses sulfur dioxide to dechlorinate effluent. An operator needs to adjust the sulfonator so that the dosing concentration is 1.5 mg/L more than the chlorine residual. Based on the following information, what should the sulfonator feed rate be in pounds per day? Design flow = 5 mgd, Chlorine dosage rate = 4 mg/L, Chlorine residual = 0.9 mg/L.

19. A 2.5 mgd activated sludge process has two aeration basins. Each basin is 150 feet long, 55 feet wide, and 12 feet deep. The MLSS concentration is 3500 mg/L. There are two clarifiers. Each clarifier is 45 feet in diameter and 15 feet deep. A clarifier core sample indicates that the solids concentration in the clarifier is equivalent to 500 mg/L. The final effluent TSS is 25 mg/L. If the RAS/WAS concentration is 7,500 mg/L, find the WAS pumping rate in gallons per day to maintain a sludge age of 18 days.

20. For the plant in problem #19, assume an influent BOD concentration of 300 mg/L. If the desired F:M ratio is 0.20, should wasting be increased or decreased?

21. Wastewater influent contains 30 mg/L of ammonia, 250 mg/L of BOD and TSS, and 280 mg/L of alkalinity. If the final effluent contains 1 mg/L of ammonia and 12 mg/L of nitrate, what is the theoretical concentration of alkalinity?

22. A treatment plant aeration basin holds 2 million gallons. If the influent flow is 8 mgd and the BOD concentration is 350 mg/L, what is the space loading? Express your answer as pounds of BOD per 1000 cf.

23. A lift station has a 12-inch shut off valve located outside to isolate the force main for repairs. The water pressure inside the line is 75 psi. Find the amount of force in tons exerted on the valve if the lift station pumps start while it is in the closed position.

24. MLSS is pumped to an anaerobic digester. The MLSS is 3,000 mg/L and contains 83% volatile suspended solids. The digester contains solids at 2.3% total solids. Biosolids withdrawn from the digester are 67% volatile solids. What was the percent VSS reduction through the digestion process?

25. Given the following information, find the solids loading rate to the secondary clarifier.
    MLSS = 2500 mg/L   Influent Flow = 2 mgd
    RAS = 6000 mg/L   RAS = 70% of influent flow
    Secondary clarifier is 65 feet in diameter and 12 feet deep.

26. A small treatment plant has decided to accept septic waste. The plant currently receives about 0.8 mgd of flow with an influent ammonia concentration of 35 mg/L. If the treatment plant accepts 3 loads of septic waste per day at 3,000 gallons each, what will the new influent ammonia concentration become? Assume an ammonia concentration of 450 mg/L.

27. Ferric chloride is added to precipitate phosphorus in the clarifier wet well. The ferric chloride is delivered as a concentrated solution at 47% ferric chloride. The desired dose in the floc well is 30 mg/L. If the influent flow to the clarifier is 80,000 gpm, find the chemical dose rate in gallons per day.

28. Liquid alum contains 642.3 milligrams of aluminum per milliliter of solution. Jar tests indicate that the best alum dose for phosphorus removal is 9 mg/L. Determine the setting on the liquid alum feeder in ml/min when the plant flow is 3.2 mgd.

29. An anaerobic digester is in start-up mode. The digester is 40 feet in diameter and 25 feet tall. The digester is equipped with a boiler capable of putting out 140,000 BTUs per hour. If the current digester temperature is 70 degrees Fahrenheit and the desired operating temperature is 95 degrees Fahrenheit, how many hours will the boiler run? Assume the digester contents have a specific gravity of 1.12.

30. A treatment plant has one aeration basin and one clarifier. The aeration basin holds 300,000 gallons and the clarifier holds 60,000 gallons. The MLSS concentration is 2500 mg/L, the RAS and WAS concentrations are 7,000 mg/L, and the clarifier core concentration is 600 mg/L. Find the SRT if the WAS pump operates continuously at 10 gpm.

31. An operator needs to collect a composite effluent sample for permit compliance. They collect a total of four grab samples at 8:00 am, 10:00 am, noon, and 2:00 pm. The average daily flow for the facility is 1.5 mgd. The desired composite sample volume is 2 liters. If the instantaneous flow at noon is 1.75 mgd, what will the aliquot size be, in milliliters, for that time?

