# Sidney's Big Book of Water and Wastewater Math

INDIGO WATER GROUP

## Unit Conversions to Know by Heart

1 inch = 2.54 centimeters
1 meter = 3.28 feet
1 mile = 5280 feet

1 acre = 43,560 $ft^2$
1 $m^2$ = 10.76 $ft^2$

1 gallon = 3.785 liters
1 $ft^3$ = 7.48 gallons
1 $m^3$ = 35.31 $ft^3$

1 ft water = 0.433 psi

1 gallon = 8.34 lbs when specific gravity is 1.0
1 kg = 2.2 lbs

1% = 10,000 mg/L
1 mg/L = 1 ppm
1 µg/L = 1 ppb

1 day = 1440 minutes
1 hp = 0.746 kW

1 gram = 15.43 grains
1 grain per gallon = 17.1 mg/L

## Water Formulas

pounds per day = (concentration in mg/L)*(flow rate in mgd)*(8.34)

chlorine dose = demand + residual

velocity = $\frac{\text{flow}}{\text{area}}$ $\quad V = \frac{Q}{A}$

flow rate = $\frac{\text{volume}}{\text{time}}$ $\quad Q = \frac{V}{t}$

overflow rate = $\frac{\text{flow rate}}{\text{area}}$

weir loading rate = $\frac{\text{flow rate}}{\text{feet of weir}}$

(concentration 1)*(volume 1) = (concentration 2)*(volume 2) $\quad C_1V_1 = C_2V_2$

(conc. 1)*(volume 1) + (conc. 2)*(volume 2) = (conc. 3)*(volume 3)

$$C_1V_1 + C_2V_2 = C_3V_3$$

horsepower = $\frac{\text{(flow in gpm)*(lift in feet)}}{3960}$

### *STATE OF CALIFORNIA*
### *DEPARTMENT OF HEALTH SERVICES*
### *WATER DISTRIBUTION OPERATOR CERTIFICATION PROGRAM*

## Units and Conversion Factors

1 cubic foot of water weighs 62.3832 lb
1 gallon of water weighs 8.34 lb
1 liter of water weighs 1,000 gm
1 mg/L = 1 part per million (ppm)
1 ug/L = 1 part per billion (ppb)
1 mile = 5,280 feet (ft)
1 yd = 3 feet
1 $yd^3 = 27ft^3$
1 acre (a) = 43,560 square feet ($ft^2$)
1 acre foot = 325,829 gallons
1 cubic foot ($ft^3$) = 7.48 gallons (gal)
1 gal = 3.785 liters (L)
1 L = 1,000 milliliters (ml)
1 pound (lb) = 454 grams (gm)
1 lb = 7,000 grains (gr)
1 grain per gallon (gpg) = 17.1 mg/L
1 gm = 1,000 milligrams (mg)
1 gm = 1,000,000 micrograms (ug)

## CHLORINATION

**Dosage, mg/l** = (Demand, mg/l) + (Residual, mg/l)

**(Gas) lbs/day** = (Vol, MG) x (Dosage, mgl) x (8.34 lbs/gal)

**HTH Solid (lbs/day)** =

$$\frac{(\text{Vol, MG}) \times (\text{Dosage, mg/l}) \times (8.34\text{lbs/gal})}{(\text{\% Strength})}$$

**Liquid (gal/day)** =

$$\frac{(\text{Vol, MG}) \times (\text{Dosage, mg/l}) \times (8.34 \text{ lbs/gal})}{(\text{\% Strength}) \times (\text{Specific Gravity} \times 8.34)}$$

## PRESSURE

**PSI** $= \frac{(\text{Head, ft.})}{2.31\text{ft./psi}}$  **PSI** = Head, ft x 0.433 PSI/ft.

**lbs Force** = $(0.785)(\text{D, ft.})^2 \times 144\ in^2/ft^2$ PSI.

## VOLUME

**Rectangular Basin Volume, gal** =
(Length, ft) x (Width, ft) x (Height, ft) x7.48 gal/cu.ft.

**Cylinder, Volume, gal** =
$(0.785) \times (\text{Dia, ft})^2 \times$ (Height, Length, or Depth, in ft.) x 7.48 $gal/ft^3$

**Time, Hrs.** $= \frac{\text{Volume, gallons}}{(\text{Pumping Rate, GPM, x 60 Min/Hr})}$

**Supply, Hrs.**$= \frac{\text{Storage Volume, Gals}}{(\text{Flow In, GPM} - \text{Flow Out, GPM}) \times 60\text{ min/hr.})}$

## SOLUTIONS

**Lbs/Gal** $= \frac{(\text{Solution \%})}{100} \times 8.34$ lbs/gal x Specific Gravity

**Lbs Chemical** =
Specific Gravity x 8. 34 lbs/gallons x Solution(gal)

**Specific Gravity** $= \frac{\text{Chemical Wt. (lbs/gal)}}{8.34 \text{ (lbs/gal)}}$

**% of Chemical in Solution** $= \frac{(\text{Dry Chemical, Lbs})}{(\text{Dry Wt. Chemical, Lbs}) + (\text{Water, Lbs})} \times 100$

**GPD** $= \frac{(\text{Vol, MG}) \times (\text{Conc., mg/l}) \times (8.34 \text{ lb/gal})}{(\text{\% Strength}) \times \text{Chemical Wt. (lbs/gal)}}$

**GPD** $= \frac{(\text{Feed, ml/min.} \times 1{,}440 \text{ min/day})}{(1{,}000 \text{ ml/L} \times 3.785 \text{ L/Gal})}$

**Two – Normal Equations:**
a) $C_1V_1 = C_2V_2$  $\frac{Q_1}{V_1} = \frac{Q_2}{V_2}$

b) $C_1V_1 + C_2V_2 = C_3V_3$

C = Concentration, V = Volume, Q = Flow

## PUMPING

1 horsepower (Hp) = 746 watts = 0.746 kw = 3,960 gal/min/ft

**Water Hp** $= \frac{(\text{GPM}) \times (\text{Total Head, ft})}{(3{,}960 \text{ gal/min/ft})}$

**Brake Hp** $= \frac{(\text{GPM}) \times (\text{Total Head, ft})}{(3{,}960) \times (\text{Pump \% Efficiency})}$

**Motor Hp** $= \frac{(\text{GPM}) \times (\text{Total Head, ft})}{(3{,}960) \times \text{Pump \% Eff.} \times \text{Motor \% Eff.}}$

**"Wire to Water" Efficiency**
= (Motor, % Efficiency x Pump % Efficiency)

**Cost, $** =
(Hp) x (0.746 Kw/Hp) x (Operating Hrs.) x cents/Kw-Hr

## Flow, velocity, area

Q = A x V  Quantity = Area x Velocity

Flow ($ft^3$/sec) = Area($ft^2$) x Velocity (ft/sec)

## General

**($) Cost / day** = Lbs/day x ($) Cost/lb

**Removal, Percent** $= \frac{(\text{In} - \text{Out})}{\text{In}} \times 100$

**Specific Capacity, GPM/ft.** $= \frac{\text{Well Yield, GPM}}{\text{Drawdown, ft.}}$

**Gals/Day** = (Population) x (Gals/Capita/Day)

**GPD** $= \frac{(\text{Meter Read 2} - \text{Meter Read 1})}{(\text{Number of Days})}$

**Volume, Gals** = GPM x Time, minutes

## SCADA = 4 mA to 20 mA analog signal

$\frac{(\text{live signal mA} - 4 \text{ mA off set})}{(16 \text{ mA span})} \times$ process unit and range

4 mA = 0  20 mA full -range

# Conversion of Measurement Units

## Length

1 in. = 25.4 mm
1 in. = 2.54 cm
1 in. = 0.0254 m
1 ft = 0.3048 m
1 mile = 5280 ft
1 mile = 1.609 km
1 km = 3281 ft
1 m = 39.37 in.

## Area

1 in.$^2$ = 645.2 mm$^2$
1 in.$^2$ = 6.452 cm$^2$
1 ft$^2$ = 144 in.$^2$
1 m$^2$ = 10.76 ft$^2$
1 m$^2$ = 1550 in.$^2$

## Volume

1 in.$^3$ = 16.39 cm$^3$
1 ft$^3$ = 1728 in.$^3$
1 U.S. gal. = 231 in.$^3$
1 U.S. gal. = 0.1337 ft$^3$
1 U.S. gal. = 0.8327 Imp. gal.
1 U.S. gal. = 3.7854 liters
1 ft$^3$ = 28.32 liters
1 m$^3$ = 35.31 ft$^3$
1 m$^3$ = 264.2 U.S. gal.
1 m$^3$ = 220 Imp. gal.
1 m$^3$ = 1000 liters
1 liter = 61.02 in.$^3$
1 liter = 1000 cm$^3$
1 ml = 1 cm$^3$

## Density

1 lb/ft$^3$ = 16.02 kg/m$^3$
1 lb./ft$^3$ = 0.01602 g/cm$^3$
1 lb./in.$^3$ = 1728 lb/ft$^3$

density = specific gravity x reference density
density = 1/specific volume

## Specific Volume

specific volume = 1/density

## Temperature

$$T(°C) = \frac{T(°F - 32)}{1.8}$$

T(°F) = 1.8 T(°C) + 32
T(°R) = T(°F) + 460
T(°K) = T(°C) + 273
T(°R) = 1.8 T(°K)

where:
°C = degrees Celsius
°F = degrees Fahrenheit
°K = degrees Kelvin (absolute temperature)
°R = degrees Rankine (absolute temperature)

## Specific Gravity – Liquids

$$G_l = \frac{\text{density of liquid}}{\text{density of water at reference condition}}$$

Commonly used relations are:

$$G_l = \frac{\text{density of liquid}}{\text{density of water at 60°F and atmospheric pressure}} = \frac{\rho\ (\text{lb/ft}^3)}{62.38\ (\text{lb/ft}^3)}$$

and

$$G_l = \frac{\text{density of liquid}}{\text{density of water at 4°C and atmospheric pressure}} = \frac{\rho\ (\text{kg/m}^3)}{1000\ (\text{kg/m}^3)}$$

For practical purposes, these specific gravities may be used interchangeably, as the reference densities are nearly equivalent.

Specific gravities are sometimes given with two temperatures indicated, e.g.,

$$G_l\ \frac{60°F}{60°F},\ G_l\ \frac{15.5°C}{4°C},\ G_l\ 60°F/60°$$

The upper temperature is that of the liquid whose specific gravity is given, and the lower value indicates the water temperature of the reference density. If no temperatures are shown, assume that the commonly used relations apply.

For petroleum liquids having an "API degrees" specification:

$$G_l 60°F/60° = \frac{141.5}{131.5 + \text{API degrees}}$$

## Pressure

1 Mpa = 145 psi
1 pond = 1 gf
1 std atm = 14.696 psi
1 std atm = 1.0133 bar
1 std atm = 1.0133 x 10$^5$ N/m$^2$
1 psi = 6895 Pa
1 psi = 6895 N/m$^2$
1 Pa = 1 N/m$^2$
1 bar = 14.50 psi
1 bar = 100,000 N/m$^2$
1 kgf/cm$^2$ = 14.22 psi
1 std atm = 760 torr absolute pressure = gage pressure + atmospheric pressure

## Specific Gravity – Gases

$$G_g = \frac{\text{density of gas (at pressure and temperature of interest)}}{\text{density of air (at same pressure and temperature)}}$$

Because the relation between density, pressure and temperature does not always behave in an ideal way (i.e., ideally, density is proportional to pressure divided by temperature, in absolute units), use of the above relation requires that the pressure and temperature of interest be specified. This means that the specific gravity of a gas as defined may vary with pressure and temperature (due to "compressibility" effects).

Frequently, specific gravity is defined using:

$$G_g = \frac{\text{molecular weight of gas}}{\text{molecular weight of air}} = \frac{M_w}{28.96}$$

If this relation is used to calculate density, one must be careful to consider "compressibility" effects. When the pressure and temperature of interest are at or near "standard" conditions (14.73 psia, 60°F) or "normal" conditions (1.0135 bar abs, 0°C), specific gravities calculated from either of the above relations are essentially equal.

## Pressure Head

1 foot of water at 60°F = 0.4332 psi

$$p(\text{psi}) = \frac{\rho(\text{lb/ft}^3) \times h(\text{feet of liquid})}{144}$$

$$p(\text{N/m}^2) = \frac{\rho(\text{kg/m}^3) \times h(\text{meters of liquid})}{0.1020}$$

$$p(\text{bar}) = \frac{\rho(\text{kg/m}^3) \times h(\text{meters of liquid})}{10200}$$

1 meter of water at 20°C = 9.790 kN/m$^2$
1 meter of water at 20°C = 97.90 mbar
1 meter of water at 20°C = 1.420 psi

## Flow Rate

- mass units

1 lb/hr = 0.4536 kg/hr
1 metric tonne/hr = 2205 lb/hr

- liquid volume units

1 U.S. gpm = 34.28 BOPD
BOPD = barrels oil per day
1 U.S. gpm = 0.8327 Imp. gpm
1 U.S. gpm = 0.2273 m$^3$/hr
1 U.S. gpm = 3.785 liters/min
1 m$^3$/hr = 16.68 liters/min
1 ft$^3$/s = 448.8 U.S. gpm

- mixed units

w(lb/hr) = 8.021 q(U.S. gpm) x $\rho$(lb/ft$^3$)
w(lb/hr) = 500 q(U.S. gpm of water at 70°F or less)

In the following:
STP (standard conditions) refers to 60°F, 14.73 psia
NTP (normal conditions) refers to 0°F, 1.0135 bar abs

$$G_g = \frac{\text{molecular weight of gas}}{\text{molecular weight of air}} = \frac{M_w}{28.96}$$

w(lb/hr) = 60 q(scfm of gas) x $\rho$(lb/ft$^3$) at STP
w(lb/hr) = q(scfh of gas) x $\rho$(lb/ft$^3$) at STP
w(lb/hr) = 4.588 q(scfm of gas) x $G_g$
w(lb/hr) = 0.07646 q(scfh of gas) x $G_g$
w(lb/hr) = 3186 q(MMscfd of gas) x $G_g$
Mmscfd = millions of standard cubic feet per day
w(kg/hr) = q(normal m$^3$/hr of gas) x $\rho$(kg/m$^3$ at NTP)
w(kg/hr) = 1.294 q(normal m3/hr of gas) x $G_g$

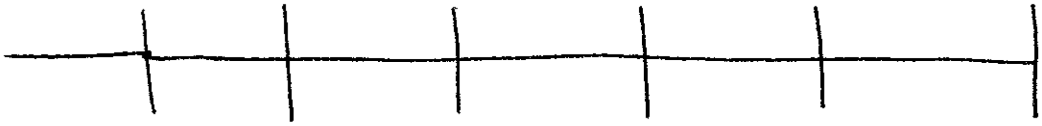
# Unit Conversions

# DIMENSIONAL ANALYSIS
(or how to convert anything to anything else)

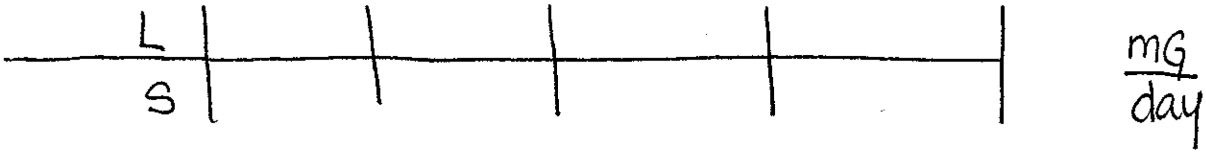
Step 1 – Decide what you have.

Step 2 – Decide what you need.

Step 3 – Draw the unit conversion grid



Step 4 – Fill in start and ending units.



Step 5 – Begin entering conversion factors. To cancel out, like units must be on top and bottom.

$$\frac{L}{s}\,\Bigg|\,\frac{1\text{ gal}}{3.785\text{ L}}\,\Bigg|\,\frac{1\text{ mG}}{1{,}000{,}000\text{ gal}}\,\Bigg|\,\frac{60\text{ s}}{1\text{ min}}\,\Bigg|\,\frac{60\text{ min}}{1\text{ hour}}\,\Bigg|\,\frac{24\text{ hr}}{1\text{ day}}\,\Bigg| = \frac{\text{mG}}{\text{day}}$$

Step 6 – Verify that units cancel.

Step 7 – Multiply through.

What does it mean to multiply through? For the example we just did, you can put the numbers into your calculator two different ways. Use whichever one works the best for you.

METHOD 1:

① multiply all of the numbers above the line together

(1)(1)(60)(60)(24) = 86400

② multiply all of the numbers below the line together.

(3.785)(1,000,000)(1)(1)(1) = 3785000

③ divide the first number by the second number

$$\frac{86400}{3785000} = 0.0228$$

METHOD 2:

① multiply all of the numbers above the line together just like you did in method 1.

② divide by each of the numbers below the line.

86400 ÷ 3.785 ÷ 1,000,000 ÷ 1 ÷ 1 = 0.0228

We get the same number either way.

Basically, If the number is above the line
MULTIPLY.
If the number is below the line
DIVIDE.
The order that each number is used really isn't important, as long as we follow these simple rules.

$$\frac{6}{3} = \text{DIVIDE}$$

$$\frac{6}{1} \cdot \frac{3}{1} = \text{MULTIPLY}$$

Lets do some more.

Convert 60 mph to feet/sec

The first set of units is miles per hour. Anytime I hear the word per, I know that the next unit has to go on the bottom.

So mph becomes miles (on top)
hour (on the bottom)

This works for more complicated units too. How about gallons per square foot per day?

gallons has to go on the top. Since I heard the word per, square feet must go on the bottom.

$$\frac{\text{gallons}}{ft^2}$$

But, its gallons per square feet per day, Since I heard the word per again, I know that day also has to go on the bottom.

$$\frac{\text{gallons}}{ft^2 \cdot \text{day}}$$

There is only one top and one bottom!

Back to my unit conversion of miles per hour to feet per second.

$$\begin{array}{l|l|r} 60\ \text{miles} & \qquad\qquad\qquad\qquad & \text{feet} \\ \hline \text{hour} & & \text{second} \end{array}$$

what I have

what I want

Step 5 is filling in the units that allow me to change what I have into what I want.

| | | |
|---|---|---|
| 60 miles | | feet |
| hour | | sec |

I'll convert one unit at a time. First, I need to change miles into feet. Looking at my unit conversion chart, I see that there are 5280 feet in one mile. Let's add that unit conversion to our equation.

| | | | |
|---|---|---|---|
| 60 miles | 5280ft | | feet |
| hour | 1mile | | sec |

mile has to go on the bottom so it will cancel with the other miles on top.

Next, I need to convert hours to seconds.

| | | | | | |
|---|---|---|---|---|---|
| 60 miles | 5280ft | 1 hour | 1 min | | feet |
| hour | 1 mile | 60 min | 60sec | | sec |

Can you see how the units cancel?

| | | | | | |
|---|---|---|---|---|---|
| 60 $\cancel{\text{miles}}$ | 5280 $\bigcirc$ft ✓ | 1 $\cancel{\text{hour}}$ | 1 $\cancel{\text{min}}$ | | feet |
| $\cancel{\text{hour}}$ | 1 $\cancel{\text{mile}}$ | 60 $\cancel{\text{min}}$ | 60 $\bigcirc$sec ✓ | | sec |

I'm left with feet on top and seconds on the bottom; exactly where I want them.