32. A treatment plant headworks wet well is filling at a rate of 60 gpm. The influent pump is capable of discharging 500 gpm. The wet well is 10 feet deep and 15 feet in diameter. What is the pump cycle time in minutes?

33. A treatment plant does not have flow monitoring on their Return Activated Sludge line. The operator wants to know what the percent RAS rate is relative to the influent flow. Calculate the RAS rate given the following information: MLSS concentration is 2500 mg/L, influent flow is 4.0 mgd, RAS concentration is 7,000 mg/L, WAS concentration is 7,200 mg/L, WAS pump rate is 60 gpm.

34. Calculate the Sludge Volume Index (SVI) for two different operating conditions. In situation one, the MLSS concentration is 3,000 mg/L and the settled sludge volume after 30 minutes (SSV30) is 250 mL. In situation two, the MLSS concentration is 8,000 mg/L and the SSV30 is 980 mL.

35. Find the surface overflow rate for a secondary clarifier that is 120 feet in diameter when the influent flow is 120 gpm.

1. $SRT = \frac{\text{Solids in Digester}}{\text{Solids Leaving}}$ 1% = 10,000 mg/L

Volume = L × W × H
Volume = (100 ft)(40 ft)(12 ft)
Volume = 48000 cf

$$48000\ \text{cf} \left| \frac{7.48\ \text{gal}}{1\ \text{cf}} \right| \frac{1\ \text{MG}}{1000000\ \text{gal}} \right| = 0.359\ \text{mg}$$

lbs in Digester = (mg/L)(Q, mgd)(8.34)
= (20,000 mg/L)(0.359 mg)(8.34)
= 59,881.2 lbs

lbs in Decant = (mg/L)(Q, mgd)(8.34)
= (400 mg/L)(0.002 mgd)(8.34)
= 6.67 lbs

lbs for Disposal = (mg/L)(Q, mgd)(8.34)
= (20,000 mg/L)(0.004 mgd)(8.34)
= 667.2 lbs

$$SRT = \frac{\text{lbs in digester}}{\text{lbs leaving}}$$

$$SRT = \frac{59881.2\ \text{lbs}}{667.2\ \text{lbs} + 6.67\ \text{lbs}}$$

SRT = 88.9 DAYS

2. DEGREE DAYS $= (°C \times SRT, \text{days})$

$$°F = \frac{9}{5}°C + 32$$

$$95°F = \frac{9}{5}°C + 32$$

$$95°F - 32 = \frac{9}{5}°C + 32 - 32$$

$$63° = \frac{9}{5}°C$$

$$\frac{5}{9}(63°) = \left[\frac{9}{5}°C\right]\frac{5}{9}$$

$$35 = °C$$

* could also convert $\frac{9}{5}$ to 1.8

DEGREE DAYS $= (°C \times SRT)$

$$= (35°C \times 40 \text{ days})$$

$$= 1400$$

3. % VSS REDUCTION $= \left[\frac{IN - OUT}{IN - (IN)(OUT)}\right] * 100$

$$\% \text{ VSS REDUCTION} = \left[\frac{0.8 - 0.67}{0.8 - (0.8)(0.67)}\right] * 100$$

$$\% \text{ VSS REDUCTION} = \left[\frac{0.13}{0.8 - 0.536}\right] * 100$$

$$\% \text{ VSS REDUCTION} = \left[\frac{0.13}{0.264}\right] * 100$$

$$\% \text{ VSS REDUCTION} = 49.2$$

4. $$\text{MCRT} = \frac{\text{lbs MLSS in system}}{\text{lbs MLSS leaving system}}$$

a. Volume A-basins = $L \times W \times H$

$= (100\text{ ft})(35\text{ ft})(12\text{ ft})$

$= 42{,}000\text{ cf}$

multiply by 3 for three basins = 126,000 cf total

$$126{,}000\text{ cf}\,\left|\,\frac{7.48\text{ gal}}{1\text{ cf}}\,\right|\,\frac{1\text{ MG}}{1000000\text{ gal}}\,\right| = 0.942\text{ mg}$$

b. Volume Clarifiers = $0.785d^2h$

$= (0.785)(35\text{ ft})^2(12\text{ Ft})$

$= 11539.5\text{ ft}^3$

multiply by 2 for two clarifiers = 23,079 cf total

$$23{,}079\text{ cf}\,\left|\,\frac{7.48\text{ gal}}{1\text{ cf}}\,\right|\,\frac{1\text{ mg}}{1000000\text{ gal}}\,\right| = 0.173\text{ mg}$$

c. lbs in A-basin = (mg/L)(mg)(8.34)