Now, just multiply through.

$$\frac{60\ \text{miles}}{\text{hour}} \Bigg| \frac{5280\ \text{ft}}{1\ \text{mile}} \Bigg| \frac{1\ \text{hour}}{60\text{min}} \Bigg| \frac{1\ \text{min}}{60\ \text{sec}} \Bigg| \frac{88\ \text{feet}}{\text{second}}$$

$$\frac{60 \times 5280 \times 1 \times 1}{1 \times 60 \times 60} = \frac{316800}{3600} = 88$$

Many of the unit conversions that we need for wastewater math are given to us at the front of the exam booklets.

However, you can improve your speed and accuracy on the test and in your daily operational duties if you can remember these basic conversions.

1 gallon = 3.785 Liters
7.48 gallons = 1 cubic foot
1 gallon = 8.34 pounds
10.76 square feet = 1 square meter
43,560 square feet = 1 acre
5,280 feet = 1 mile
2.54 centimeters = 1 inch
3.28 feet = 1 meter
2.2 pounds = 1 kilogram
0.433 psi = 1 foot head

# DIMENSIONAL ANALYSIS PROBLEMS

1. Convert 20 gpm to MGD.

2. Convert 8 gal/ft$^2$ to L/m$^2$

3. Convert 25 lbs/ft$^3$ to kg/m$^3$

4. Convert 60 mph to ft/second

5. MORE?

1. $$\frac{20 \text{ gallons}}{\text{min}} \Bigg| \qquad\qquad\qquad\qquad \Bigg| \frac{\text{MG}}{\text{day}}$$

* note that minutes and days have to go on the bottom because I heard the word <u>per</u>.

$$\frac{20 \text{ gallons}}{\text{min}} \Bigg| \frac{1 \text{ MG}}{1{,}000{,}000 \text{ gallons}} \Bigg| \frac{60 \text{ min}}{1 \text{ hour}} \Bigg| \frac{24 \text{ hours}}{1 \text{ day}} \Bigg| \frac{\text{MG}}{\text{day}}$$

Now, cancel units. REMEMBER that units only cancel top to bottom.

$$\frac{20 \cancel{\text{gallons}}}{\cancel{\text{min}}} \Bigg| \frac{1 \ \text{MG}}{1{,}000{,}000 \cancel{\text{gallons}}} \Bigg| \frac{60 \cancel{\text{min}}}{1 \cancel{\text{hr}}} \Bigg| \frac{24 \cancel{\text{hours}}}{1 \ \text{day}} \Bigg| \frac{\text{MG} \checkmark}{\text{day} \checkmark}$$

The leftover units are what I want <u>AND</u> where I want them. Multiply through to get the answer.

$$\frac{20 \text{ gallons}}{\text{min}} = 0.0288 \text{ MGD}$$

Pretty cool!

2. $$\begin{array}{c|c|c|c} \dfrac{8\ \cancel{gal}}{\cancel{ft^2}} & \dfrac{3.785\ \textcircled{L}}{1\ \cancel{gal}} & \dfrac{10.76\ \cancel{ft^2}}{1\ \textcircled{m^2}} & \dfrac{L}{m^2} \end{array}$$

$$\frac{8\ gal}{ft^2} = \frac{325.8\ L}{m^2}$$

3. $$\begin{array}{c|c|c|c} \dfrac{25\ lbs}{cuft} & \dfrac{35.31\ cuft}{1\ m^3} & \dfrac{1\ kg}{2.2\ lbs} & \dfrac{kg}{m^3} \end{array}$$

$$\frac{25\ lbs}{cuft} = \frac{401.6\ kg}{m^3}$$

4. $$\begin{array}{c|c|c|c|} \dfrac{60\ miles}{hour} & \dfrac{5280\ feet}{1\ mile} & \dfrac{1\ hour}{60\ min} & \dfrac{1\ min}{60\ sec} \end{array} = 88\ \frac{ft}{sec}$$

This formula is used to calculate pounds per day

$$ppd = (\text{concentration in } mg/L)(\text{flow in } MGD)(8.34)$$

where does that 8.34 come from?

DIMENSIONAL ANALYSIS

what are we converting?

$\frac{mg}{L}$ to $\frac{lbs}{day}$ Yes?

$$\frac{mg}{L} \bigg| \frac{1g}{1000\,mg} \bigg| \frac{1kg}{1000g} \bigg| \frac{2.2\,lbs}{1kg} \bigg| \frac{3.79\,L}{1\,gallon} \bigg| \underbrace{\frac{1{,}000{,}000\,gallons}{day}}_{\text{There is MGD in the equation}} \bigg| = 8.34\,\frac{lbs}{day}$$

Good thing we can just remember 8.34!

## Unit Conversion Problems

1. Convert 7 days into seconds.

2. Convert 120 feet of static head into psi

3. Convert 20 cft into gallons.

4. Convert 5 mgd into cfs

5. Convert 14 acres into square feet

6. Convert 37,850 liters into cubic feet

7. Convert 43,560 cf into gallons

8. Convert 2000 pounds into grams

9. Convert 3 yards into gallons

10. Convert 34 square miles into acres

11. Convert 60,000 milliliters into cf

12. Convert 15,000 mg/L into percent

13. Convert gpm/sf into liters per second per square meter

14. Convert 80 mph into fps

15. Convert 1 acre-ft/day into gpm

16. Convert 50 gallons of water into pounds

17. Convert 600 gpm into mgd

18. Convert 50 psi into feet of static head

19. Convert 6% into mg/L

20. Convert 4000 gallons of water into cubic yards

21. Convert 30HP to kwh.

## Unit Conversion Problems

1. Convert 7 days into seconds.

$$\begin{array}{l|l|l|l} 7\text{ days} & 1440\text{ mintes} & 60\text{seconds} & = 604,800\text{ seconds} \\ \hline & 1\text{ day} & 1\text{ minute} & \end{array}$$

2. Convert 120 feet of static head into psi

$$\begin{array}{l|l|l} 120\text{ feet} & 0.433\text{ psi} & = 51.96\text{ psi} \\ \hline & 1\text{ ft} & \end{array}$$

3. Convert 20 cft into gallons.

$$\begin{array}{l|l|l} 20\text{ cf} & 7.48\text{ gal} & = 149.6\text{ gallons} \\ \hline & 1\text{ cf} & \end{array}$$

4. Convert 5 mgd into cfs

$$\begin{array}{l|l|l|l|l|l} 5\text{ mg} & 1,000,000\text{ gal} & 1\text{ cf} & 1\text{ day} & 1\text{min} & = 7.73\ \frac{\text{cf}}{\text{s}} \\ \hline \text{day} & 1\text{ mg} & 7.48\text{ gal} & 1440\text{ min} & 60\text{ sec} & \end{array}$$

5. Convert 14 acres into square feet

$$\begin{array}{l|l|l} 14\text{ acres} & 43,560\text{ sf} & = 609,840\text{ sf} \\ \hline & 1\text{ acre} & \end{array}$$

6. Convert 37,850 liters into cubic feet

$$\begin{array}{l|l|l|l} 37850\text{ Liters} & 1\text{ gal} & 1\text{ cf} & = 1337\text{ cf} \\ \hline & 3.785\text{ L} & 7.48\text{ gal} & \end{array}$$

7. Convert 43,560 cf into gallons

$$\begin{array}{l|l|l} 43,560\text{ cf} & 7.48\text{ gal} & = 325,829\text{ gal} \\ \hline & 1\text{ cf} & \end{array}$$

8. Convert 2000 pounds into grams

$$\begin{array}{l|l|l|l} 2000\text{ lbs} & 1\text{ kg} & 1000\text{ grams} & 909,091\text{ grams} \\ \hline & 2.2\text{ lbs} & 1\text{ kg} & \end{array}$$

9. Convert 3 yards into gallons

$$\begin{array}{l|l|l|l} 3\text{ yards} & 27\text{ cf} & 7.48\text{ gal} & = 605.88\text{ gallons} \\ \hline & 1\text{ yard} & 1\text{ cf} & \end{array}$$

10. Convert 34 square miles into acres

$$34\text{ square miles}\,\Big|\,\frac{5280\text{ ft}}{1\text{ mile}}\,\Big|\,\frac{5280\text{ ft}}{1\text{ mile}}\,\Big|\,\frac{1\text{ acre}}{43560\text{ sf}}\,\Big| = 21,760\text{ acres}$$

11. Convert 60,000 milliliters into cf

$$60,000\text{ mL}\,\Big|\,\frac{1\text{L}}{1000\text{mL}}\,\Big|\,\frac{1\text{ gal}}{3.785\text{ L}}\,\Big|\,\frac{1\text{ cf}}{7.48\text{ gal}}\,\Big| = 2.13\text{ cf}$$

12. Convert 15,000 mg/L into percent

$$15,000\text{ mg/L}\,\Big|\,\frac{1\%}{10,000\text{ mg/L}}\,\Big| = 1.5\%$$

13. Convert gpm/sf into liters per second per square meter

$$\frac{1\text{ gal}}{\text{min}\cdot\text{sf}}\,\Big|\,\frac{3.785\text{ Liters}}{1\text{ gal}}\,\Big|\,\frac{1\text{ min}}{60\text{sec}}\,\Big|\,\frac{10.76\text{ sf}}{1\text{ m}^2}\,\Big|\quad 0.68\ \frac{\text{L}}{\text{s}\cdot\text{m}^2}$$

14. Convert 80 mph into fps

$$\frac{80\text{ miles}}{\text{hour}}\,\Big|\,\frac{5280\text{ ft}}{1\text{ mile}}\,\Big|\,\frac{1\text{ hr}}{60\text{ min}}\,\Big|\,\frac{1\text{ min}}{60\text{ sec}}\,\Big| = 117.3\ \frac{\text{ft}}{\text{s}}$$

15. Convert 1 acre-ft/day into gpm

$$\frac{1\text{ acre}\cdot\text{ft}}{\text{day}}\,\Big|\,\frac{43,560\text{ sf}}{1\text{ acre}}\,\Big|\,\frac{7.48\text{ gal}}{1\text{ cf}}\,\Big|\,\frac{1\text{ day}}{1440\text{ min}}\,\Big| = 226\text{ gpm}$$

16. Convert 50 gallons of water into pounds

$$50\text{ gallons}\,\Big|\,\frac{8.34\text{ lbs}}{1\text{ gallon}}\,\Big| = 417\text{ lbs}$$

17. Convert 600 gpm into mgd

$$\frac{600\text{ gal}}{\text{min}}\,\Big|\,\frac{1\text{ mg}}{1000000\text{ gal}}\,\Big|\,\frac{1440\text{ min}}{1\text{ day}}\,\Big| = 0.864\text{ mgd}$$

18. Convert 50 psi into feet of static head

$$50\text{ psi}\,\Big|\,\frac{1\text{ ft}}{0.433\text{ psi}}\,\Big| = 115.47\text{ ft}$$

or

$$50\text{ psi}\,\Big|\,\frac{2.31\text{ ft}}{1\text{ psi}}\,\Big| = 115.5\text{ ft}$$

19. Convert 6% into mg/L

$$6\% \left| \frac{10{,}000 \text{ mg/L}}{1\%} \right| = 60{,}000 \text{ mg/L}$$

20. Convert 4000 gallons of water into cubic yards

$$4000 \text{ gallons} \left| \frac{1 \text{ cf}}{7.48 \text{ gal}} \right| \frac{1 \text{ cy}}{27 \text{ cf}} \right| = 19.8 \text{ cy}$$

21. Convert 30 HP to kwh

$$30 \text{ HP} \left| \frac{0.746 \text{ kW/hr}}{1 \text{ HP}} \right| = 22.38 \text{ kwh}$$

Unit Conversions

1. One cubic foot of water contains
a) 7.48 gallons
b) 8.34 gallons
c) 3.785 gallons
d) 62.4 gallons

2. Five gallons of water weighs
a) 41.7 pounds
b) 37.4 pounds
c) 5.0 pounds
d) 18.9 pounds

3. How many gallons of water are there in 5 cubic feet?
a) 41.7 gallons
b) 37.4 gallons
c) 15.0 gallons
d) 100.0 gallons

4. If water weighs 8.34 lbs/gal, how much will 7.5 gal weigh?
a) 50.8 lbs
b) 62.5 lbs
c) 75.6 lbs.
d) 77.3 lbs

5. A flow of 1.55 cubic feet per second is how many gallons per minute?
a) 11.6 gpm
b) 776 gpm
c) 965 gpm
d) 696 gpm

6. Your pump ran continuously for 24 hrs and delivered 288,000 gal. The capacity of the pump is _____ gpm. Select the closest answer.
a) 100
b) 200
c) 1000
d) 12000

7. A fluid with a specific gravity of 1.05 weighs _____ lb/gal.
a) 8.4
b) 8.8
c) 7.2
d) 8.5

8. You have a water storage tank that is 90' tall and 45' in diameter, it currently has 56' of water in it, what is the pressure in the bottom of the tank

a) 24.2 psi
b) 14 psi
c) 2 psi
d) 100 psi
e) 56 psi

9. A flow of 2500 gal/min is equal to how many million gallons per day?

a) 2.5 mgd
b) 3.6 mgd
c) 5.0 mgd
d) 7.2 mgd

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10. Regardless of shape, 1 ac-ft of water is equal to

a) 33,000 ft3
b) 43,560 ft3
c) 55,560 ft3
d) 77,840 ft3

None of these answers are correct

11. A potable water flowmeter reads 76 gal/min. What is the total flow, in gal/d?

a) 633.8 gal/d
b) 1824 gal/d
c) 14,085 gal/d
d) 109,440 gal/d

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12. The pressure gauge on the bottom of a water holding tank reads 15 psi. The tank is 15 ft in diameter and 40 ft high. How many feet of water are in the tank?

a) 11.8 ft
b) 25.0 ft
c) 34.6 ft
d) 38.9 ft

13. A liquid has a specific gravity of 1.16 How much would 300 gallons of this liquid weigh?

a) 2901 pounds
b) 348 pounds
c) 2603 pounds
d) 2156 pounds

14. Eight boxes of packing (for pumps) were delivered. The invoice showed $15.93 each. What is the total cost of the packing?
a) $106.34
b) $127.44
c) $1.99
d) $95.58

15. A water treatment plant used 647 chlorine cylinders during one year of operation. The average withdrawal from each cylinder was 138 lbs. What was the total number of pounds of chlorine used for the year?
a) 50370
b) 70872
c) 69876
d) 89286

16. A pump delivering 288,000 gallons of water in 24 hours operates at what average flow rate?
a) 12000 gpm
b) 200 gpm
c) 1000 gpm
d) 100 gpm

17. A clear well pump delivers 750 GPM to the main water storage tank, The demand for water from this tank is approximately six million gallons per week. How many hours does the pump need to run each week to meet the demand?
a) 80 Hours per Week
b) 13 Hours Per Week
c) 56 Hours Per Week
d) 133 Hours Per Week
e) 168 Hours Per Week

18. Your Water plant treats water at a rate of 700 GPM. How many MGD is this?
a) 1.008 MGD
b) 0.700 MGD
c) 0.1008 MGD
d) 1.800 MGD
e) 0.420 MGD

## UNIT CONVERSIONS

1. a

2. $$5\text{ gallons}\;\Big|\;\frac{8.34\text{ lbs}}{1\text{ gallon}}\;\Big| = 41.7\text{ lbs}$$

gallons on top cancel
with gallons on the bottom

3. $$5\text{ cuft}\;\Big|\;\frac{7.48\text{ gallons}}{1\text{ cuft}}\;\Big| = 37.4\text{ gallons}$$

since I started with cuft on top, I
know that cuft has to go on the bottom.

4. $$7.5\text{ gallons}\;\Big|\;\frac{8.34\text{ lbs}}{1\text{ gallon}}\;\Big| = 62.6\text{ lbs}$$

5. $$\frac{1.55\text{ cuft}}{\text{sec}}\;\Big|\;\frac{7.48\text{ gallons}}{1\text{ cuft}}\;\Big|\;\frac{60\text{ seconds}}{1\text{ minute}}\;\Big| = 695.6\text{ gpm}$$

in this problem, we needed to convert
two units. Setting up the grid makes
this easy. Just take one unit at a time.

6. $$\frac{280{,}000\text{ gallons}}{24\text{ hours}}\;\Big|\;\frac{1\text{ hour}}{60\text{ min}}\;\Big| = \frac{194\text{ gallons}}{\text{minute}}$$

7. Specific gravity is the ratio of the density
of water to another liquid. By definition,
the specific gravity of water is 1.0

Let's set this up as a ratio; water on one side and our new liquid on the other.

$$\frac{1.0}{8.34 \text{ lbs/gal}} = \frac{1.05}{x \text{ lbs/gal}}$$

$$(1.0)(x) = (1.05)(8.34)$$
$$x = 8.76 \text{ lbs/gallon}$$

The equation that we use to calculate pounds per day is:

$$ppd = (\text{mg/L})(\text{flow, mgd})(8.34)(\underset{\text{specific gravity}}{\underset{\uparrow}{\rho}})$$

Normally, we don't write this down because for most of the things we calculate, $\rho = 1.0$ — the specific gravity of water

> Note: when $\rho > 1.0$, the liquid is heavier than water. When $\rho < 1.0$, the liquid is lighter than water.

A $FeCl_2$ solution that has 10,000 mg/L Fe and a specific gravity of 1.25 is used at a rate of 0.250 mgd. How many ppd of solution was used?

$$ppd = (10{,}000 \text{ mg/L})(0.250 \text{ mgd})(8.34)(1.25)$$
$$ppd = 26{,}063$$

8. I know that a foot of water exerts 0.433 psi of pressure. The other tank dimensions are just extra information.

$$56 \text{ feet depth} \Big| \frac{0.433 \text{ psi}}{\text{foot}} \Big| = 24.2 \text{ psi}$$

9. $$\frac{2500 \text{ gallons}}{\text{minute}} \Big| \frac{1440 \text{ min}}{1 \text{ day}} \Big| \frac{1 \text{ MG}}{1000000 \text{ gal}} \Big| = 3.6 \frac{\text{mg}}{\text{day}}$$

10. b.