$= (2800\text{ mg/L})(0.942\text{ mg})(8.34)$

$= 21{,}997.5\text{ lbs}$

d. lbs in Clarifiers = (mg/L)(mg)(8.34)

$= (500\text{ mg/L})(\overset{0.173}{\text{mg}})(8.34)$

$= 721.4\text{ lbs}$

e. $$\text{MCRT} = \frac{\text{lbs A·basin} + \text{lbs Clarifier}}{\text{lbs WAS} + \text{lbs Effluent}}$$

$$15 \text{ days} = \frac{21{,}997.5 \text{ lbs} + 721.4 \text{ lbs}}{\text{lbs WAS} + 0}$$

we assume zero since we don't know

$$15 \text{days} = \frac{22718.9 \text{ lbs}}{\text{lbs WAS}}$$

$$1514.6 = \text{lbs WAS}$$

f. $$\text{lbs WAS} = (\text{mg/L})(\text{mgd})(8.34)$$

$$1514.6 \text{ lbs} = (6000 \text{ mg/L})(\text{mgd})(8.34)$$

$$\frac{1514.6 \text{ lbs}}{(6000 \text{ mg/L})(8.34)} = \text{mgd}$$

$$0.00303 = \text{mgd}$$

g. $$\frac{0.00303 \text{ mg}}{\text{day}} \Big| \frac{1000000 \text{ gal}}{1 \text{ mg}} \Big| = \boxed{30{,}268 \text{ gal/day}}$$

A review of the steps

- a+b find volumes of basin + clarifiers in gallons
- c+d find lbs of MLSS in basins + clarifiers
- e find lbs of WAS
- f back out mg of WAS
- g convert units

5. If the pump runs 15 minutes of every hour, the pump rate should be 4 times the average daily rate.

$$30{,}268\,\frac{\text{gal}}{\text{day}}\left|\frac{1\text{ day}}{1440\text{ min}}\right| = 21\,\frac{\text{gal}}{\text{min}} \text{ average}$$

$$21\text{ gpm} * 4 = 84\text{ gpm}$$

6. basic formula is

$$C_1V_1 + C_2V_2 = C_3V_3$$

we can only solve equations with 1 unknown, so we have to turn V_2 into something that looks like V_1

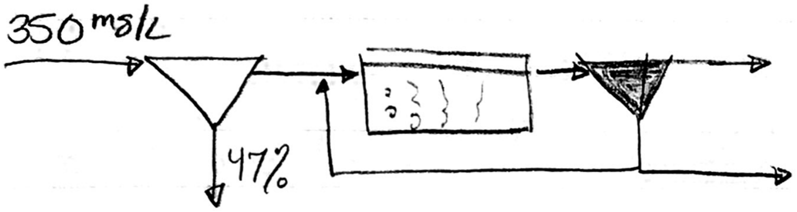
We know that $V_1 + V_2 = V_3$

50000 $V_2 = V_3 - V_1$

$$C_1V_1 + C_2V_2 = C_3V_3$$
$$C_1V_1 + C_2(V_3 - V_1) = C_3V_3$$
$$(60\,\mu g/L)(V_1) + (3\,\mu g/L)(60{,}000\text{ gpd} - V_1) = (25\,\mu g/L)(60{,}000)$$
$$60V_1 + 180{,}000 - 3V_1 = 1{,}500{,}000$$
$$57V_1 + 180{,}000 = 1{,}500{,}000$$
$$57V_1 = 1{,}320{,}000$$
$$V_1 = 23{,}158\text{ gpd}$$

WELL 1 = 23,158 gpd
WELL 2 = 36,842 gpd

7.



$$100\% - 47\% = 53\%$$

$(350 \text{ mg/L})(0.53) = 185.5 \text{ mg/L}$ to a-basin

$$\text{lbs/day} = (\text{mg/L})(\text{mgd})(8.34)$$
$$\text{lbs/day} = (185.5 \text{ mg/L})(4.0 \text{ mgd})(8.34)$$
$$\text{lbs/day} = 6{,}188$$

8.

$$\frac{F}{M} = \frac{\text{lbs BOD}}{\text{lbs MLSS}}$$
$$0.10 = \frac{6{,}188 \text{ lbs BOD}}{\text{lbs MLSS}}$$
$$(0.10)(\text{lbs MLSS}) = 6{,}188 \text{ lbs BOD}$$
$$\text{lbs MLSS} = 61{,}880$$

$$\text{lbs MLSS} = (\text{mg/L})(\text{mgd})(8.34)$$
$$61{,}880 = (\text{mg/L})(1.25 \text{ mgd})(8.34)$$

$$\frac{61{,}880}{(1.25)(8.34)} = \text{mg/L}$$
$$5{,}935 = \text{mg/L}$$

YIKES!

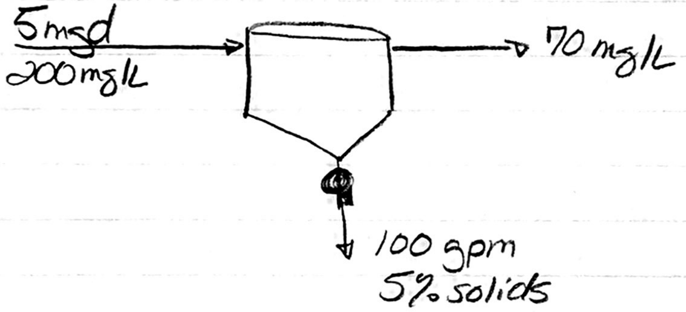
9. a complicated unit conversion

$$\frac{240 \text{ tons}}{160 \text{ acres}} \Bigg| \frac{2000 \text{ lbs biosolids}}{1 \text{ ton biosolids}} \Bigg| \frac{1 \text{ kg biosolids}}{2.2 \text{ lbs biosolids}} \Bigg| \frac{22 \text{ mg Cd}}{1 \text{ kg biosolids}} \Bigg| = 30{,}000 \ \frac{\text{mg Cd}}{\text{acre}}$$

then

$$30{,}000 \ \frac{\text{mg Cd}}{\text{acre}} \Bigg| \frac{1 \text{ g}}{1000 \text{ mg}} \Bigg| \frac{1 \text{ kg}}{1000 \text{ g}} \Bigg| \frac{2.2 \text{ lbs}}{1 \text{ kg}} \Bigg| = 0.066 \ \frac{\text{lbs Cd}}{\text{acre}}$$

10.



find lbs of solids going to bottom of clarifier

lbs = (mg/L)(mgd)(8.34)
lbs = (200 − 70)(5 mgd)(8.34)
lbs = (130)(5)(8.34)
lbs = 5,421

now find total gallons to pump
lbs = (mg/L)(mgd)(8.34)
5,421 = (50,000 mg/L)(mgd)(8.34)
0.013 = mgd

↳ SAME AS 13,000 gpd

Pump rate is 100 gpm

$$\frac{13{,}000 \text{ gallons total}}{100 \text{ gpm}} = 130 \text{ minutes}$$

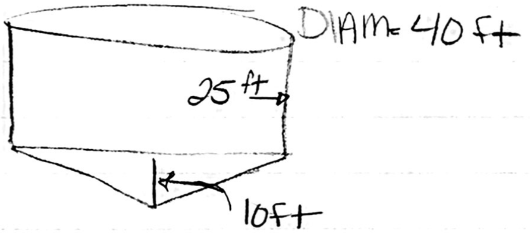
$$130 \text{ minutes} \left| \frac{1 \text{ hr}}{60 \text{ min}} \right| = \boxed{\begin{gathered}2.17 \text{ hours} \\ \text{OR} \\ 2 \text{ hrs } 10 \text{ minutes}\end{gathered}}$$