11. $$\frac{76 \text{ gallons}}{\text{min}} \Big| \frac{1440 \text{ gal}}{1 \text{ day}} \Big| = 109{,}440 \frac{\text{gallons}}{\text{day}}$$

12. Again, the dimensions of the tank don't actually matter. We only need to know the water depth.

$$15 \text{ psi} \Big| \frac{\text{foot } H_2O}{0.433 \text{ psi}} \Big| = 34.6 \text{ feet}$$

13. First find the weight in lbs/gallon (see #7)

$$\frac{1.0}{8.34 \text{ lbs/gallon}} = \frac{1.16}{X \text{ lbs/gallon}}$$

$$x = 9.67 \text{ lbs/gallon}$$

$$300 \text{ gallons} \Big| \frac{9.67 \text{ lbs}}{1 \text{ gallon}} \Big| = 2901 \text{ lbs}$$

14. $$8 \text{ boxes} \left| \frac{\$15.93}{1 \text{ box}} \right| = \$127.44$$

15. $$\frac{647 \text{ cylinders}}{\text{year}} \left| \frac{138 \text{ lbs}}{\text{cylinder}} \right| = 89286 \frac{\text{lbs}}{\text{year}}$$

16. $$\frac{288{,}000 \text{ gallons}}{24 \text{ hours}} \left| \frac{1 \text{ hour}}{60 \text{ min}} \right| = 200 \frac{\text{gallons}}{\text{min}}$$

17. First, convert the pump rate to gallons per hour.

$$\frac{750 \text{ gallons}}{\text{min}} \left| \frac{60 \text{ min}}{1 \text{ hr}} \right| = 45{,}000 \frac{\text{gallons}}{\text{hour}}$$

then convert demand to hours

$$6{,}000{,}000 \text{ gallons} \left| \frac{1 \text{ hour}}{45{,}000 \text{ gallons}} \right| = 133.3 \text{ hours}$$

18. $$\frac{700 \text{ gallons}}{\text{minute}} \left| \frac{1 \text{ MG}}{1000000 \text{ gallons}} \right| \frac{1440 \text{ min}}{1 \text{ day}} \right| = 1.008 \text{ MGD}$$

## UNIT CONVERSIONS

1. If water weighs 8.34 lbs/gal, how much will 7.5 gal weigh?
   a) 50.8 lbs
   b) 62.5 lbs
   c) 75.6 lbs.
   d) 77.3 lbs

2. Your pump ran continuously for 24 hrs and delivered 288,000 gal. The capacity of the pump is _____ gpm.
   a) 100
   b) 200
   c) 1000
   d) 12000

3. A fluid with a specific gravity of 1.05 weighs _____ lb/gal.
   a) 8.4
   b) 8.7
   c) 7.2
   d) 8.5

4. A flow of 2500 gal/min is equal to how many million gallons per day?
   a) 2.5 mgd
   b) 3.6 mgd
   c) 5.0 mgd
   d) 7.2 mgd

?Operations Forum March 2001

5. Regardless of shape, 1 ac-ft of media in a trickle filter is equal to
   a) 33,000 ft3
   b) 43,560 ft3
   c) 55,560 ft3
   d) 77,840 ft3
   e) None of these answers are correct

?Operations Forum July 1999

6. A potable water flowmeter reads 76 gal/min. What is the total flow, in gal/d?
   a) 633.8 gal/d
   b) 1824 gal/d
   c) 14,085 gal/d
   d) 109,440 gal/d

?Operations Forum November 1997

7. The pressure gauge on the bottom of a water holding tank reads 15 psi. The tank is 15 ft in diameter and 40 ft high. How many feet of water are in the tank?

a) 11.8 ft
b)25.0 ft
c) 34.6 ft
d)38.9 ft

?Operations Forum November 1997

JOB UNIT CONVERSIONS JOB NO. 16

SHEET NO. ______ OF ______

CALCULATED BY ______ DATE ______

CHECKED BY ______ DATE ______

SUBJECT ______

1. $7.5\text{ gal} \left| \frac{8.34\text{ lbs}}{1\text{ gal}} \right| = 62.5\text{ lbs}$

2. $\frac{288000\text{ gal}}{\text{day}} \Big/ \frac{1\text{ day}}{1440\text{min}} \Big/ = 200\ \frac{\text{gal}}{\text{min}}$

3. specific gravity is the ratio of the density of a fluid to the density of water.

By definition, water has a specific gravity = 1.0

$$p = \frac{\text{density of fluid}}{\text{density of water}}$$

$$1.05 = \frac{\text{density of fluid}}{8.34\ \text{lbs/gallons}}$$

$$8.76\ \frac{\text{lbs}}{\text{gal}} = \text{density of fluid}$$

4. $\frac{2500\text{ gal}}{\text{min}} \Big/ \frac{1440\text{ min}}{1\text{ day}} \Big| \frac{1\text{ MG}}{10^6\text{ gal}} \Big/ = 3.6\ \frac{\text{MG}}{\text{day}}$

5. 1 acre ft = 43,560 $ft^2$ of area by 1 ft deep

43,560 $ft^3$

6. $\frac{76\text{ gal}}{\text{min}} \Big| \frac{1440\text{min}}{1\text{day}} \Big| = 109{,}440\ \frac{\text{gal}}{\text{day}}$

JOB UNIT CONVERSIONS JOB NO. 17

SHEET NO. ______ OF ______

CALCULATED BY ______ DATE ______

CHECKED BY ______ DATE ______

SUBJECT ______

7. One foot of water exerts a pressure of 0.433 psi - lbs per square inch

$$15 \text{ psi} \left| \frac{1 \text{ ft}}{0.433 \text{ psi}} \right| = 34.6 \text{ ft}$$

# Algebra Review
# (rearranging equations)

# ALGEBRA REVIEW

A BIG SCAREY WORD FOR A FAIRLY SIMPLE TOPIC. TO BE SUCCESSFUL IN EVALUATING ALGEBREIC EQUATIONS, WE ONLY NEED TO REMEMBER TWO THINGS:

1. POLY MAKES DONUTS AFTER SCHOOL

AND

2. EQUALITY RULES

POLY MAKES DONUTS AFTER SCHOOL = PMDAS
P for powers and parethesis
M for multiply
D for divide
A for add
S for subtract

If we always do these things in order, we will always get the right answer.

For example:

$$(3+2)*8-4 = x$$
$$5*8-4 = x$$
$$40-4 = x$$
$$36 = x$$

If we don't follow the order rule:
POLY MAKES DONUTS AFTER SCHOOL,
we will get a different (and wrong!) answer.

$$(3+2)*8-4=x$$
$$(3+2)*4=x$$
$$5*4=x$$
$$20=x$$

Can you imagine the impact a 20 gpm pumping return rate instead of a 36 gpm pumping return rate would have on your clarifier?
~ DISASTER ~

The second thing to remember when dealing with equations is that equality rules.

You can do anything to an equation, anything at all, as long as you do it equally.
By equally, we mean to both sides of the equation.

FOR EXAMPLE:

$$PV = nRT$$ (the ideal gas law)

If I want to move the "T" to the other side of the equation, I divide <u>BOTH SIDES of the equation by T</u>

$$\frac{PV}{T} = \frac{nRT}{T}$$

Now, the "T"s cancel eachother out on the right side of the equation.

> Any number or letter divided by itself is equal to 1.
> $\frac{T}{T} = 1$ $\frac{6}{6} = 1$ etc.

$$\frac{PV}{T} = nR$$

TRY AGAIN:

$$Q = \frac{V}{t}$$

Put t on the left side of the equation and Q on the right side.

$$Q = \frac{V}{t}$$

1. multiply BOTH SIDES by t

$$tQ = \frac{V}{t}t$$

2. cancel "t" out on right side

$$tQ = V$$

3. divide both sides by Q

$$\frac{tQ}{Q} = \frac{V}{Q}$$

4. cancel "Q" out on left side

$$t = \frac{V}{Q}$$

Voila!

One more example:

$$A + B = \frac{C}{(D+E)}$$

$A = 2$
$B = 3$
$C = 10$
$D = 1$
FIND E

$$A+B=\frac{C}{(D+E)}$$

First, plug in what you know.

$$2+3=\frac{10}{(1+E)}$$

Next, simplify with the PMDAS rule in mind.

$$5=\frac{10}{(1+E)}$$

Then, use the equality rule to finish solving.

$$\left.5=\frac{10}{(1+E)}\right\} \quad 1$$

$$\left.\begin{aligned}(1+E)(5)&=\frac{10(1+E)}{(1+E)}\\(1+E)(5)&=10\end{aligned}\right\} \quad 2$$

$$\left.\begin{aligned}\frac{(1+E)(5)}{5}&=\frac{10}{5}\\(1+E)&=2\end{aligned}\right\} \quad 3$$

$$\left.\begin{aligned}(1+E)-1&=2-1\\E&=1\end{aligned}\right\} \quad 4$$

One more piece of advice:

<u>ALWAYS</u> put your units into your equations. Check for consistency.

Do any conversions need to be made before solving?

Example:

Plant A has an influent flow of 2 MGD. THE GRIT BASIN volume is 20,000 ft³. Find the hydraulic retention time in hours.

$$Q = \frac{V}{t}$$

$$2\ \frac{MG}{D} = \frac{20{,}000\ ft^3}{t}$$

$$\left(2\ \frac{MG}{D}\right)t = 20{,}000\ ft^3$$

UNITS DON'T MATCH! CONVERT ONE.

$$20{,}000\ ft^3 \Big| \frac{7.48\ gal}{1\ ft^3} \Big| \frac{1\ MG}{1{,}000{,}000\ gal} \Big| = 0.1496\ MG$$

$$\left(2\ \frac{MG}{D}\right)(t) = 0.1496\ MG$$

$$t = 0.0748\ DAYS$$

$$0.0748\ DAYS \Big| \frac{24\ HRS}{1\ DAY} \Big| \frac{60\ min}{1\ HR} \Big| = 108\ minutes$$

# Sidney's Big Book of Water and Wastewater Math

INDIGO WATER GROUP

## Unit Conversions to Know by Heart

1 inch = 2.54 centimeters
1 meter = 3.28 feet
1 mile = 5280 feet

1 acre = 43,560 $ft^2$
1 $m^2$ = 10.76 $ft^2$

1 gallon = 3.785 liters
1 $ft^3$ = 7.48 gallons
1 $m^3$ = 35.31 $ft^3$

1 ft water = 0.433 psi

1 gallon = 8.34 lbs when specific gravity is 1.0
1 kg = 2.2 lbs

1% = 10,000 mg/L
1 mg/L = 1 ppm
1 µg/L = 1 ppb

1 day = 1440 minutes
1 hp = 0.746 kW

1 gram = 15.43 grains
1 grain per gallon = 17.1 mg/L

## Water Formulas

pounds per day = (concentration in mg/L)*(flow rate in mgd)*(8.34)

chlorine dose = demand + residual

$$\text{velocity} = \frac{\text{flow}}{\text{area}} \qquad V = \frac{Q}{A}$$

$$\text{flow rate} = \frac{\text{volume}}{\text{time}} \qquad Q = \frac{V}{t}$$

$$\text{overflow rate} = \frac{\text{flow rate}}{\text{area}}$$

$$\text{weir loading rate} = \frac{\text{flow rate}}{\text{feet of weir}}$$

(concentration 1)*(volume 1) = (concentration 2)*(volume 2) $C_1V_1 = C_2V_2$

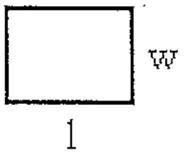
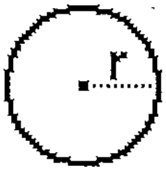
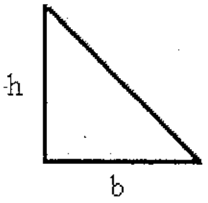
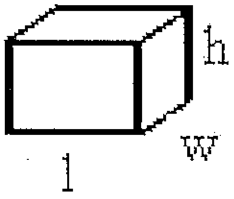
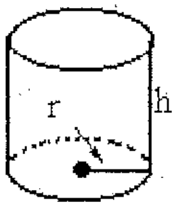
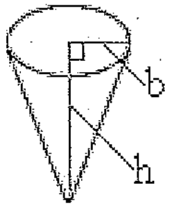
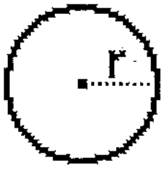
(conc. 1)*(volume 1) + (conc. 2)*(volume 2) = (conc. 3)*(volume 3)

$$C_1V_1 + C_2V_2 = C_3V_3$$

$$\text{horsepower} = \frac{\text{(flow in gpm)*(lift in feet)}}{3960}$$

# Geometry
# (volumes and areas)

# Useful Geometric Formulas

| | |
|---|---|
|  | Area = (Length)*(Width)<br>*Applies to squares and rectangles |
|  | Area = $\Pi * r^2$<br>Area = $\Pi * r * r$<br>* The radius, r, is equal to one-half the diameter |
|  | Area = $\frac{(Base)*(Height)}{2}$ |
|  | Volume = (Length)*(Width)*(Height) |
|  | Volume = $\Pi * r^2 * h$<br>Volume = $\Pi * r * r * h$ |
|  | Volume = $\frac{\Pi * r^2 * h}{3}$ |
|  | Perimeter = (2)*( $\Pi$ )*(r)<br>Or<br>Perimeter = ($\Pi$)*(d)    where d = diameter |

## TANK GEOMETRIES

1. The formula for calculating the volume of a wet well is:
   - a) V = L * W * C
   - b) V = W * A * P
   - c) V = W * L * H
   - d) V = W * H * D

2. The diameter of a wet well is 10 ft. If filled to a depth of 10 ft. It will contain approximately:
   - a) 2987 gal.
   - b) 5872 gal.
   - c) 6024 gal.
   - d) 10,602 gal.

3. Find how many gallons of liquid are in a tank which measures 40' long, 25' wide and 12' high.
   - a) 89760
   - b) 79872
   - c) 67859
   - d) 90272

4. A cylindrical tank is 10 ft in diameter and 20 ft in height. What is the approximate capacity in liters?
   - a) 44,450 liters
   - b) 31,030 liters
   - c) 5,942 liters
   - d) 4,445 liters

5. Approximately how many gallons would 600 ft of 6" pipe hold?
   - a) 740
   - b) 880
   - c) 900
   - d) 930

6. What is the volume of water (in gallons) in an upright 25 foot diameter cylindrical tank with a water depth of 22 feet?
   - a) 10,794
   - b) 13,750
   - c) 80,737
   - d) 90,022
   - e) 102,850

7. A plant has a 90-ft diameter sludge tank with a sidewall depth of 20 ft. The tank also has a conical bottom that is 8 ft deep. The tank has a sludge liquid level of 15 ft (sidewater depth). How many gallons of sludge liquid are in the tank?

a) 586,593
b) 713,424
c) 840,255
d) 1,093,936

?Operations Forum December 1998

JOB Tank Geometries JOB NO. 26

SHEET NO. OF

CALCULATED BY DATE

CHECKED BY DATE

SUBJECT

2. $V = \pi r^2 h$

$V = (3.14)(5\text{ ft})(5\text{ ft})(10\text{ ft})$

$V = 785\text{ ft}^3$

r = radius or $\frac{1}{2}$ the diameter

h = height of tank or water depth

now convert to gallons

$$785\text{ ft}^3 \left| \frac{7.48\text{ gallons}}{1\text{ ft}^3} \right| = 5872\text{ gallons}$$

3. V = length * width * height

$V = (40\text{ ft})(25\text{ ft})(12\text{ ft})$

$V = 12{,}000\text{ ft}^3$

$$12{,}000\text{ ft}^3 \left| \frac{7.48\text{ gal}}{1\text{ ft}^3} \right| = 89760\text{ gallons}$$

4. $V = \pi r^2 h$

$V = (3.14)(5\text{ ft})(5\text{ ft})(20\text{ ft})$

$V = 1570\text{ ft}^3$

$$1570\text{ ft}^3 \left| \frac{7.48\text{ gal}}{1\text{ ft}^3} \right| \frac{3.785\text{ Liters}}{1\text{ gal}} \right| = 44{,}450\text{ LITERS}$$

5. A pipe is just a tank on its side. First convert all of the dimensions to feet.

diameter = 6" = 0.5 ft

$V = \pi r^2 h$

$V = (3.14)(0.25\text{ ft})(0.25\text{ ft})(600\text{ ft})$

$V = 117.75\text{ ft}^3$

$$117.75\text{ ft}^3 \left| \frac{7.48\text{ gal}}{1\text{ ft}^3} \right| = 880.77\text{ gallons}$$

JOB TANK GEOMETRIES JOB NO. 27

SHEET NO. ______ OF ______

CALCULATED BY ______ DATE ______

CHECKED BY ______ DATE ______

SUBJECT ______

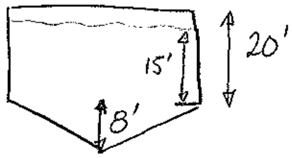
6. $V = \pi r^2 h$

$V = (3.14)(12.5\ ft)(12.5\ ft)(22\ ft)$

$V = 10793.75\ ft^3$

$10793.75\ ft^3 \left| \frac{7.48\ gal}{1\ ft^3} \right| = 80737$ gallons

7.



Step 1: find the volume of the top part of the tank

$V = \pi r^2 d$

$V = (3.14)(45\ ft)(45\ ft)(15\ ft)$

$V = 95377.5\ ft^3$

Step 2: find the volume of the cone

$V = \frac{1}{3}\pi r^2 d$

$V = (\frac{1}{3})(3.14)(45\ ft)(45\ ft)(8\ ft)$

$V = 16956\ ft^3$

Step 3: add the volumes and convert to gallons

$$\begin{array}{r} 95377.5\ ft^3 \\ +\ \ 16956\ ft^3 \\ \hline 112333.5\ ft^3 \end{array}$$

$112333.5\ ft^3 \left| \frac{7.48\ gal}{1\ ft^3} \right| = 840,255$ gallons

# Geometry

1. A clearwell is 50 feet long by 8 feet wide by 10 feet deep. What is the volume of the clearwell in cubic feet?

Answer: cft

2. A sedimentation basin has a surface area of 625 sft. If the basin can hold a maximum of 6250 cubic feet of water, how deep is the basin?

Answer: ft

3. A water storage tank currenty holds 323136 gallons. If the water depth in the tank is 12 feet, what is the area of the tank is square feet?

Answer: ft

4. A clearwell is 30 feet long by 30 feet wide by 20 feet deep. What is the volume of the clearwell in gallons?

Answer: gallons

5. The distribution system has 3 storage tanks. Each tank is 25 feet long by 15 feet long by 12 feet deep. What is the maximum storage volume of the distribution system in gallons?

Answer: gallons

6. A sedimentation basin is 25 feet long by 15 feet wide by 12 feet deep. Find the perimeter of the basin in feet.

Answer: feet

7. The inside walls and bottom of a concrete tank must be painted. The floor of the tank is 25 feet long by 15 feet wide. If the tank is 12 feet deep, how many square feet of area require painting?

Answer: square feet

8. Find the volume of a pipe that is 2 feet in diameter and 300 feet long.

Answer: cft

9. A water tank currently holds 528730 gallons. If the tank is filled to a depth of 25 feet, what is the diameter of the tank?

Answer: feet

10. Find the length of 12-inch pipe required to hold 146.8 gallons.

Answer: feet

11. A round storage tank has a surface area of 78.54 square feet. The tank holds 1963.5 cubic feet of water. What is the diameter of the tank?

Answer: feet

12. The distribution system contains 2 large mains. Each main is 300 feet long and 15 inches in diameter. How much water can both mains hold? Express your answer in gallons.

Answer: gallons

13. Find the perimeter of a round sedimendation basin if the diameter is 20 feet.

Answer: feet

14. A tank must be painted on all of the inside surfaces. The tank is round with an open top. If the tank has a 10 foot radius, find the area to be painted in square feet. The tank is 15 ft deep.