11. lbs = (mg/L)(mgd)(8.34)

lbs VSS = (50,000 mg/L)(0.75)(0.013 mgd)(8.34)

lbs VSS = 4065.75

this turns lbs solids into lbs VSS



$$V_{CYLINDER} = 0.785 d^2 h$$
$$= (0.785)(40 ft)^2 (25 ft)$$
$$= 31{,}400 \text{ cf}$$

$$V_{CONE} = \frac{0.785 d^2 h}{3}$$
$$= \frac{(0.785)(40')^2 (10')}{3}$$
$$= 4187 \text{ cf}$$

$$V_{TOTAL} = V_{CYLINDER} + V_{CONE}$$

$$V_{TOTAL} = 31{,}400 \text{ cf} + 4{,}187 \text{ cf}$$

$$V_{TOTAL} = 35{,}581 \text{ cf}$$

Pump rate is 100 gpm

$$\frac{13{,}000 \text{ gallons total}}{100 \text{ gpm}} = 130 \text{ minutes}$$

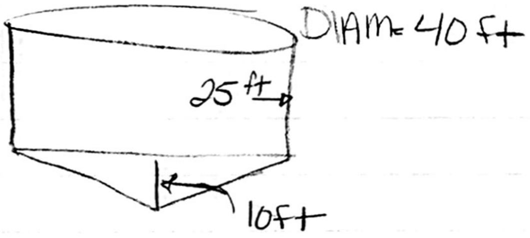
$$130 \text{ minutes} \left| \frac{1 \text{ hr}}{60 \text{ min}} \right| = \boxed{\begin{matrix} 2.17 \text{ hours} \\ \text{OR} \\ 2 \text{ hrs } 10 \text{ minutes} \end{matrix}}$$

11. $\text{lbs} = (\text{mg/L})(\text{mgd})(8.34)$

$\text{lbs VSS} = (50{,}000 \text{ mg/L})(0.75)(0.013 \text{ mgd})(8.34)$

$\text{lbs VSS} = 4065.75$

this turns lbs solids into lbs VSS



$V_{\text{CYLINDER}} = 0.785 d^2 h$

$= (0.785)(40\text{ft})^2(25\text{ft})$

$= 31{,}400 \text{ cf}$

$V_{\text{CONE}} = \dfrac{0.785 d^2 h}{3}$

$= \dfrac{(0.785)(40')^2(10')}{3}$

$= 4187 \text{cf}$

$V_{\text{TOTAL}} = V_{\text{CYLINDER}} + V_{\text{CONE}}$

$V_{\text{TOTAL}} = 31{,}400 \text{cf} + 4{,}187 \text{cf}$

$V_{\text{TOTAL}} = 35{,}581 \text{cf}$

lbs VSS = 406.6

V_{TOTAL} = 35,587 cf

$$\text{VSS Loading} = \frac{4065.75\text{ lbs}}{35{,}587\text{ cf}}$$

= 0.11 lbs VSS/cf

pretty typical for an anaerobic digester

12. Pump formula only works with gpm. Convert

$$5.0\,\frac{mg}{day}\left|\frac{1000000\text{ gal}}{1\text{ mg}}\right|\frac{1\text{ day}}{1440\text{ min}}\right| = 3472\,\frac{gal}{min}$$

$$HP_{MOTOR} = \frac{(gpm)(head, ft)}{(3960)(E_p)(E_m)}$$

$$HP_{MOTOR} = \frac{(3472\text{ gpm})(15\text{ ft})}{(3960)(0.70)(0.90)}$$

$$HP_{MOTOR} = 20.88$$

13. $50\,\frac{gal}{min}\left|\frac{60\,min}{1\,hr}\right| = 3{,}000\,\frac{gal}{hr}$

eight hours gives $(8)(3{,}000) = 24{,}000$ gallons goin into belt press

$$C_1V_1 = C_2V_2$$

$$(3\%)(24{,}000\,gal) = (20\%)(V_2)$$

$$\frac{(3\%)(24{,}000\,gal)}{20\%} = V_2$$

$$3{,}600\,gal = V_2$$

$3{,}600\,gal = 481\,cf = 17.8$ cubic yards

14. The easiest way to do this problem is to find the velocity if all the flow goes through 1 basin

$$4.0\,\frac{mg}{day}\left|\frac{1000000\,gal}{1\,mg}\right|\frac{1\,cf}{7.48\,gal}\left|\frac{1\,day}{1440\,min}\right|\frac{1\,min}{60\,sec}\right| = 6.19\,\frac{cf}{s}$$