Answer square feet

15. A 10 foot diameter tank has a conical bottom. The sidewater depth (top of cone to water surface level) is 15 feet. The cone is 8 feet deep at its deepest point. What is the volume of the cone in cubic feet?

Answer: cft

16. A 24 foot diameter tank has a conical bottom. The sidewater depth (top of cone to water surface level) is 20 feet. The cone is 6 feet deep at its deepest point. How many gallons of water are in the tank?

Answer: gallons

17. A round tank with a conical bottom holds293739 gallons. If the cone is 6 feet deep at its deepest point and the diameter of the tank is 50 feet, what is the depth of the main part of the tank?

Answer: feet

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1. $V = l \cdot w \cdot h$

$V = (50')(8')(10')$

$V = 4{,}000$ cf

2. $V = l \cdot w \cdot h$

$V = \text{Area} \cdot h$

$\frac{6250\text{ cf}}{625} = \frac{\cancel{625}\text{sf} \cdot h}{\cancel{625}}$

$10\text{ ft} = h$

3. Volume must be converted

$$323{,}136\text{ gallons} \left| \frac{1\text{ cf}}{7.48\text{ gal}} \right| = 43{,}200\text{ cf}$$

$\text{Volume} = \text{Area} \cdot h$

$\frac{43{,}200\text{ cf}}{12} = \frac{\text{Area} \times \cancel{12\text{ ft}}}{\cancel{12}}$

$3600\text{ sf} = \text{Area}$

4. $V = l \cdot w \cdot h$

$V = (30')(30')(20')$

$V = 18{,}000$ cf

$$18{,}000\text{ cf} \left| \frac{7.48\text{ gal}}{1\text{ cf}} \right| = 134{,}640\text{ gal}$$

5. $V = l \cdot w \cdot h$

$V = (25')(15')(12')$

$V = 4{,}500$ cf per tank

$$\frac{4{,}500\text{ cf}}{\text{tank}} \left| \frac{3\text{ tanks}}{\text{system}} \right| \frac{7.48\text{ gal}}{1\text{ cf}} \right| = 100{,}980 \frac{\text{gal}}{\text{system}}$$

6. Perimeter $= 2l + 2w$

$P = (2)(25) + (2)(15)$

$P = 50 + 30$

$P = 80$ ft

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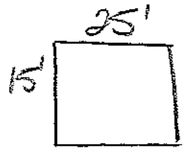
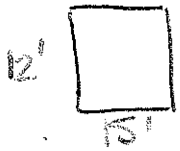
7.



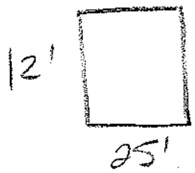
Bottom of tank

$$A = l \cdot w$$
$$A = 25 \times 15$$
$$A = 375 \text{ sf}$$



2 walls like this

$$A = l \cdot w \cdot 2$$
$$A = (15)(12)(2)$$
$$A = 360 \text{ sf}$$



2 walls like this

$$A = l \cdot w \cdot 2$$
$$A = (25)(12)(2)$$
$$A = 600$$

$$\text{TOTAL AREA} = 375 + 360 + 600$$
$$= 1{,}335 \text{ sf}$$

8. $$\text{Volume} = \pi r^2 h$$
$$V = (\pi)(1')(1')(300')$$
$$V = 942.45 \text{ cf}$$

if diameter = 2 ft
then radius = 1 ft

9. $$528730 \text{ gallons} \left| \frac{1 \text{ cf}}{7.48 \text{ gal}} \right| = 70{,}685.8 \text{ cf}$$

$$V = \pi r^2 h$$
$$\frac{70{,}685.8 \text{ cf}}{25} = \frac{\pi r^2 (25 \text{ ft})}{25}$$

$$\frac{2827.43}{\pi} = \frac{\pi r^2}{\pi}$$

$$899.99 = r^2$$

take the square root of both sides

$$30 = r$$

The diameter = $2 \times r$ = 60 ft

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10. 12 inches = 1ft diameter = 0.5 ft radius

$$146.8 \text{ gallons} \left| \frac{1\text{ cf}}{7.48\text{ gal}} \right| = 19.62 \text{ cf}$$

$$V = \pi r^2 h$$

$$19.62 \text{ cf} = (\pi)(0.5 \text{ ft})(0.5 \text{ ft})h$$

$$\frac{19.62}{(\pi)(0.5)(0.5)} = h$$

$$25 \text{ ft} = h$$

11.

$$A = \pi r^2$$

$$\frac{78.54}{\pi} = \frac{\cancel{\pi} r^2}{\cancel{\pi}}$$

$$25 = r^2$$

$$5 = r \qquad \text{diameter} = 10\text{ft}$$

12. $15\text{inches} \left| \frac{1\text{ ft}}{12\text{ inches}} \right| = 1.25$ ft diameter ÷ 2 = 0.625 ft radius

$$V_{main} = \pi r^2 h$$

$$V = (\pi)(0.625 \text{ ft})^2(300\text{ft})$$

$$V = 368.16 \text{ cf}/\text{main}$$

$$\frac{368.16 \text{ cf}}{\text{main}} \left| \frac{2 \text{ mains}}{\text{system}} \right| \frac{7.48\text{gal}}{1\text{ cf}} \Bigg| = 5{,}507.6 \text{ gallons}$$

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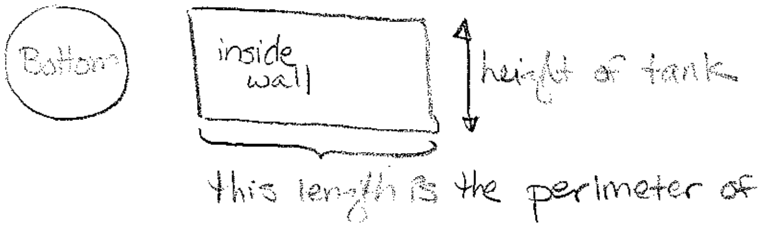
B. Perimeter $= \pi d$

$P = (3.1416)(20\ ft)$

$P = 62.8\ ft$

14. TANK HAS 2 AREAS



$A = \pi r^2$

$A = (3.1416)(5ft)^2$

$A = 78.54\ ft^2$

$A =$ Perimeter × height

$A = \pi d \times h$

$A = (3.1416)(10\ ft)(15\ ft)$

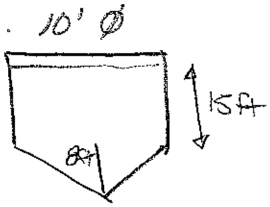
$A = 471.24\ sf$

TOTAL AREA TO PAINT $=$ 78.54 sf

+ 471.24 sf

549.78 sf

15.



$\text{Volume}_{TOP} = \pi r^2 h$

$= (3.1416)(5)^2(15)$

$= 1178.1\ ft^3$

$\text{Volume}_{CONE} = \frac{1}{3}\pi r^2 h$

$= (\frac{1}{3})(3.1416)(5)^2(8)$

$= 209.44\ ft^3$

TOTAL VOLUME $=$ 1178.1 $ft^3$

+ 209.44 $ft^3$

1387.54 $ft^3$

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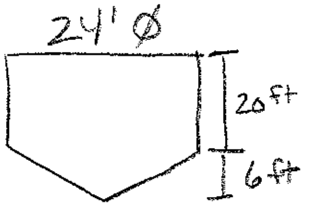
16.



$V_{TOP} = \pi r^2 h$
$= (3.1416)(12\,ft)^2(20\,ft)$
$= 9,047.81\ ft^3$

$V_{CONE} = \frac{1}{3}\pi r^2 h$
$= \frac{1}{3}(3.1416)(12\,ft)^2(6\,ft)$
$= 904.78\ ft^3$

TOTAL V= $9047.81\ ft^3$
$\underline{904.78\ ft^3}$
$9952.59\ ft^3$

$$9952.59\ ft^3 \left| \frac{7.48\ gal}{1\ ft^3} \right| = 74,445 \text{ gallons}$$

17. $$293739 \text{ gallons} \left| \frac{1\ cf}{7.48\ gal} \right| = 39,270\ ft^3$$

$$V_{TOTAL} = \pi r^2 h + \frac{\pi r^2 h}{3}$$

$$39,270\ ft^3 = (3.1416)(25)^2 h + \frac{(3.1416)(25')^2(6')}{3}$$

$$39,270\ ft^3 = 1963.5h + 3927$$

$$39,270 - 3927 = 1963.5h + 3927 - 3927$$

$$\frac{35343}{1963.5} = \frac{1963.5h}{1963.5}$$

$$18\ ft = h$$

Tank Geometries and Volumes

19. Find how many gallons of liquid are in a tank which measures 40' long, 25' wide and 12' high.

a) 79872
b) 67859
c) 90272
d) 89760

20. The diameter of a clear well is 10 ft. If filled to a depth of 10 ft. It will contain approximately:

a) 2987 gal.
b) 5872 gal.
c) 6024 gal.
d) 10,602 gal.

21. A cylindrical tank is 10 ft in diameter and 20 ft in height. What is the approximate capacity in liters?

a) 44,450 liters
b) 31,030 liters
c) 5,942 liters
d) 4,445 liters

22. Approximately how many gallons would 600 ft of 6" pipe hold?

a) 740
b) 880
c) 900
d) 930

23. The effluent weir of a clarifier is located along the rim of a 60-ft diameter tank. What is the approximate length of the weir?

a) 2826 feet
b) 377 feet
c) 188 feet
d) 540 feet

24. The entire surface of a free-standing cylindrical tank with an exposed, flat bottom must be painted. The tank does not have a top cover. The tank is 50 inches in diameter and 8 feet high. What is the total interior and exterior surface area to be painted?

a) 237 square feet
b) 105 square feet
c) 245 square feet
d) 118 square feet

25. What is the volume of water (in gallons) in an upright 25 foot diameter cylindrical tank with a water depth of 22 feet?
a) 10,794
b) 13,750
c) 80,737
d) 90,022
e) 102,850

26. You are going to add 6" of coal to one of the filters in your plant. The filter measures 10' x 12'. Each bag of coal contains 3 cubic feet. How many bags will you need to order?
a) 32 bags
b) 60 bags
c) 10 bags
d) 20 bags
e) 15 bags

27. Your system has just installed 2,000 feet of 8" pipe. How many gallons of water will it take to fill it?
a) 5,115
b) 521.4
c) 2,145
d) 6,971
e) 697.1

28. A plant has a 90-ft diameter storage tank with a sidewall depth of 20 ft. The tank also has a conical bottom that is 8 ft deep. The tank has a liquid level of 15 ft (sidewater depth). How many gallons of water are in the tank?
a) 586,593
b) 713,424
c) 840,255
d) 112,334

29. The flow velocity in a 6-in. diameter pipe is twice that in a 12-in diameter pipe if both are carrying 50 gal/min of wastewater.
a) True
b) False
Operations Forum January 1997

## TANK GEOMETRIES

19. Volume = (length) × (width) × (height)

$V = (40') \times (25') \times (12')$

$V = 12{,}000\ ft^3$

$12{,}000\ ft^3 \left| \frac{7.48\ gallon}{1\ ft^3} \right| = 89{,}760$ gallons

20. Volume = $\pi r^2 d$ where r = radius

d = depth

$V = (\pi)(5\ ft)^2(10\ ft)$

this is 5 ft because the radius is one-half the diameter

$V = (3.14)(5)(5)(10)$

$V = 785\ ft^3$

$785\ ft^3 \left| \frac{7.48\ gallon}{1\ ft^3} \right| = 5871.8$ gallons

21. $V = \pi r^2 d$

$V = \pi (5\ ft)^2 (20\ ft)$

$V = (3.14)(5)(5)(20)$

$V = 1570\ ft^3$

$1570\ ft^3 \left| \frac{7.48\ gallons}{1\ ft^3} \right| \frac{3.785\ L}{1\ gallon} \right| = 44{,}449.5$ LITERS

22. Pipes are just long skinny tanks.

$V = \pi r^2 d$

diameter = 6'' = 0.5'

$V = (3.14)(0.25')(0.25')(600')$

radius = 0.25'

$V = 117.75\ ft^3$

*always check units!

$$117.75\ ft^3 \left| \frac{7.48\ gallons}{1\ ft^3} \right| = 880.8\ gallons$$

23. For this problem, we need to find the perimeter or outer edge length of a circular tank.

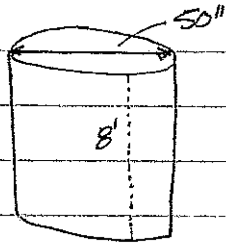
$P = \pi d$ where $d$ = diameter

$P = (\pi)(60\ ft)$

$P = (3.14)(60\ ft)$

$P = 188.4\ ft$

24.



To solve this problem, we need to find the area of the tank bottom and the area of the side of the tank.

$$\text{Area of bottom} = \pi r^2$$
$$= (\pi)(50''/2)^2$$

I don't like to work in square inches, so let's convert the 50 inch diameter into feet.

$$50\ inches \left| \frac{1\ foot}{12\ inches} \right| = 4.17\ feet \quad \therefore radius = 2.08\ ft$$

$$\text{Area of bottom} = (\pi)(2.08\ ft)^2$$
$$= (3.14)(2.08\ ft)(2.08\ ft)$$
$$= 13.65\ ft^2$$

The side of the tank is a rectangle that has been curled up.
The length of the rectangle is equal to the perimeter of the tank bottom.

Area = (length) $\times$ (width)
Area = $(\pi d) \times$ (width)
Area = (3.14)(4.17 ft)(8 ft)
Area = 104.75 $ft^2$

We need to paint the tank bottom (both sides) and the walls of the tank (both sides)

$$\begin{array}{r} 13.65\ ft^2 \\ 13.65\ ft^2 \\ 104.75\ ft^2 \\ +\ 104.75\ ft^2 \\ \hline 236.8\ ft^2 \end{array}$$

25. Volume = $\pi r^2 d$ where r = radius
$V = \pi (12.5\ ft)^2 (22\ ft)$ d = depth
V = (3.14)(12.5)(12.5)(22)
V = 10793.75 $ft^3$

$$10793.75\ ft^3 \left| \frac{7.48 \text{ gallons}}{1\ ft^3} \right| = 80737 \text{ gallons}$$

26. First, determine the volume you need to fill in $ft^3$

Volume = (length)(width)(height)

$V = (10\ ft)(12\ ft)(6\ inches)$

$\uparrow$ convert to feet

$V = (10ft)(12ft)(0.5\ ft)$

$V = 60\ ft^3$

Then convert to bags

$$60\ ft^3 \left| \frac{1bag}{3\ ft^3} \right| = 20\ bags$$

27. First, convert 8" to feet

$$8\ inches \left| \frac{1\ ft}{12\ inches} \right| = 0.67\ ft$$

so radius is 0.34 ft

Volume = $\pi r^2 d$     d = depth, or in this case, length of pipe

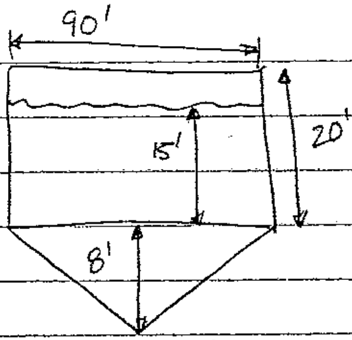
$V = \pi (0.34\ ft)^2 (2000\ ft)$

$V = (3.14)(0.34\ ft)(0.34ft)(2000\ ft)$

$V = 725.97\ ft^3$

$$725.97\ ft^3 \left| \frac{7.48\ gallons}{1\ ft^3} \right| = 5430\ gallons$$

28.



We need to find the volume of the cylinder and the volume of the cone.

$$V = \overbrace{\pi r^2 d}^{\text{cylinder}} + \overbrace{\tfrac{1}{3}\pi r^2 d}^{\text{cone}}$$

$$V = (\pi)(45')^2(15') + (\tfrac{1}{3})(\pi)(45')^2(8')$$

$$V = (3.14)(45')(45')(15') + (\tfrac{1}{3})(3.14)(45')(45')(8')$$

$$V = 95377.5\ ft^3 + 16956\ ft^3$$

$$V = 112333.5\ ft^3$$

$$112333.5\ ft^3 \left| \frac{7.48\ \text{gallons}}{1\ ft^3} \right| = 840255\ \text{gallons}$$

29. Velocity $= \frac{\text{flow}}{\text{area}}$

Since the areas will be in $ft^2$, let's begin by converting the flow rate from gpm to $ft^3/min$.

$$\frac{50 \text{ gallons}}{\text{min}} \left| \frac{1 \text{ ft}^3}{7.48 \text{ gallons}} \right| = 6.68 \frac{ft^3}{min}$$

Next, let's find the radius of each pipe in feet

$$6 \text{ inches} \left| \frac{1 \text{ ft}}{12 \text{ inches}} \right| = 0.5 \text{ ft}, \quad \text{radius} = 0.25 \text{ ft}$$

$$12 \text{ inches} \left| \frac{1 \text{ ft}}{12 \text{ inches}} \right| = 1.0 \text{ ft}, \quad \text{radius} = 0.5 \text{ ft}$$

6" Pipe

Velocity $= \frac{\text{flow}}{\text{area}}$

$V = \frac{6.68 \, ft^3/min}{\pi r^2}$

$V = \frac{6.68 \, ft^3/min}{(3.14)(0.25')(0.25')}$

Velocity = 34.0 ft/min

12" Pipe

Velocity $= \frac{\text{flow}}{\text{area}}$

$V = \frac{6.68 \, ft^3/min}{\pi r^2}$

$V = \frac{6.68 \, ft^3/min}{(3.14)(0.5')(0.5')}$

Velocity = 8.5 ft/min

four times slower

$\boxed{\text{False}}$

# Sidney's Big Book of Water and Wastewater Math

INDIGO WATER GROUP

## Unit Conversions to Know by Heart

1 inch = 2.54 centimeters
1 meter = 3.28 feet
1 mile = 5280 feet

1 acre = 43,560 $ft^2$
1 $m^2$ = 10.76 $ft^2$

1 gallon = 3.785 liters
1 $ft^3$ = 7.48 gallons
1 $m^3$ = 35.31 $ft^3$

1 ft water = 0.433 psi

1 gallon = 8.34 lbs when specific gravity is 1.0
1 kg = 2.2 lbs

1% = 10,000 mg/L
1 mg/L = 1 ppm
1 µg/L = 1 ppb

1 day = 1440 minutes
1 hp = 0.746 kW

1 gram = 15.43 grains
1 grain per gallon = 17.1 mg/L

## Water Formulas

pounds per day = (concentration in mg/L)*(flow rate in mgd)*(8.34)

chlorine dose = demand + residual

$$\text{velocity} = \frac{\text{flow}}{\text{area}} \qquad V = \frac{Q}{A}$$

$$\text{flow rate} = \frac{\text{volume}}{\text{time}} \qquad Q = \frac{V}{t}$$

$$\text{overflow rate} = \frac{\text{flow rate}}{\text{area}}$$

$$\text{weir loading rate} = \frac{\text{flow rate}}{\text{feet of weir}}$$

(concentration 1)*(volume 1) = (concentration 2)*(volume 2) $C_1V_1 = C_2V_2$

(conc. 1)*(volume 1) + (conc. 2)*(volume 2) = (conc. 3)*(volume 3)

$$C_1V_1 + C_2V_2 = C_3V_3$$

$$\text{horsepower} = \frac{(\text{flow in gpm})*(\text{lift in feet})}{3960}$$

# Hydraulic Retention Time

# HYDRAULIC RETENTION TIME

EXAMPLE:

PLANT A HAS A 2.5 MG FLOW EQUALIZATION TANK. WATER IS BEING PUMPED INTO THE TANK BY A POSITIVE DISPLACEMENT PUMP WITH THE FOLLOWING CHARACTERISTICS:

PUMP CAVITY = 4.2 $ft^3$

STROKES PER MINUTE = 40

HOW LONG DOES IT TAKE TO FILL THE TANK?