$$velocity = \frac{flow}{area}$$

$$velocity = \frac{6.19\,cfs}{(2.5\,ft)(2\,ft)}$$

Note: area is the cross section of the basin

$$velocity = 1.23\,ft/s$$

therefor $\therefore$ 2 basins needed

15. 6 inches = 0.5 ft
12 inches = 1.0 ft } convert because square inches aren't useful

find volume per stroke

$$V = 0.785 d^2 h$$
$$V = (0.785)(0.5\text{ ft})^2(1.0\text{ ft})$$
$$V = 0.19625\text{ ft}^3$$

$$\frac{0.19625\text{ cf}}{\text{stroke}} \Big| \frac{22\text{ strokes}}{1\text{ min}} \Big| \frac{7.48\text{ gal}}{1\text{ cf}} \Big| = 32.3 \frac{\text{gal}}{\text{min}}$$

16. find hours of run time
8 hrs/day × 7 days/week = 56 hours/week

6 weeks × 56 hrs/week = 336 hours

$$25\text{ HP} \Big| \frac{0.746\text{ kw}}{1\text{ HP}} \Big| \frac{\$0.07}{1\text{ kwh}} \Big| \frac{336\text{ hrs}}{} \Big| = \$438.65$$

17. We will use the ppd formula to find out how much bleach we need. First, we need volume in mg.

18 inches = 1.5 ft

$$V = 0.785 d^2 h$$
$$V = (0.785)(1.5\text{ ft})^2(180\text{ ft})$$
$$V = 317.925\text{ cf}$$

$$317.925\text{ cf} \Big| \frac{7.48\text{ gal}}{1\text{ cf}} \Big| \frac{1\text{ MG}}{1000000\text{ gal}} \Big| = 0.0024\text{ MG}$$

$$ppd = \frac{(mg/L)(MG)(8.34)}{\%\ PURITY}$$

$$ppd = \frac{(100 + 15\ mg/L)(0.0024\ MG)(8.34)}{0.0525}$$

$$ppd_{BLEACH} = 43.8$$

they asked for gallons

$$43.8\ ppd\ bleach \left| \frac{1\ gal}{8.34\ lbs} \right| = 5.25\ gallons$$

18. Chlorine residual = 0.9 mg/L

Sulfonator dose = Chlorine Residual + 1.5 mg/L

= 0.9 + 1.5 mg/L

= 2.4 mg/L

$$ppd = (mg/L)(mgd)(8.34)$$

$$ppd = (2.4\ mg/L)(5\ mgd)(8.34)$$

$$ppd = 100$$

19. $V_{BASIN} = L \times W \times H$
$V_{BASIN} = (150 \text{ ft})(55 \text{ ft})(12 \text{ ft})$
$V_{BASIN} = 99000 \text{ ft}^3$

2 BASINS, SO 2x 99,000 = 198,000 cf

$$198{,}000 \text{ cf} \left| \frac{7.48 \text{ gal}}{1 \text{ cf}} \right| \frac{1 \text{ MG}}{1000000 \text{ gal}} \right| = 1.48 \text{ mg}$$

lbs A-basin = (mg/L)(mg)(8.34)
lbs A-basin = (3500 mg/L)(1.48 mg)(8.34)
lbs A-basin = 43,201

$V_{CLARIFIER} = 0.785 d^2 h$
$V_{CLARIFIER} = (0.785)(45 \text{ ft})^2(15 \text{ ft})$
$V_{CLARIFIER} = 23{,}844 \text{ ft}^3$

2 CLARIFIERS, SO 2x 23,844 = 47,688 cf

$$47{,}688 \text{ cf} \left| \frac{7.48 \text{ gal}}{1 \text{ cf}} \right| \frac{1 \text{ MG}}{1000000 \text{ gal}} \right| = 0.357 \text{ mg}$$

lbs CLARIFIER = (mg/L)(MG)(8.34)
lbs CLARIFIER = (500 mg/L)(0.357 MG)(8.34)
lbs CLARIFIER = 1488.69
= 1489 lbs

Since MLVSS was not available, just use MLSS. The MLVSS/MLSS ratio for a given facility tends to be fairly constant.

$$\text{MCRT} = \frac{\text{lbs A-Basin} + \text{lbs Clarifier}}{\text{lbs WAS}}$$

$$18\ \text{days} = \frac{43{,}201\ \text{lbs} + 1489\ \text{lbs}}{\text{lbs WAS}}$$

$$18\ \text{days} = \frac{44690\ \text{lbs}}{\text{lbs WAS}}$$

$$(18\ \text{days})(\text{lbs WAS}) = 44690\ \text{lbs}$$

$$\text{lbs WAS} = 2482.78$$

now, back out the volume of WAS from the lbs formula

$$\text{lbs WAS} = (\text{mg/L})(\text{MGD})(8.34)$$

$$2482.78\ \text{lbs} = (7{,}500\ \text{mg/L})(\text{MG})(8.34)$$

$$\frac{2482.78}{(7500)(8.34)} = \text{MGD}$$

$$0.03969 = \text{MGD}$$

which is 39,692 $\frac{\text{gallons}}{\text{day}}$

20. $\text{lbs BOD} = (\text{mg/L})(\text{MGD})(8.34)$

$\text{lbs BOD} = (300\ \text{mg/L})(2.5\ \text{mgd})(8.34)$

$\text{lbs BOD} = 6255$

have 43,201 lbs MLSS in Basin
6255 lbs BOD

$$\frac{F}{M} = \frac{\text{lbs BOD}}{\text{lbs MLSS}}$$

$$\frac{F}{M} = \frac{6255 \text{ lbs BOD}}{43201 \text{ lbs MLSS}}$$

$$\frac{F}{M} = 0.14$$

if we want an $\frac{F}{M}$ of 0.2, we need less MLSS in the basin

SO . . . INCREASE wasting

21. Nitrification consumes 7.14 mg/L of alkalinity for every mg/L of ammonia

30 mg/L IN − 1 mg/L OUT = 29 mg/L
nitrified

USED = (29 mg/L)(7.14 mg/L) = 207.06 mg/L Alkalinity

Denitrification produces 3.57 mg/L
of [illegible] for every mg/L of nitrate
alkalinity

turned into nitrogen gas

29 mg/L NO_3 made − 12 mg/L EFF = 17 mg/L
Denitrified

alkalinity produced = $(17\ \text{mg/L}\ NO_3)(3.57\ \text{mg/L})$
alkalinity produced = 60.7 mg/L

INFLUENT ALKALINITY = 280 mg/L
CONSUMED = −207.1 mg/L
PRODUCED = + 60.7 mg/L

EFFLUENT ALKALINITY = 133.6 mg/L

22. SPACE LOADING = $\dfrac{\text{lbs BOD}}{1000\ \text{cf}}$

$$2\ \text{mg}\left|\frac{1000000\ \text{gal}}{1\ \text{mg}}\right|\frac{1\ \text{cf}}{7.48\ \text{gal}}\Big| = 267{,}380\ \text{cf}$$

or

$$267.38 \times 1000\ \text{cf}$$

lbs BOD = (mg/L)(mgd)(8.34)
lbs BOD = (350 mg/L)(8 mgd)(8.34)
lbs BOD = 23,352

$$\text{SPACE LOADING} = \frac{\text{lbs BOD}}{1000\ \text{cf}}$$

$$= \frac{23{,}352\ \text{lbs BOD}}{267.38 \times 1000\ \text{cf}}$$

$$= 87\ \text{lbs BOD}/1000\ \text{cf}/\text{day}$$

NORMAL RANGE IS
5 - 15 for extended aeration
20 - 40 for conventional system

23. FORCE = PRESSURE × AREA

force is one of the only times we'll use square inches for area.