I know that the hydraulic retention time is a measure of how much water is moving through the tank over a certain amount of time.

$$Q = \frac{Volume}{Time}$$

I know that V is 2.5 mg, but I don't know the flow rate of the pump. Plus, I need the units to match. Lets convert.

HAVE — WANT

$$\left.\frac{4.2\ ft^3}{stroke}\right| \qquad \qquad \left| \frac{mg}{day}\right.$$

FILL IN UNITS, MULTIPLY THROUGH

$$\frac{4.2\ ft^3}{stroke}\left|\frac{10\ strokes}{1\ min}\right|\frac{60\ min}{1\ hour}\left|\frac{24\ hours}{1\ day}\right|\frac{7.48\ gallons}{1\ ft^3}\Bigg| \qquad \frac{gallons}{day}$$

$$= 452390.4\ \frac{gallons}{day}$$

$$= 0.452390\ MGD$$

Put things back into the formula above and solve for time.

$$Q = \frac{V}{t}$$

$$\left.0.4523904 \text{ mGD} = \frac{2.5 \text{ mG}}{\text{time}}\right\} \text{step } 1$$

$$\left.(\text{time})(0.4523904 \text{ mGD}) = 2.5 \text{ mG}\right\} \text{step } 2$$

$$\left.\text{time} = \frac{2.5 \text{ mG}}{0.4523904 \text{ mGD}}\right\} \text{step } 3$$

$$\left.\text{time} = 5.53 \text{ days}\right\} \text{step } 4$$

We'll learn more about solving equations in the next sections of the book.

HRT

30. What is the average detention time in a basin given the following: diameter = 30' depth = 15' flow = 700 gpm
a) 1hr. 34min.
b) 1hr. 53min.
c) 1hr. 47min.
d) 2 hrs. 3 min.

31. What is the average detention time in a basin given the following: diameter = 80' depth = 12.2' flow = 5 MGD
a) 2.2 hrs.
b) 1.68 hrs.
c) 2.4 hrs.
d) 1.74 hrs.

32. Two 50-ft diameter, 10-ft deep sedimentation basins operating in parallel handle a flow of 2 mgd. What is the detention time in hours (assume the basins have flat floors)?
a) 3.5 hrs
b) 6.7 hrs
c) 7.0 hrs
d) 2.0 hrs
Operations Forum March 1998

33. Your finished water storage tank is 35 feet in diameter and 65 feet high. With no water entering it the level dropped 4' in 5 hours. How many gallons of water were used in this period?
a) 7,193
b) 71,930
c) 467,542
d) 28,772
e) 62,506

34. If two pumps will pump 120 gpm each, how long will it take to fill a tank 50' long, 20' wide, and 8' deep?
a) 2 hours, 27 minutes
b) 4 hours, 42 minutes
c) 4 hours, 9 minutes
d) 1 hour, 49 minutes

35. Given the following information, what is the water tank detention time? Diameter = 80 ft Depth = 25 ft Flow rate = 25000 gpd

a) 47.8 days
b) 25.2 days
c) 37.6 days
d) 15.7 days

36. Compute the detention time in hours in a final sedimentation basin given: Diameter = 95' Depth = 11' Flow rate = 7.0 MGD

a) 1 hr. 59 min
b) 2 hrs 10 min
c) 4 hrs 10 min
d) 1 hr

37. A settling basin 60' by 12' and 12' deep is used to treat a flow of 2.4 MGD. What is the detention time?

a) ‘15 min.
b) ‘39 min.
c) ‘1.1 hrs
d) ‘2.3 hrs

38. What is the detention time in a reservoir if the influent flow rate is 0.785 MGD, the reservoir depth is 22 feet, and the reservoir covers 17 acres?

a) 97 days
b) 56 days
c) 155 days
d) 180 days
e) 420 days

39. Your filters fill your clearwell at a rate of 375 gpm. The clearwell measures 10' wide x 80' long x 12' deep. If it had 5' of water in it how long would it take to fill completely?

1.9 hours
111.7 minutes
19.1 minutes
11.1 hours
191 minutes

## HYDRAULIC RETENTION TIME

30. $Q = \frac{V}{t}$

from the information I'm given, I can find the volume in $ft^3$.
The flow rate is in gpm.
One of these must be converted.

$$Volume = \pi r^2 d$$
$$V = (3.14)(15\ ft)(15\ ft)(15\ ft)$$
$$V = 10597.5\ ft^3$$

$$10597.5\ ft^3 \left| \frac{7.48\ gallons}{1\ ft^3} \right| = 79269.3\ gallons$$

$$Q = \frac{V}{t}$$

$$\frac{700\ gallons}{min} = \frac{79269.3\ gallons}{t}$$
$$700t = 79269.3$$
$$t = 113\ minutes$$

OR 1 hour 53 minutes

31. $Volume = \pi r^2 d$
$$V = (3.14)(40\ ft)(40ft)(12.2\ ft)$$
$$V = 61292.8\ ft^3$$

$$\frac{5\ MG}{day} \left| \frac{1\ day}{24\ hours} \right| \frac{1{,}000{,}000\ gallons}{1\ MG} \left| \frac{1\ ft^3}{7.48\ gallons} \right| = 27852.0\ ft^3/hour$$

now that all of our units match, we can use our formula for HRT

31 (cont.) $Q = \frac{V}{t}$

$$\frac{27852.0\ ft^3}{hr} = \frac{61292.8\ ft^3}{t}$$

$$27852.0\ t = 61292.8$$

$$t = 2.2\ \text{hours}$$

32. This problem is similar to #31 except that we have two basins on-line.

$$V = \pi r^2 d$$

$$V = (3.14)(25\ ft)(25\ ft)(10\ ft)$$

$V = 19625\ ft^3$ <u>per tank</u>

$$\text{total volume} = (2) \cdot (19625\ ft^3)$$

$$= 39250\ ft^3$$

$$\frac{2\ mg}{day} \bigg| \frac{1\ day}{24\ hrs} \bigg| \frac{1000\,000\ gal}{1\ mg} \bigg| \frac{1\ cuft}{7.48\ gal} \bigg| = 11140.8\ ft^3/hour$$

$$Q = \frac{V}{t}$$

$$11140.8\ \frac{ft^3}{hr} = \frac{39250\ ft^3}{t}$$

$$(11140.8)(t) = 39250$$

$$t = 3.5\ \text{hours}$$

33. We are only interested in the volume lost, not the total volume of the tank.

$V = \pi r^2 d$

$V = (3.14)(17.5\ ft)(17.5\ ft)(4\ ft)$

$V = 3846.5\ ft^3$

$3846.5\ ft^3 \left| \frac{7.48\ gallons}{1\ ft^3} \right| = 28772$ gallons

34. $V = (l)(w)(h)$

$V = (50\ ft)(20\ ft)(8\ ft)$

$V = 8000\ ft^3$

$8000\ ft^3 \left| \frac{7.48\ gal}{1\ ft^3} \right| = 59,840$ gallons

$Q = \frac{V}{t}$

$240\ gpm = \frac{59,840\ gallons}{t}$

$240t = 59,840$

$t = 249.3$ minutes

$249.3\ minutes \left| \frac{1\ hr}{60\ minutes} \right| = 4.16$ hours

$0.16\ hours \left| \frac{60\ minutes}{1\ hr} \right| = 9$ minutes

4 hours 9 minutes

35. $V = \pi r^2 d$

$V = (3.14)(40 \text{ ft})^2(25 \text{ ft})$

$V = (3.14)(40 \text{ ft})(40 \text{ ft})(25 \text{ ft})$

$V = 125600 \text{ ft}^3$

$125600 \text{ ft}^3 \left| \dfrac{7.48 \text{ gallons}}{1 \text{ ft}^3} \right| = 939488 \text{ gallons}$

$Q = \dfrac{V}{t}$

$25{,}000 \text{ gpd} = \dfrac{939488 \text{ gallons}}{t}$

$25{,}000\, t = 939488$

$t = 37.6$ days

36. $V = \pi r^2 d$

$V = (3.14)(47.5 \text{ ft})^2(11 \text{ ft})$

$V = (3.14)(47.5 \text{ ft})(47.5 \text{ ft})(11 \text{ ft})$

$V = 77931 \text{ ft}^3$

$77931 \text{ ft}^3 \left| \dfrac{7.48 \text{ gallons}}{1 \text{ ft}^3} \right| = 582922.9 \text{ gallons}$

$Q = \dfrac{V}{t}$

$7{,}000{,}000 \text{ gpd} = \dfrac{582923 \text{ gallons}}{t}$

$7000000\, t = 582923$

$t = 0.083$ days

$0.083 \text{ days} \left| \dfrac{24 \text{ hrs}}{1 \text{ day}} \right| = 1.99$ hours $=$ 1 hr 59 minutes

37. $V=(l)(w)(h)$

$V=(60\,ft)(12\,ft)(12\,ft)$

$V=8640\,ft^3$

$8640\,ft^3 \left| \frac{7.48\,\text{gallons}}{1\,ft^3} \right| = 64,627$ gallons

$$Q=\frac{V}{t}$$

$2,400,000\ \text{gallons} = \frac{64,627\ \text{gallons}}{t}$

$2400000t = 64627$

$t = 0.0269$ days

$0.0269\ \text{days} \left| \frac{24\,\text{hrs}}{1\,\text{day}} \right| \frac{60\,\text{min}}{1\,\text{hr}} \right| = 39$ minutes

38. $17\ \text{acres} \left| \frac{43.560\,ft^2}{1\,\text{acre}} \right| = 740520\,ft^2$

an acre is an <u>area</u>
area is the
same as length
multiplied by width

$V=(l)(w)(h)$

$V=(740520\,ft^2)(22\,ft)$

$V=1629\,1440\,ft^3$

$16291440\,ft^3 \left| \frac{7.48\,\text{gallons}}{1\,ft^3} \right| = 121859971$ gallons

38. (cont) $Q = \frac{V}{t}$

$785000 \text{ gpd} = \frac{121859971 \text{ gallons}}{t}$

$785000t = 121859971$

$t = 155 \text{ days}$

39. The volume of the clearwell is only the volume that needs to be filled - not the whole volume.

$V = (l)(w)(h)$

$V = (10 \text{ ft})(80 \text{ ft})(12 - 5 \text{ ft})$

$V = (10 \text{ ft})(80 \text{ ft})(7 \text{ ft})$

$V = 5600 \text{ ft}^3$

$5600 \text{ ft}^3 \left| \frac{7.48 \text{ gallons}}{1 \text{ ft}^3} \right| = 41888 \text{ gallons}$

$Q = \frac{V}{t}$

$375 \text{ gpm} = \frac{41888 \text{ gallons}}{t}$

$375t = 41888$

$t = 111.7 \text{ minutes}$

# Hydraulic Retention Time

18. The wet well holds 5 million gallons and the finished water production rate at peak hour is 2800 gpm. What is the hydraulic retention time of the wet well in minutes?

Answer: minutes

19. A number of pumps are used to fill a water tank. Each pump transfers water into the tank at a rate of 2800 gallons per minute when 4 pumps are used. The tank can be filled in 29.76 hours. What is the volume of the tank in cubic feet?

Answer: cubic feet

20. A water main feeds a subdivision. The main is 500 feet long and is 12 inches in diameter. The distribution crew is flushing the main to remove sediment. How long should they flush the line to achieve 2 pipe volumes? Express your answer in minutes. The pipe delivers 30 cfm of flow.

Answer: minutes

21. A rectangular basin measures 100 feet long, by 50 feet wide, by 12 feet deep. A pump drawing water out of the full tank is able to empty the tank in 1.24 days. What is the pump rate in gallons per minute?

Answer: gpm

22. A rectangular tank is being filled by 4 pumps. If the tank is 100 feet long by 50 feet wide by 12 feet long and takes 1.24 days to fill. At what rate is each pump moving water into the tank? Express your answer in gpm.

Answer: gpm

23. Water enters the distribution system at 4.03 mgd. The transmission line has a diameter of 12 inches and is 500 feet long. The transmission main feeds a 5000000 gallon storage tank. If water leaves the tank at the same rate that it enters, calculate the water age as it leaves the tank. Assume the tank is full. Express your answer in hours and minutes.

Answer:

24. Water leaves a full, cylindrical tank at a rate of 6.24 cfs. The tank volume is reduced by 50% after 29.76 hours. If the tank is 20 feet high, what is the diameter in feet?

Answer: feet

25. A water tank on the top of a hill holds 60000 cf of water. The tank is completely empty. The tank is fed by a booster pump station with 4 pumps. Each pump is rated at 1120 gpm. If the distribution crew needs to fill the tank in less than 29.76 hours, what is the least number of pumps that could be used? Assume that pump rates remain constant regardless of the volume of water in the tank.

Answer: pumps

26. A 12 inch pipeline needs to be flushed. If the desired length of pipeline to be flushed is 500 feet, how many minutes will it take to flush the line at 50 gpm?

Answer: minutes

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18. $Q = \frac{V}{t}$

$2800\ gpm = \frac{5\ mgd}{t}$ $\qquad \frac{5\ mg}{day}\left|\frac{1{,}000{,}000\ gal}{1\ mg}\right|\frac{1\ day}{1440\ min}\Big| = 3472.2\ gpm$

$2800\ gpm = \frac{3472\ gpm}{t}$

$2800t = 3472$

$t = 1.24$ minutes

19. 4 pumps → TANK

$Q = \frac{V}{t}$ $\qquad 29.76\ hours\left|\frac{60\ min}{1\ hr}\right| = 1785.6\ min$

$2800\ gpm = \frac{V}{29.76\ hours}$

$2800\ gpm = \frac{V}{1785.6\ min}$

$4{,}999{,}680\ gal = V$ $\qquad 4{,}999{,}680\ gal\left|\frac{1\ cf}{7.48\ gal}\right| = 668{,}406\ cf$

20. $Q = \frac{V}{t}$ $\qquad V = \pi r^2 h$

$V = (\pi)(0.5\ ft)^2(500\ ft)$

$30\ cfm = \frac{785.4\ cf}{t}$ $\qquad V = 392.7\ ft^3$

$30t = 785.4$ $\qquad 2\ volumes = 785.4\ ft^3$

$t = 26.18$ minutes

21. $V = l \cdot w \cdot h$

$V = (100\ ft)(50\ ft)(12\ ft)$

$V = 60{,}000\ cf$

$60{,}000\ cf\left|\frac{7.48\ gal}{1\ cf}\right| = 448{,}800\ gal$

$1.24\ days\left|\frac{1440\ min}{1\ day}\right| = 1{,}785.6\ min$

$Q = \frac{V}{t}$

$Q = \frac{448{,}000\ gal}{1785.6\ min}$

$Q = 250.8\ gpm$

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22. Unit conversions from problem 21

Volume = 448,000 gal

$t$ = 1785.6 min

$$Q = 250.8 \text{ gpm total} \quad \text{OR} \quad \frac{250.8}{4} = 62.7 \text{ gpm/pump}$$

23. $Q = 4.03$ mgd

$$V_{PIPE} = \pi r^2 h$$

$$V_{TANK} = 5{,}000{,}000 \text{ gal}$$

$$V_{PIPE} = (\pi)(0.5\text{ft})^2(500\text{ft})$$

$$V_{PIPE} = 392.7\text{cf}$$

$$392.7\text{cf} \left| \frac{7.48\text{gal}}{1\text{cf}} \right| = 2{,}937 \text{ gal}$$

TOTAL VOLUME = 5,002,937 gal

$$Q = \frac{V}{t}$$

$$4.03 \text{ mgd} = \frac{5{,}002{,}937 \text{ gal}}{t}$$

$$4{,}030{,}000 \frac{\text{gal}}{\text{day}} = \frac{5{,}002{,}937 \text{ gal}}{t}$$

$$4030000t = 5002937$$

$$t = 1.24 \text{ days}$$

$$1.24 \text{ days} \left| \frac{24 \text{ hours}}{1 \text{ day}} \right| = 29.76 \text{ hours}$$

$$0.76 \text{ hours} \left| \frac{60 \text{ min}}{1 \text{ hr}} \right| = 46 \text{ minutes}$$

29 hours and 46 minutes

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24. $Q = \frac{V}{t}$

$6.24 \text{ cfs} = \frac{V}{29.76 \text{ hrs}}$

$29.76 \text{ hours} \left| \frac{60 \text{ min}}{\text{hr}} \right| \frac{60 \text{ sec}}{1 \text{ min}} \Big| = 107{,}136 \text{ secs}$

$6.24 \text{ cfs} = \frac{V}{107{,}136 \text{ sec}}$

$668{,}528.6 \text{ cf} = V$ ← This is ½ the volume of the tank, as the total volume is 2 × 668,528.6 cf OR 1,337,057.2 cf

$V = \pi r^2 h$

$1{,}337{,}057.2 \text{ cf} = (\pi)(r^2)(20 \text{ ft})$

$21{,}279.88 = r^2$

$145.88' = r$

$2r = \text{diameter} = \boxed{292 \text{ feet}}$

25. $60{,}000 \text{ cf} \left| \frac{7.48 \text{ gal}}{1 \text{ cf}} \right| = 448{,}800 \text{ gal}$

$29.76 \text{ hours} \left| \frac{60 \text{ min}}{1 \text{ hour}} \right| = 1785.6 \text{ minutes}$

$Q = \frac{V}{t}$

$Q = \frac{448{,}000 \text{ gal}}{1785.6 \text{ min}}$

$Q = 250.9 \text{ gpm}$ ← this is less than the flow rate of 1 pump, so only 1 pump needed

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26. $V = \pi r^2 h$

$V = (3.1416)(0.5\,ft)^2(500\,ft)$

$V = 392.7\ cf$

$392.7\ cf \left| \frac{7.48\ gal}{1\ cf} \right| = 2,937.396\ gal$

$Q = \frac{V}{t}$

$50\ gpm = \frac{2,937.396\ gal}{t}$

$50t = 2,937.396$

$t = 59$ minutes

## HYDRAULIC RETENTION TIME

1. If two pumps will pump 120 gpm each, how long will it take to fill a tank 50' long, 20' wide, and 8' deep?
   a) 2 hours, 27 minutes
   b) 4 hours, 42 minutes
   c) 4 hours, 9 minutes
   d) 1 hour, 49 minutes

2. What is the average detention time in a clarifier given the following: diameter = 30' depth = 15' flow = 700 gpm
   a) 1hr. 34min.
   b) 1hr. 53min.
   c) 1hr. 47min.
   d) 54 minutes

3. What is the average detention time in a clarifier given the following: diameter = 80' depth = 12.2' flow = 5 MGD
   a) 2.2 hrs.
   b) 1.68 hrs.
   c) 2.4 hrs.
   d) 0.94 hrs.