$$
\begin{aligned}
\text{AREA} &= 0.785d^2 \\
&= (0.785)(12\ \text{inches})^2 \\
&= 113\ \text{in}^2
\end{aligned}
$$

$$
\begin{aligned}
\text{FORCE} &= \text{PRESSURE} \times \text{AREA} \\
&= (75\ \text{lbs/in}^2)(113\ \text{in}^2) \\
&= 8475\ \text{lbs}
\end{aligned}
$$

$$8475\ \text{lbs} \left| \frac{1\ \text{ton}}{2000\ \text{lbs}} \right| = 4.2\ \underline{\underline{\text{tons}}}\ \text{of force}$$

24.

$$\%VSS = \left[\frac{In - Out}{In - (In)(Out)}\right] * 100$$

$$\%VSS = \left[\frac{0.83 - 0.67}{0.83 - (0.83)(0.67)}\right] * 100$$

$$\%VSS = \left[\frac{0.16}{0.83 - 0.5561}\right] * 100$$

$$\%VSS = 58.4$$

25. The clarifier actually has 2 influent flows
- the Influent wastewater
- the RAS

both flows push solids (MLSS) out of the a-basin

$$\text{lbs MLSS} = (Q_{INF} + Q_{RAS})(\text{MLSS, mg/L})(8.34)$$

$$\text{lbs MLSS}_{\text{to Clarifier}} = (2\,\text{MGD} + 1.4\,\text{MGD})(2500\,\text{mg/L})(8.34)$$

$$= 70{,}890\ \text{lbs/day}$$

$$\text{Area of Clarifier} = 0.785\,d^2$$

$$= (0.785)(65\,\text{ft})^2$$

$$= 3316.6\ \text{ft}^2$$

$$\text{solids load} = \frac{\text{lbs MLSS to clarifier}}{\text{clarifier area}}$$

$$= \frac{70{,}890\ \text{lbs/day}}{3316.6\,\text{ft}^2}$$

$$= 21.4\ \text{lbs/ft}^2\cdot\text{day}$$

26. $(3{,}000 \text{ gallons})(3) = 9{,}000 \text{ gallons}$

$= 0.009 \text{ MG}$

$C_1V_1 + C_2V_2 = C_3V_3$

$(35 \text{ mg/L})(0.8 \text{ mgd}) + (450 \text{ mg/L})(0.009 \text{ MG}) = (0.809 \text{ MG})(C_3$

$28 + 4.05 = (0.809 \text{ MG})(C_3)$

$32.05 = (0.809 \text{ MG})(C_3)$

$39.6 \text{ mg/L} = C_3$

27. $47\% \left| \frac{10.000 \text{ mg/L}}{1\%} \right| = 470{,}000 \text{ mg/L}$

$\frac{80{,}000 \text{ gal}}{\text{min}} \left| \frac{1440 \text{ min}}{1 \text{ day}} \right| = 115{,}200{,}000 \frac{\text{gal}}{\text{day}}$

$C_1V_1 = C_2V_2$

$(470{,}000 \text{ mg/L})(V_1) = (30 \text{ mg/L})(115{,}200{,}000 \text{ gal/d})$

$V_1 = \frac{(30)(115\,200000)}{470000}$

$V_1 = 7{,}353 \text{ gal/day}$

OR

5.1 gpm

28. there is a special formula for this problem AND the certification exam gives it to us in the front of the test booklet

$$\text{FeedPump}\ {}^{\text{mL}}/_{\text{min}} = \frac{(\text{MGD})(\text{mg/L})(3.785\ {}^{\text{L}}/_{\text{gal}})(1{,}000{,}000\ {}^{\text{gal}}/_{\text{MG}})}{(\text{liquid}\ {}^{\text{mg}}/_{\text{ml}})(24\ {}^{\text{hr}}/_{\text{d}})(60\ {}^{\text{min}}/_{\text{hr}})}$$

$$\text{FeedPump,}\ {}^{\text{mL}}/_{\text{min}} = \frac{(3.2\ \text{mgd})(9\ \text{mg/L})(3.785\ {}^{\text{L}}/_{\text{gal}})(1{,}000{,}000\ {}^{\text{gal}}/_{\text{mg}})}{(642.3\ \text{mg/ml})(24\ {}^{\text{hr}}/_{\text{d}})(60\ {}^{\text{min}}/_{\text{hr}})}$$

$$\text{FeedPump}\ {}^{\text{mL}}/_{\text{min}} = 117.9$$