4. Determine the flow capacity of a pump in gpm if the pump lowers the wastewater in a six-foot square sump by 8 inches in 5 minutes.
   a) 35.9 gpm
   b) 57.6 gpm
   c) 92.4 gpm
   d) 179.5 gpm
   e) 430 gpm

5. What is the detention time in a stabilization pond if the influent flow rate is 0.785 MGD, the pond depth is 4.5 feet, and the pond covers 17 acres?
   a) 97 days
   b) 56 days
   c) 32 days
   d) 14 days
   e) 4.2 days

6. A 20-ft diameter clarifier with a depth of 8.25 ft receives a flow of 0.314 mgd. What is the detention time?
   a) 1.22 hours
   b) 1.48 hours
   c) 1.75 hours
   d) 2.25 hours

?Operations Forum October 1998

7. Compute the detention time in hours in a final clarifier given: Diameter = 95' Depth = 11' Flow rate = 7.0 MGD
  a) 1 hr. 55 min
  b) 2.0 hrs
  c) 2 hrs. 10 min

8. Compute the lagoons detention time. Surface area = 6.0 acres, Average depth = 3.0 ft, Average daily flow = 0.25 MGD
  a) 3 days
  b) 8 days
  c) 24 days
  d) 29 days

9. A settling basin 60' by 12' and 12' deep is used to treat a flow of 2.4 MGD. What is the detention time?
  a) 15 min.
  b) 39 min.
  c) '1.1 hrs
  d) 2.3 hrs

10. Two 50-ft diameter, 10-ft deep secondary clarifiers operating in parallel handle a flow of 2 mgd. What is the detention time in hours (assume the clarifier has a flat floor)?
  a) 3.5 hrs
  b) 6.7 hrs
  c) 7.0 hrs
?Operations Forum March 1998

11. A chemical feed pump has been rebuilt and must be calibrated for maximum pump rate. If it takes 1 hour and 15 minutes to fill a 10-ft X 5-ft X 10-ft rectangular tank, what is the maximum pump rate in gal/min?
  a) 67 gal/min
  b) 50 gal/min
  c) 45 gal/min
?Operations Forum March 1998

JOB HYDRALIC RETENTION TIME JOB NO. 33

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1. V = length × width × length

$V = (50\,ft)(20\,ft)(8\,ft)$

$V = 8000\,ft^3$

$8000\,ft^3 \left| \frac{7.48\,gal}{1\,ft^3} \right| = 59840\,gal$

$Q = \frac{V}{t}$

Q = flow rate, in this case 120 gpm × 2 OR 240 gpm since two pumps are working to fill the tank

$\frac{240\,gal}{min} = \frac{59840\,gal}{time}$

$(240)(time) = 59840$

time = 249 minutes

$249\,min \left| \frac{1\,hour}{60\,min} \right| = 4.15\,hours$

$0.15\,hours \left| \frac{60\,min}{1\,hour} \right| = 9\,minutes$

4 hrs 9 min

2. $V = \pi r^2 h$

$V = (3.14)(15\,ft)(15\,ft)(15\,ft)$

$V = 10597.5\,ft^3$

$10597.5\,ft^3 \left| \frac{7.48\,gal}{1\,ft^3} \right| = 79269.3\,gal$

$Q = \frac{V}{t}$

$700\,gpm = \frac{79269.3\,gal}{time}$

$(700)(time) = 79269.3$

time = 113.2 minutes

113.2 minutes
− 60 minutes
53 minutes

1 hr 53 minutes

JOB Hydraulic Retention Time JOB NO. 34

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3. $V = \pi r^2 h$

$V = (3.14)(40\ ft)(40\ ft)(12.2\ ft)$

$V = 61292.8\ ft^3$

$$61292.8\ ft^3 \left| \frac{7.48\ gal}{1\ ft^3} \right| = 458470\ gal$$

$Q = \frac{V}{t}$ $Q = 5\ MGD = 5{,}000{,}000\ \frac{gal}{day}$

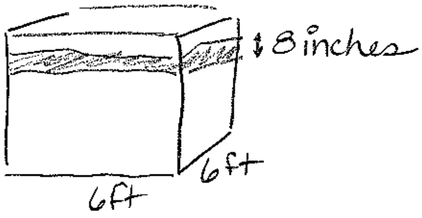
$$5{,}000{,}000\ \frac{gal}{day} = \frac{458470\ gal}{time}$$

$$(5{,}000{,}000\ \tfrac{gal}{day})(t) = 458470\ gal$$

$$t = 0.092\ days$$

$$0.092\ days \left| \frac{24\ hours}{1\ day} \right| = 2.2\ hours$$

4.



$$8\ inches \left| \frac{1\ ft}{12\ inches} \right| = 0.67\ ft$$

$V = length \times width \times height$

$V = (6\ ft)(6\ ft)(0.67\ ft)$

$V = 24.12\ ft^3$

$$24.12\ ft^3 \left| \frac{7.48\ gal}{1\ ft^3} \right| = 180.42\ gal$$

$Q = \frac{V}{t}$

$Q = \frac{180.42\ gal}{5\ min}$

$Q = 36\ gpm$

JOB Hydraulic Retention Time JOB NO. 35
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5. $1 \text{ ACRE} = 43{,}560 \text{ ft}^2$

$$\text{Volume} = \text{length} \times \text{width} \times \text{height}$$
$$\text{Volume} = \text{AREA} \times \text{height}$$
$$\text{Volume} = (17 \text{ acres})(43{,}560 \text{ ft}^2/\text{acre})(4.5 \text{ ft})$$
$$\text{Volume} = 3332340 \text{ ft}^3$$

$$3332340 \text{ ft}^3 \left| \frac{7.48 \text{ gal}}{1 \text{ ft}^3} \right| \frac{1 \text{ MG}}{1{,}000{,}000 \text{ gal}} \bigg| = 24.93 \text{ mg}$$

$$Q = \frac{V}{t}$$
$$0.785 \text{ mgd} = \frac{24.93 \text{ mg}}{t}$$
$$(0.785)(t) = 24.93$$
$$t = 31.8 \text{ days}$$

6. $V = \pi r^2 h$
$$V = (3.14)(10 \text{ ft})(10 \text{ ft})(8.25 \text{ ft})$$
$$V = 2590.5 \text{ ft}^3$$

$$2590.5 \text{ ft}^3 \left| \frac{7.48 \text{ gal}}{1 \text{ ft}^3} \right| = 19376.94 \text{ gal}$$

$$0.314 \text{ mgd} = 314{,}000 \text{ gpd}$$

$$Q = \frac{V}{t}$$
$$314{,}000 \frac{\text{gal}}{\text{day}} = \frac{19376.94 \text{ gal}}{t}$$
$$(314{,}000)(t) = 19376.94$$
$$t = 0.06171 \text{ days}$$

$$0.06171 \text{ day} \left| \frac{24 \text{ hrs}}{1 \text{ d}} \right| = 1.48 \text{ hrs}$$

JOB Hydraulic Retention Time JOB NO. 36

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7. $V = \pi r^2 h$

$V = (3.14)(47.5\ ft)(47.5\ ft)(11\ ft)$

$V = 77930.875\ ft^3$

$77930.875\ ft^3 \left| \frac{7.48\ gal}{1\ ft^3} \right| = 582923$ gallons

$Q = \frac{V}{t}$

$7{,}000{,}000\ \frac{gal}{d} = \frac{582923\ gal}{t}$

$t = 0.0833$ days

$0.0833\ days \left| \frac{24\ hrs}{1\ day} \right| \frac{60\ min}{1\ hr} \Big| = 120$ minutes OR

2 hours

8. $1\ acre = 43{,}560\ ft^2$

Volume = length · width · height

Volume = AREA × height

$V = (6\ acres)(43{,}560\ ft^2/acre)(3\ ft)$

$V = 784080\ ft^3$

$784080\ ft^3 \left| \frac{7.48\ gal}{1\ ft^3} \right| = 5864918.4\ gal$

$Q = \frac{V}{t}$

$250{,}000\ \frac{gal}{day} = \frac{5864918.4\ gal}{t}$

$(250{,}000)t = 5864918.4$

$t = 23.5$ days

JOB Hydraulic Retention Time JOB NO. 37
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9. $V = l \times w \times h$
$V = (60\ ft)(12\ ft)(12\ ft)$
$V = 8640\ ft^3$

$$8640\ ft^3 \left| \frac{7.48\ gal}{1\ ft^3} \right| = 64627.2\ gal$$

$$\frac{2.4\ MG}{day} \left| \frac{1\ day}{1440\ min} \right| \frac{1{,}000{,}000\ gal}{1\ MG} \right| = 1666.7\ \frac{gal}{min}$$

$$Q = \frac{V}{t}$$

$$1666.7\ \frac{gal}{min} = \frac{64627.2\ gal}{t}$$

$(1666.7)(t) = 64627.2$
$t = 38.8$ minutes

10. Find the volume of 1 tank and then multiply by 2 to find the total volume

$V = \pi r^2 h$
$V = (3.14)(25\ ft)(25\ ft)(10\ ft)$
$V = 19625\ ft^3$

$$\frac{19625\ ft^3}{} \left| \frac{7.48\ gal}{1\ ft^3} \right| = 146795\ gal$$ in one clarifier

293590 gal in two clarifiers

$$Q = \frac{V}{t}$$

$$2{,}000{,}000\ \frac{gal}{day} = \frac{293590\ gal}{t}$$

$t = 0.147$ days

$$0.147\ days \left| \frac{24\ hrs}{1\ day} \right| = 3.52\ hours$$

JOB Hydraulic Retention Time JOB NO. 38

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11.

$$V = l \times w \times h$$

$$V = (10\ ft)(5\ ft)(10\ ft)$$

$$V = 500\ ft^3$$

$$500\ ft^3 \left| \frac{7.48\ gal}{1\ ft^3} \right| = 3740\ gal$$

$$Q = \frac{V}{t}$$

$$Q = \frac{3740\ gal}{1\ hr\ 15\ min}$$

$$Q = \frac{3740\ gal}{75\ min}$$

$$Q = 49.9\ min$$

# Sidney's Big Book of Water and Wastewater Math

INDIGO WATER GROUP

## Unit Conversions to Know by Heart

1 inch = 2.54 centimeters
1 meter = 3.28 feet
1 mile = 5280 feet

1 acre = 43,560 $ft^2$
1 $m^2$ = 10.76 $ft^2$

1 gallon = 3.785 liters
1 $ft^3$ = 7.48 gallons
1 $m^3$ = 35.31 $ft^3$

1 ft water = 0.433 psi

1 gallon = 8.34 lbs when specific gravity is 1.0
1 kg = 2.2 lbs

1% = 10,000 mg/L
1 mg/L = 1 ppm
1 µg/L = 1 ppb

1 day = 1440 minutes
1 hp = 0.746 kW

1 gram = 15.43 grains
1 grain per gallon = 17.1 mg/L

## Water Formulas

pounds per day = (concentration in mg/L)*(flow rate in mgd)*(8.34)

chlorine dose = demand + residual

$$\text{velocity} = \frac{\text{flow}}{\text{area}} \qquad V = \frac{Q}{A}$$

$$\text{flow rate} = \frac{\text{volume}}{\text{time}} \qquad Q = \frac{V}{t}$$

$$\text{overflow rate} = \frac{\text{flow rate}}{\text{area}}$$

$$\text{weir loading rate} = \frac{\text{flow rate}}{\text{feet of weir}}$$

(concentration 1)*(volume 1) = (concentration 2)*(volume 2) $C_1V_1 = C_2V_2$

(conc. 1)*(volume 1) + (conc. 2)*(volume 2) = (conc. 3)*(volume 3)

$$C_1V_1 + C_2V_2 = C_3V_3$$

$$\text{horsepower} = \frac{\text{(flow in gpm)*(lift in feet)}}{3960}$$

# Process Efficiency

# PROCESS EFFICIENCY

$$\text{PERCENT REMOVAL} = \frac{(\text{In} - \text{Out})}{\text{In}} * 100$$

Example:
Primary clarifier influent TSS = 150 mg/L
effluent TSS = 90 mg/L
Find percent removal.

$$\text{PERCENT REMOVAL} = \frac{(\text{In} - \text{OUT})}{\text{In}} * 100$$

$$\text{PERCENT REMOVAL} = \frac{(150\ \text{mg/L} - 90\ \text{mg/L})}{150\ \text{mg/L}} * 100$$

Are units consistent? Do we need to correct?

## PERCENT REMOVAL or PERCENT EFFICIENCY

1. If the influent SS are 200 mg/l and the effluent SS are 16 mg/l what is the removal efficiency?
 a) 93%
 b) 92%
 c) 85%
 d) 97%

2. What is the percent of BOD removed in a plant when the influent BOD is 245 mg/L and the effluent BOD is 22 mg/L?
 a) 92%
 b) 86%
 c) 35%
 d) 13%
 e) 9%

3. Calculate the percentage reduction of BOD through the plant, given the following data: Wastewater entering the plant has a BOD of 275 mg/l; Plant effluent has a BOD of 30 mg/l
 a) 11%
 b) 30%
 c) 45%
 d) 89%
?Operations Forum June 2001

4. The influent suspended solids concentration is 80 mg/l. The effluent suspended solids concentration is 20 mg/l. Calculate the treatment efficiency of the plant.
 a) 25%
 b) 40%
 c) 60%
 d) 75%
?Operations Forum April 2001

5. If primary treatment can be expected to remove 30% of BOD and secondary treatment can remove 85% of BOD, then the expected overall BOD removal will be
 a) 95%
 b) 89.5%
 c) 77.5%
?Operations Forum September 1998

JOB EFFICIENCY JOB NO. 48

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1. $\% \text{ REMOVAL} = \left[\dfrac{\text{IN} - \text{OUT}}{\text{IN}}\right] * 100$

$\% \text{ REMOVAL} = \left[\dfrac{200 - 16}{200}\right] * 100$

$\% \text{ REMOVAL} = 92.0$

2. $\% \text{ REMOVAL} = \left[\dfrac{245 - 22}{245}\right] * 100$

$\% \text{ REMOVAL} = 91.0$

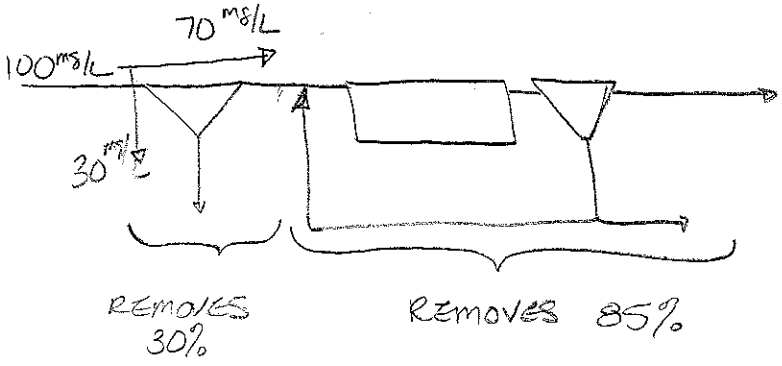
3. $\% \text{ REDUCTION} = \left[\dfrac{275 - 30}{275}\right] * 100$

$\% \text{ REDUCTION} = 89.0$

4. $\% \text{ EFFICIENCY} = \left[\dfrac{80 - 20}{80}\right] * 100$

$\% \text{ EFFICIENCY} = 75.0$

5.



ASSUME:
100 mg/L
ENTERS THE
WWTP

70 mg/L GOES TO SECONDARY PROCESS WHICH REMOVES 85%. $(70 \text{ mg/L})(0.85) = 59.5 \text{ mg/L}$ SO $70 \text{ mg/L} - 59.5 \text{ mg/L} = 10.5 \text{ mg/L}$ IN THE FINAL EFFLUENT

JOB EFFICIENCY JOB NO. 49

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5. CONT

$$\% \text{ EFFICIENCY} = \left[\frac{\text{IN} - \text{OUT}}{\text{IN}}\right] * 100$$

$$\% \text{ EFFICIENCY} = \left[\frac{100 - 10.5}{100}\right] * 100$$

$$\% \text{ EFFICIENCY} = 89.5$$

# Sidney's Big Book of Water and Wastewater Math

INDIGO WATER GROUP

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1 inch = 2.54 centimeters
1 meter = 3.28 feet
1 mile = 5280 feet

1 acre = 43,560 $ft^2$
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1 grain per gallon = 17.1 mg/L

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pounds per day = (concentration in mg/L)*(flow rate in mgd)*(8.34)

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$$\text{flow rate} = \frac{\text{volume}}{\text{time}} \qquad Q = \frac{V}{t}$$

$$\text{overflow rate} = \frac{\text{flow rate}}{\text{area}}$$

$$\text{weir loading rate} = \frac{\text{flow rate}}{\text{feet of weir}}$$

(concentration 1)*(volume 1) = (concentration 2)*(volume 2) $C_1V_1 = C_2V_2$

(conc. 1)*(volume 1) + (conc. 2)*(volume 2) = (conc. 3)*(volume 3)

$$C_1V_1 + C_2V_2 = C_3V_3$$

$$\text{horsepower} = \frac{\text{(flow in gpm)*(lift in feet)}}{3960}$$

# Velocity

# VELOCITY

1. What is the approximate volume of flow (MGD) treated in a 7' wide, 4'deep grit chamber, if a floating stick moves 24' in 30 seconds.
a) 13.65 MGD
b) 16.7 MGD
c) 15.42 MGD
d) 14.5 MGD

2. A 42" diameter pipe is flowing at a rate of 6.5 ft/sec. What is the flow rate in cu ft/sec?
a) 17.86
b) 35.71
c) 62.50
d) 521.25

3. Given the following data, calculate the average velocity in the channel. 2.5 ft wide channel, flow depth is 1.4 ft, flow rate is 7.2 MGD
a) 1.2 ft.sec
b) 3.2 ft/sec
c) 11.2 ft/sec
d) 32.2 ft/sec

4. A plastic float is dropped into a wastewater channel and is found to travel 10 feet in 4.2 seconds. The channel is 2.4 feet wide and is flowing 1.8 feet deep. Calculate the flow rate of this wastewater in cubic feet per second.
a) 1.0 ft3/sec
b) 2.3 ft3/sec
c) 4.2 ft3/sec
d) 5.7 ft3/sec
e) 10.3 ft3/sec

5. What is the average flow velocity in ft/sec in a 12-in diameter force main carrying a daily flow of 2.5 mgd?
a) 4.9 ft/sec
b) 5.3 ft/s
c) 18.0 ft/sec
d) 18.85 ft/sec
?Operations Forum January 1997

6. The flow velocity in a 6-in. diameter pipe is twice that in a 12-in diameter pipe if both are carrying 50 gal/min of wastewater.
a) True
b) False
?Operations Forum January 1997

JOB VELOCITY JOB NO. 51
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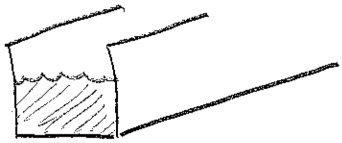
VELOCITY IS FLOW PASSING THROUGH OR PAST AN AREA. IN OTHER WORDS, HOW FAST IS THE WATER MOVING PAST A PARTICULAR POINT?



THE AREA IS ALWAYS THE CROSS SECTIONAL AREA OF THE PIPE OR CHANNEL.

1. $v = \frac{Q}{A}$

AREA = WIDTH × DEPTH
AREA = (7 FT)(4 FT)
AREA = 28 FT$^2$

$$\frac{24\ FT}{30\ sec} = \frac{Q}{28\ FT^2}$$

$$0.8\ \frac{FT}{SEC} = \frac{Q}{28\ FT^2}$$

$$22.4\ \frac{FT^3}{SEC} = Q$$

$$\frac{22.4\ FT^3}{SEC} \bigg| \frac{60\ SEC}{1\ MIN} \bigg| \frac{1440\ min}{1\ DAY} \bigg| \frac{7.48\ gal}{1\ FT^3} \bigg| \frac{1\ MG}{1000000\ gal} = 14.5\ MGD$$

2. AREA = $\pi r^2$    42" = 3.5 ft
AREA = $(3.14)(1.75\ FT)^2$
AREA = 9.62 FT$^2$

$$v = \frac{Q}{A}$$

$$6.5\ \frac{FT}{sec} = \frac{Q}{9.62\ FT^2}$$

$$62.5\ CFS = Q$$

JOB VELOCITY JOB NO. 52
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3. $$\frac{7.2\ \text{MG}}{\text{day}}\bigg|\frac{1\ \text{day}}{1440\ \text{min}}\bigg|\frac{1\ \text{min}}{60\ \text{sec}}\bigg|\frac{1000000\ \text{gal}}{1\ \text{MG}}\bigg|\frac{1\ \text{cf}}{7.48\ \text{gal}}\bigg| = 11.14\ \frac{\text{CF}}{\text{sec}}$$

$$v = \frac{Q}{A}$$

$$v = \frac{11.14\ \text{CFS}}{3.5\ \text{FT}^2}$$

$$v = 3.18\ \frac{\text{FT}}{\text{SEC}}$$

AREA = (WIDTH)(DEPTH)
AREA = (2.5 FT)(1.4 FT)
AREA = 3.5 $\text{FT}^2$

4. AREA = (WIDTH)(DEPTH)
AREA = (2.4 FT)(1.8 FT)
AREA = 4.32 $\text{FT}^2$

$$v = \frac{Q}{A}$$

$$\frac{10\ \text{FT}}{4.2\ \text{SEC}} = \frac{Q}{4.32\ \text{FT}^2}$$

$$2.38\ \frac{\text{FT}}{\text{SEC}} = \frac{Q}{4.32\ \text{FT}^2}$$

$$10.3\ \frac{\text{FT}^3}{\text{sec}} = Q$$

5. AREA = $\pi r^2$ 12" = 1 FT, SO RADIUS = 0.5 FT
AREA = $(3.14)(0.5)^2$
AREA = 0.785 $\text{FT}^2$

$$\frac{2.5\ \text{MG}}{\text{day}}\bigg|\frac{1\ \text{day}}{1440\ \text{min}}\bigg|\frac{1\ \text{min}}{60\ \text{sec}}\bigg|\frac{1{,}000{,}000\ \text{gal}}{1\ \text{MG}}\bigg|\frac{1\ \text{cf}}{7.48\ \text{gal}}\bigg| = 3.87\ \frac{\text{CF}}{\text{sec}}$$

$$v = \frac{Q}{A}$$

$$v = \frac{3.87\ \text{CFS}}{0.785\ \text{FT}^2}$$

$$v = 4.9\ \text{FT}/\text{sec}$$

JOB VELOCITY JOB NO. 53
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6. FALSE

AREA = $\pi r^2$
AREA = $(3.14)(0.25\ FT)^2$
AREA = 0.196 $FT^2$

AREA = $\pi r^2$
AREA = $(3.14)(0.5\ FT)^2$
AREA = 0.785 $FT^2$

AREA IS 4X BIGGER FOR A 12" VS 6" PIPE, SO VELOCITY IS $\frac{1}{4}$ VELOCITY AT THE SAME FLOW RATE

# Velocity

1. What should the flow meter read in gallons per minute, if a 4 inch diameter main is to be flushed at 4.6 feet per second?

Answer: gpm

2. The velocity through a channel is 4.18 fps. If the channel is 4 feet wide by 2 feet deep by 10 feet long, what is the flow in cubic feet per second?

Answer: cfs

3. A 6 inch diameter pipe conveys 380 gpm from the clear well into the distribution system. What is the velocity of water in the pipe?

Answer: fps

4. Distribution main flushing is done to maintain a minimum velocity in the pipe of 5.68 fps. A particular main discharges 4.46 cfs. If the main is 450 feet long, what is the diameter?

Answer: inches

5. A stick dropped into a channel travels 15 feet in 8 seconds. What is the velocity of the water through the channel?

Answer: fps

6. The velocity through a channel is 3.96 fps. If the channel is 3 feet wide by 1.5 feet deep by 40 feet long, what is the flow in cubic feet per second?

Answer: cfs

7. A stick dropped into a channel travels 32 feet in 6 seconds. What is the velocity of the water through the channel?

Answer: fps

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1. $v = \frac{Q}{A}$

$4\text{inches} \left| \frac{1\text{ft}}{12\text{inches}} \right| = 0.33\text{ ft diameter}$

0.167 ft radius

$4.6\text{ fps} = \frac{Q}{0.0876\text{sf}}$

$0.403\text{ cfs} = Q$

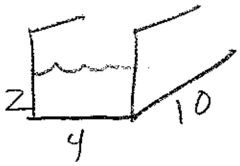
$\text{Area} = \pi r^2$

$\text{Area} = (3.1416)(0.167\text{ ft})^2$

$\text{Area} = 0.0876\text{ sf}$

$0.403\ \frac{\text{cf}}{\text{s}} \left| \frac{7.48\text{ gal}}{1\text{cf}} \right| \frac{60\text{sec}}{1\text{ min}} \right| = 180.9\text{ gpm}$

2.



$\text{Area} = 2\text{ft} \times 4\text{ft}$

$\text{Area} = 8\text{ft}^2$

$v = \frac{Q}{A}$

$4.18\text{ fps} = \frac{Q}{8\text{ft}^2}$

$33.4\text{cfs} = Q$

3. $380\ \frac{\text{gal}}{\text{min}} \left| \frac{1\text{ min}}{60\text{sec}} \right| \frac{1\text{ cf}}{7.48\text{gal}} \right| = 0.847\text{ cfs}$

6inches = 0.5 ft

$\text{Area} = \pi r^2$

$\text{Area} = (\pi)(0.25\text{ft})^2$

$\text{Area} = 0.196\text{ ft}^2$

$v = \frac{Q}{A}$

$v = \frac{0.847\text{ cfs}}{0.196\text{ sf}}$

$v = 4.32\text{ fps}$

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4. $v = \frac{Q}{A}$

$5.68 \text{ fps} = \frac{4.46 \text{ cfs}}{A}$

$5.68 A = 4.46$

$A = 0.785 \text{ sf}$

$A = \pi r^2$

$0.785 \text{ sf} = \pi r^2$

$0.25 = r^2$

$0.50 \text{ ft} = r$

diameter = 1 foot

5. $\frac{15 \text{ feet}}{8 \text{ seconds}} = 1.875 \text{ fps}$

6. $v = \frac{Q}{A}$

$3.96 \text{ fps} = \frac{Q}{(1.5 \times 3.0)}$

$17.82 \text{ cfs} = Q$

7. $\frac{32 \text{ feet}}{6 \text{ seconds}} = 5.33 \text{ fps}$

## Flow Velocities in Pipes and Channels

49. A 42" diameter pipe is flowing at a rate of 6.5 ft/sec. What is the flow rate in cu ft/sec?
  a) 17.86
  b) 35.71
  c) 62.53
  d) 521.25

50. Given the following data, calculate the average velocity in the channel. 2.5 ft wide channel, flow depth is 1.4 ft, flow rate is 7.2 MGD
  a) 1.2 ft.sec
  b) 3.2 ft/sec
  c) 11.2 ft/sec
  d) 32.2 ft/sec

51. What is the approximate volume of flow (MGD) treated in a 7 ft wide, 4 ft deep chamber, if a floating stick moves 24 inches in 30 seconds.
  a) 1.37 MGD
  b) 1.21 MGD
  c) 5.42 MGD
  d) 4.52 MGD

52. What is the average flow velocity in ft/sec in a 12-in diameter force main carrying a daily flow of 2.5 mgd?
  a) 4.9 ft/sec
  b) 5.3 ft/s
  c) 18.0 ft/sec
  d) 18.85 ft/sec

Operations Forum January 1997

53. A plastic float is dropped into a water channel and is found to travel 10 feet in 4.2 seconds. The channel is 2.4 feet wide and is flowing 1.8 feet deep. Calculate the flow rate of this wastewater in cubic feet per second.
a) ft3/sec
  a) 2.3 ft3/sec
  b) 4.2 ft3/sec
  c) 5.7 ft3/sec
  d) 10.3 ft3/sec

## FLOW VELOCITIES

Velocity is a measure of how fast a volume of water passes by a particular point. Mathematically, it is

$$\text{Velocity} = \frac{\text{Flow}}{\text{Area}}$$

49. The first step is to find the cross sectional area of the pipe in $ft^2$. The pipe diameter is in inches, so convert it to feet.

$$42 \text{ inches} \left| \frac{1 \text{ foot}}{12 \text{ inches}} \right| = 3.5 \text{ ft} \quad \therefore \text{radius} = 1.75 \text{ ft}$$

$$\text{Area} = \pi r^2$$
$$\text{Area} = (3.14)(1.75 \text{ ft})^2$$
$$\text{Area} = 9.62 \text{ ft}^2$$

$$\text{Velocity} = \frac{\text{Flow}}{\text{Area}}$$
$$6.5 \text{ ft/sec} = \frac{\text{Flow}}{9.62 \text{ ft}^2}$$
$$(6.5)(9.62) = \text{Flow}$$
$$62.5 \text{ ft}^3/\text{sec} = \text{Flow}$$

50. Convert flow rate from 7.2 mgd to ft³/sec

$$\frac{7.2\text{ MG}}{\text{day}}\Big|\frac{1000000\text{ gal}}{1\text{ MG}}\Big|\frac{1\text{ ft}^3}{7.48\text{ gallons}}\Big|\frac{1\text{ day}}{1440\text{ min}}\Big|\frac{1\text{ min}}{60\text{ sec}}\Big| = 11.14\text{ ft}^3/\text{sec}$$

$$\text{Velocity} = \frac{\text{Flow}}{\text{Area}}$$

$$\text{Velocity} = \frac{11.14\text{ ft}^3/\text{sec}}{(2.5\text{ ft})(1.4\text{ ft})}$$

$$\text{Velocity} = \frac{11.14\text{ ft}^3/\text{sec}}{3.5\text{ ft}^2}$$

$$\text{Velocity} = 3.18\text{ ft/sec}$$

51. $\text{Velocity} = \frac{\text{Flow}}{\text{Area}}$

$$\frac{2\text{ ft}}{30\text{ sec}} = \frac{\text{Flow}}{(7\text{ ft})(4\text{ ft})}$$

$$0.67 = \frac{\text{Flow}}{28}$$

$$1.87\ \frac{\text{ft}^3}{\text{sec}} = \text{Flow}$$

$$\frac{1.87\text{ ft}^3}{\text{sec}}\Big|\frac{7.48\text{ gallons}}{1\text{ ft}^3}\Big|\frac{1\text{ MG}}{1000000\text{ gal}}\Big|\frac{60\text{ sec}}{1\text{ min}}\Big|\frac{1440\text{ min}}{1\text{ day}}\Big| = 1.21\text{ MGD}$$

52. We need to convert both the flow and the area into units of feet.

$$\frac{12 \text{ inches}}{} \bigg| \frac{1 \text{ ft}}{12 \text{ inches}} \bigg| = 1 \text{ ft diameter}$$

$\therefore$ radius = 0.5 ft

$$\frac{2.5 \text{ MG}}{\text{day}} \bigg| \frac{1000000 \text{ gal}}{1 \text{ MG}} \bigg| \frac{1 \text{ ft}^3}{7.48 \text{ gal}} \bigg| \frac{1 \text{ day}}{1440 \text{ min}} \bigg| \frac{1 \text{ min}}{60 \text{ sec}} \bigg| = 3.87 \frac{\text{ft}^3}{\text{sec}}$$

$$\text{Velocity} = \frac{\text{Flow}}{\text{Area}}$$

$$\text{Velocity} = \frac{3.87 \text{ ft}^3/\text{sec}}{\pi r^2}$$

$$\text{Velocity} = \frac{3.87 \text{ ft}^3/\text{sec}}{(3.14)(0.5 \text{ ft})^2}$$

$$\text{Velocity} = \frac{3.87 \text{ ft}^3/\text{sec}}{0.785 \text{ ft}^2}$$

$$\text{Velocity} = 4.9 \text{ ft/sec}$$

53. $$\text{Velocity} = \frac{\text{Flow}}{\text{Area}}$$

$$\frac{10 \text{ ft}}{4.2 \text{ sec}} = \frac{\text{Flow}}{(2.4 \text{ ft})(1.8 \text{ ft})}$$

$$2.38 \text{ ft/sec} = \frac{\text{Flow}}{4.32 \text{ ft}^2}$$

$$10.3 \text{ ft}^3/\text{sec} = \text{Flow}$$

# Weir Loading Rates and Surface Overflow Rate

## Weir Loading Rates

40. Calculate the weir loading for a sedimentation tank that has an outlet weir 480 ft long and a flow of 5MGD.
  a) 9,220 gpd/ft
  b) 9,600 gpd/ft
  c) 9,920 gpd/ft
  d) 10,420 gpd/ft

41. Find the wier loading rate in gpd/ft for a circular tank. The tank is 40 feet in diameter and the influent flow rate is 4 mgd.
  a) 31847 gpd/ft
  b) 3185 gpd/ft
  c) 7960 gpd/ft
  d) 15794 gpd/ft

## Surface Overflow Rates

42. Find the surface overflow rate in gpd/ft2 for a circular tank. The tank is 40 feet in diameter and the influent flow rate is 4 mgd.
  a) 3185 gpd/ft2
  b) 796 gpd/ft2
  c) 1325 gpd/ft2
  d) 1760 gpd/ft2

43. A circular tank receives 12.5 mgd of flow and has a SOR of 100 gpm/ft. What is the diameter of the tank?
  a) 27.6 ft
  b) 10.5 ft
  c) 75.0 ft
  d) 14.7 ft

44. A water plant is equipped with six sedimentation basins that are operated in parallel. Each basin is 30 ft long by 25 ft wide. If the finished water demand is 30 mgd, how many basins need to be on-line to maintain a surface overflow rate of approximately 10 gpm/sft?
  a) 2
  b) 3
  c) 4
  d) 5
  e) 6

## WEIR LOADING RATES

The weir loading rate is simply the flow rate per linear foot of weir. The weir length can be one side of a tank or the perimeter of a tank.

40. $\text{WEIR LOADING} = \frac{Q}{\text{length}}$

$\text{WEIR LOADING} = \frac{5{,}000{,}000 \text{ gpd}}{480 \text{ ft}}$

$\text{WEIR LOADING} = 10{,}417 \text{ gpd/ft}$

41. $\text{Perimeter} = 2\pi r$

$\text{Perimeter} = \pi d$

$P = (3.14)(40 \text{ ft})$

$P = 125.6 \text{ ft}$ ← this is the weir length

$\text{WEIR LOADING} = \frac{Q}{\text{length}}$

$\text{WEIR LOADING} = \frac{4{,}000{,}000 \text{ gpd}}{125.6 \text{ ft}}$

$\text{WEIR LOADING} = 31{,}847 \text{ gpd/ft}$

## SURFACE OVERFLOW RATE

The Surface overflow rate or SOR is the flow rate per unit area of tank. In other words:

$$SOR = \frac{Q}{Area}$$

42. First, find the area of the tank.

$$A = \pi r^2$$
$$A = (3.14)(20\ ft)^2$$
$$A = (3.14)(20\ ft)(20\ ft)$$
$$A = 1256\ ft^2$$

$$SOR = \frac{Q}{A}$$
$$SOR = \frac{4{,}000{,}000\ gpd}{1256\ ft^2}$$
$$SOR = 3185\ gpd/ft^2$$

43. This is the same problem as #42, but going backwards.

$$SOR = \frac{Q}{A}$$
$$100\ gpm/ft^2 = \frac{12500\ 000\ gpd}{A}$$
$$100\ A = 12500\ 000$$
$$A = 125000\ ft^2$$

$$Area = \pi r^2$$
$$125000\ ft^2 = (3.14)(r^2)$$
$$39808.92\ ft^2 = r^2$$
$$r = 200\ ft$$

Uh- this isn't one of my choices! What went wrong?

looking at the equation, I can see that my units don't match. I need to correct gpd to gpm.

$$\frac{12.5\ MG}{day}\Bigg|\frac{1000000\ gal}{1\ MG}\Bigg|\frac{1\ day}{1440\ min}\Bigg| = 8680.56\ gpm$$

$$SOR = \frac{Q}{A}$$

$$100\ gpm/ft^2 = \frac{8680.56\ gpm}{A}$$

$$AREA = 86.81\ ft^2$$

$$AREA = \pi r^2$$

$$86.81\ ft^2 = (3.14)(r)^2$$

$$27.65 = r^2$$

$$r = 5.25 \quad \therefore \text{diameter} = 10.5\ ft$$

44. Find the SOR if all of the flow were moving through 1 tank.

$$\frac{30\ mg}{day}\Bigg|\frac{1000000\ gallons}{1\ mg}\Bigg|\frac{1\ day}{1440\ min}\Bigg| = 20833\ gpm$$

$$SOR = \frac{Q}{A}$$

$$SOR = \frac{20833\ gpm}{(30ft)(25ft)}$$

$$SOR = \frac{20833\ gpm}{750\ ft^2}$$

$$SOR = 27.8\ gpm/ft^2$$

∴ I need 3 tanks on line

# Filter Loading and Backwash

Filter Loading and Backwash Rates

45. A sand filter with dimensions of 12 feet by 15 feet receives 0.75 mgd. What is the hydraulic loading rate in gpm/sft?
a) 2.9 gpm/sft
b) 29.0 gpm/sft
c) 4167 gpm/sft
d) 69.4 gpm/sft

46. At what rate in gpm must wash water be delivered to a mixed media filter to attain a backwash rate of 15 gpm/sq ft if the filter is 20' wide and 30' long.
a) 600
b) 2400
c) 3000
d) 9000

47. Your filter filters at a rate of 200 GPM. On your last filter run you filtered 728,000 gallons of water before backwashing. How many hours did this filter run?
a) 6.1 hours
b) 60.7 hours
c) 3,640 hours
d) 607 hours
e) 36.4 hours

48. The optimum hydraulic loading rate for a new type of filter is 30 gpm/sft. If the flow going to the filter is 1.85 mgd, what should the dimensions of the filter be? Round to the nearest whole foot.
a) 43 sft
b) 32 sft
c) 60 sft
d) 52 sft

## FILTER LOADING & BACKWASH RATES

45. $HLR = \frac{Q}{A}$

The first step is to convert the flow rate into gpm.

$$\frac{0.75\ MG}{day} \bigg| \frac{1\,000\,000\ gallons}{1\ MG} \bigg| \frac{1\ day}{1440\ min} \bigg| = 520.8\ gpm$$

$$HLR = \frac{520.8\ gpm}{(12\ ft)(15\ ft)}$$

$$HLR = \frac{520.8\ gpm}{180\ ft^2}$$

$$HLR = 2.9\ gpm/ft^2$$

46. Same formula, but we need to solve for a different variable.

$$HLR = \frac{Q}{A}$$

$$\frac{15\ gpm}{ft^2} = \frac{Q}{(20ft)(30ft)}$$

$$15 = \frac{Q}{600\,ft^2}$$

$$9000\ gpm = Q$$

47. This is really a unit conversion problem in disguise.

$$728{,}000\text{ gallons}\,\Big|\,\frac{1\text{ minute}}{200\text{ gallons}}\,\Big| = \frac{1\text{ hour}}{60\text{ minutes}}\,\Big| = 60.7\text{ hours}$$

48. $$\frac{1.85\text{ MG}}{\text{day}}\,\Big|\,\frac{1000\,000\text{ gallons}}{1\text{ MG}}\,\Big|\,\frac{1\text{ day}}{1440\text{ min}}\,\Big| = 1284.7\text{ gpm}$$

B $$HLR = \frac{Q}{A}$$

$$\frac{30\text{ gpm}}{\text{sft}} = \frac{1284.7\text{ gpm}}{A}$$

$$30A = 1284.7$$

$$A = 42.8\text{ ft}^2$$

# Fixed Film Processes

## FIXED FILM PROCESSES

1. Calculate the lbs of BOD entering the trickling filter. Raw wastewater flow = 1.5 MGD, Raw wastewater BOD = 150 mg/l, 30% reduction in BOD through primary treatment.
   a) 562 lb/day
   b) 870 lb/day
   c) 1314 lb/day
   d) 1880 lb/day

2. A rotating biological contactor treats a flow of 2.2 MGD with a BOD of 110 mg/L. The surface area of the media is 550,000 sq ft. What is the organic loading in lb BOD/day/1000 sq ft
   a) 2.7
   b) 3.0
   c) 3.5
   d) 3.7

3. At what rate in gpm must wash water be delivered to a mixed media filter to attain a backwash rate of 15 gpm/sq ft if the filter is 20' wide and 30' long.
   a) 600
   b) 2400
   c) 3000
   d) 9000

4. The flow to a trickling filter is 2.5 mgd. The filter has a diameter of 100 ft and a media depth of 4 ft. The recirculation rate is 0.75:1. Calculate the hydraulic loading rate in gallons per day per square foot.
   a) 438 gal/d/ft2
   b) 557 gal/d/ft2
   c) 785 gal/d/ft2
   d) 995 gal/d/ft2

JOB FIXED FILM JOB NO. 58

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1. ppd = (mg/L)(Q, mgd)(8.34)

ppd = (150 mg/L)(1.5 mgd)(8.34)

ppd = 1876.5

↑ only 70% goes to TF

(1876.5 ppd)(0.7) = 1314 ppd

2. ppd = (mg/L)(Q, mgd)(8.34)

ppd = (110 mg/L)(2.2 mgd)(8.34)

ppd = 2018

$$\frac{550{,}000 \text{ sft}}{1000} = 550$$

$$\text{ORGANIC LOAD} = \frac{\text{ppd}}{1000 \text{ sft}}$$

$$= \frac{2018 \text{ ppd}}{550}$$

$$= 3.7 \text{ ppd}/1000 \text{ sft}$$

3. AREA = (LENGTH)(WIDTH)

AREA = (20 FT)(30 FT)

AREA = 600 $FT^2$

$$600 \ FT^2 \left| \frac{15 \text{ gpm}}{1 \ FT^2} \right| = 9000 \text{ gpm}$$

JOB FIXED FILM JOB NO. 59
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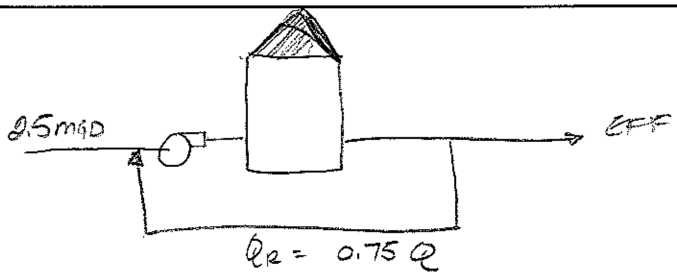
4.



TOTAL FLOW TO FILTER = $Q_{INF} + Q_{RECYCLE}$

$= 2.5\text{MGD} + (2.5\text{MGD})(0.75)$
$= 2.5\text{MGD} + 1.875\text{ MGD}$
$= 4.375\text{ MGD}$

AREA $= \pi r^2$
AREA $= (3.14)(50\text{FT})(50\text{FT})$
AREA $= 7850\text{ FT}^2$

$$HLR = \frac{FLOW}{AREA}$$

$$HLR = \frac{4{,}375{,}000\text{ gpd}}{7850\text{ ft}^2}$$

$HLR = 557\text{ gpd/ft}^2$

# Sidney's Big Book of Water and Wastewater Math

INDIGO WATER GROUP

## Unit Conversions to Know by Heart

1 inch = 2.54 centimeters
1 meter = 3.28 feet
1 mile = 5280 feet

1 acre = 43,560 $ft^2$
1 $m^2$ = 10.76 $ft^2$

1 gallon = 3.785 liters
1 $ft^3$ = 7.48 gallons
1 $m^3$ = 35.31 $ft^3$

1 ft water = 0.433 psi

1 gallon = 8.34 lbs when specific gravity is 1.0
1 kg = 2.2 lbs

1% = 10,000 mg/L
1 mg/L = 1 ppm
1 µg/L = 1 ppb

1 day = 1440 minutes
1 hp = 0.746 kW

1 gram = 15.43 grains
1 grain per gallon = 17.1 mg/L

## Water Formulas

pounds per day = (concentration in mg/L)*(flow rate in mgd)*(8.34)

chlorine dose = demand + residual

$$\text{velocity} = \frac{\text{flow}}{\text{area}} \qquad V = \frac{Q}{A}$$

$$\text{flow rate} = \frac{\text{volume}}{\text{time}} \qquad Q = \frac{V}{t}$$

$$\text{overflow rate} = \frac{\text{flow rate}}{\text{area}}$$

$$\text{weir loading rate} = \frac{\text{flow rate}}{\text{feet of weir}}$$

(concentration 1)*(volume 1) = (concentration 2)*(volume 2) $C_1V_1 = C_2V_2$

(conc. 1)*(volume 1) + (conc. 2)*(volume 2) = (conc. 3)*(volume 3)

$$C_1V_1 + C_2V_2 = C_3V_3$$

$$\text{horsepower} = \frac{\text{(flow in gpm)*(lift in feet)}}{3960}$$

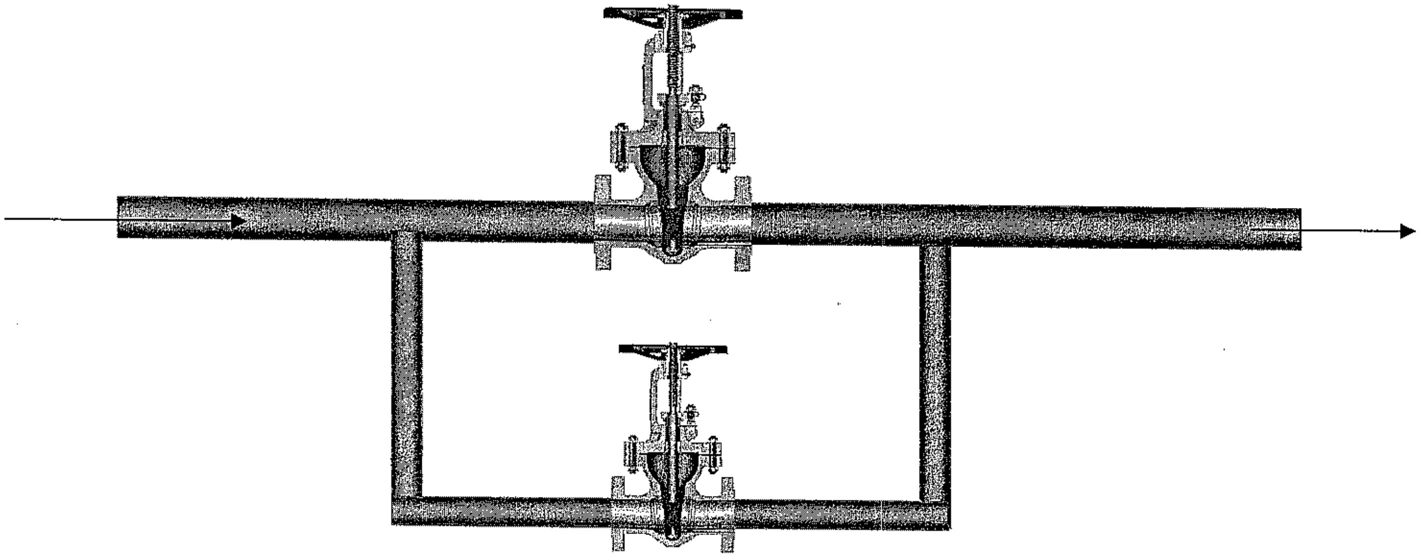
# Force

Numbers in **RED** can be changed. Numbers in **BLUE** are calculated by the spreadsheet.

$$\boxed{FORCE = (PRESSURE)(AREA)}$$

| | | |
|---|---|---|
| Bypass diameter | **10** | inches |
| Bypass area | **78.54** | square inches |
| Main line diameter | **42** | inches |
| Main line area | **1385.44** | square inches |
| | | |
| System Pressure | **60** | psi (pounds per square inch) |

| | | |
|---|---|---|
| Force on Main line | **83126.4** | pounds |
| | **41.6** | tons |
| | | |
| Force on Bypass | **4712.4** | pounds |
| | **2.4** | tons |



# Wells

## Drawdown, Specific Yield, and Yield

Numbers in RED can be changed. Numbers in **BLUE** are calculated by the spreadsheet.

| | | |
|---|---|---|
| Static Water Level | **80** | feet |
| Pumped Water Level | **110** | feet |
| Drawdown | **30** | feet |
| Pumping Rate or Yield | **300** | gpm |
| Specific Yield | **10** | gpm/ft |

Problem 1: A well is drilled through an unconfined aquifer. The top of the aquifer is 80 feet below grade. After the well was in service for a year, the water level in the well stabilized at 110 feet below grade. Calculate the well drawdown..

30 feet

Problem 2: A well produces 300 gpm. If the drawdown is 30 feet, find the specific yield of the well.

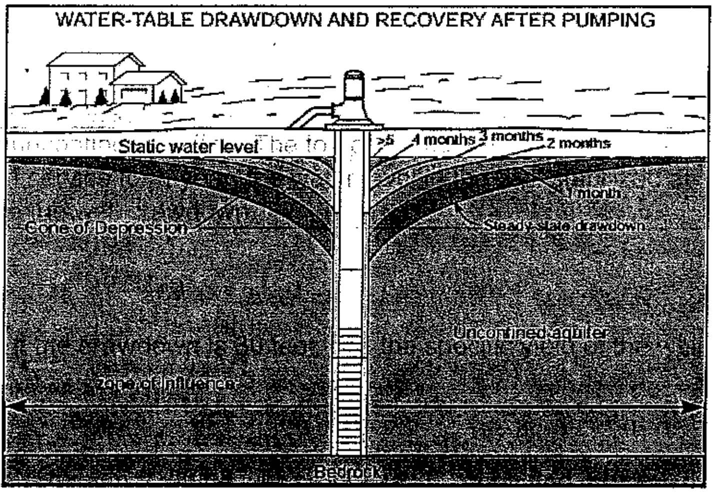
10 gpm/ft

Problem 3: The specific yield for a well is 10 gpm/ft. If the well produces 300 gpm, find the drawdown.

30 feet

Problem 4: The pumped water level of a well is 110 feet below the surface. The well produces 300 gpm. If the specific yield of the well is 10 gpm/ft, find the original water level in the aquifer. Express your answer as feet below grade.

80 feet



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# Wells

1. Drawdown is the difference

$$\begin{array}{r} 110\text{ ft} \\ -\ 80\text{ ft} \\ \hline 30\text{ ft} \end{array}$$

2. $\text{Specific yield} = \dfrac{\text{yield, gpm}}{\text{drawdown}}$

$\text{Specific yield} = \dfrac{300\text{ gpm}}{30\text{ ft}}$

$\text{specific yield} = 10\text{ gpm/ft}$

3. $\text{specific yield} = \dfrac{\text{yield, gpm}}{\text{draw down}}$

$10\text{ gpm/sf} = \dfrac{300\text{ gpm}}{\text{drawdown}}$

$(10)(\text{drawdown}) = 300$

$\text{drawdown} = 30\text{ ft}$

4. from #3 we know that the drawdown is 30ft

$$\begin{array}{r} 110 \\ -30 \\ \hline 80\text{ ft} \end{array}$$

# Distribution by Sidney

Name: ______________________________

Date: ____________________ Period: _____

1. What is the motor horsepower (mhp) for a pump with the following parameters? Motor efficiency: 87%, Total Head (TH): 107 ft, Pump efficiency: 79%, Flow: 2.544 mgd
   - (A) 87 mph
   - (B) 79 mph
   - (C) 25 mph
   - (D) 69 mph

2. W6. This term describes the amount of water that a particular well can produce in a specified amount of time.
   - (A) Cone of Depression
   - (B) Well Yield
   - (C) Specific Capacity
   - (D) Pumping Water Level
   - (E) Zone of Influence
   - (F) Static Water Level
   - (G) Drawdown

3. A well produces 365 gpm with a drawdown of 22.5 ft. What is the specific yield in gallons per minute per foot?
   - (A) 32.4
   - (B) 16.2
   - (C) 36.5
   - (D) 22.5

4. Given the following data, calculate the total kilowatts needed to operate the following small facility when everything is running: Raw water pump=300 hp, Flocculators=60 hp, Filter pump for backwashing=100 hp, Chlorination=25 hp, Clear water pump=100 hp, Lighting=11 hp, Instrumentation=4 hp
   - (A) 600 kW
   - (B) 448 kW
   - (C) 1,386 kW
   - (D) 260 kW

5. W3. After a well has been operating for some time, the water level in the well will be lower than the water level in the surrounding aquifer. The new water level is the
   - (A) Specific Capacity
   - (B) Drawdown
   - (C) Static Water Level
   - (D) Pumping Water Level
   - (E) Cone of Depression
   - (F) Zone of Influence
   - (G) Well Yield

6. A well produces 162 gpm. The drawdown for the well is 16 ft. Calculate the specific yield in gallons per minute per foot.
   - (A) 2 gpm/ft
   - (B) 5 gpm/ft
   - (C) 10 gpm/ft
   - (D) 16 gpm/ft

7. W2. The distance from ground level to the top of an aquifer is called the
   - (A) Static Water Level
   - (B) Well Yield
   - (C) Drawdown
   - (D) Specific Capacity
   - (E) Pumping Water Level
   - (F) Cone of Depression
   - (G) Zone of Influence

82

8. W5. Pumping water out of wells lowers the water level of the aquifer around the well. This term is used to describe the three dimensional shape that begins at the pumping water level and extends up and out towards the ground surface.
   (A) Pumping Water Level
   (B) Cone of Depression
   (C) Static Water Level
   (D) Specific Capacity
   (E) Zone of Influence
   (F) Drawdown
   (G) Well Yield

9. W1. This term is used to describe the area at ground level that is affected by a particular well.
   (A) Well Yield
   (B) Pumping Water Level
   (C) Static Water Level
   (D) Cone of Depression
   (E) Drawdown
   (F) Specific Capacity
   (G) Zone of Influence

10. W7. The ____________________________ is calculated by dividing the amount of water produced by a specific well by the foot of drawdown.
   (A) Cone of Depression
   (B) Drawdown
   (C) Zone of Influence
   (D) Specific Capacity
   (E) Well Yield
   (F) Pumping Water Level
   (G) Static Water Level

11. Find the drawdown of a well, if the well yields 265 gpm and the specific yield is 11.7 gpm/ft
   (A) 10.3 ft
   (B) 11.7 ft
   (C) 22.7 ft
   (D) 17.6 ft

12. W4. The difference between the static water level and the pumping water level in a well is the
   (A) Drawdown
   (B) Specific Capacity
   (C) Static Water Level
   (D) Pumping Water Level
   (E) Well Yield
   (F) Cone of Depression
   (G) Zone of Influence

13. The static level in the well is 79.12 ft and the drawdown is 26.08 ft. Calculate the pumping water level in the well.
   (A) 11.3 ft
   (B) 53.0 ft
   (C) 34.3 ft
   (D) 105.2 ft

14. Find the total head, in feet, for a pump with a total static head of 19 ft and a head loss of 3.7 ft.
   (A) 15.3 ft
   (B) 5.1 ft
   (C) 70.3 ft
   (D) 22.7 ft

15. The static water level (non-pumping well) in a well is 84.5 ft. The pumping level is 104.2 ft. What is the drawdown?
   (A) 36.6 ft
   (B) 188.7 ft
   (C) 45.1 ft
   (D) 19.7 ft

# Distribution by Sidney

Answer Key

1. D
2. B
3. B
4. B
5. D
6. C
7. A
8. B
9. G
10. D
11. C
12. A
13. ~~B~~ D
14. D
15. D

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1. $$\left.\frac{2.544\,\text{mg}}{\text{day}}\right|\left.\frac{1{,}000{,}000\,\text{gal}}{1\,\text{mg}}\right|\left.\frac{1\,\text{day}}{1440\,\text{min}}\right| = 1766.67\ \frac{\text{gal}}{\text{min}}$$

$$HP = \frac{(\text{gpm})(\text{TDH, ft})}{(3960)(E_p)(E_m)}$$

$$HP = \frac{(1766.67\,\text{gpm})(107\,\text{ft})}{(3960)(0.79)(0.87)}$$

$$HP = 69$$

3. $$\text{Specific Yield} = \frac{\text{Yield}}{\text{Drawdown}} = \frac{365\,\text{gpm}}{22.5\,\text{ft}} = 16.2\ \text{gpm/ft}$$

4.
$$\begin{array}{r} 300\ HP \\ 60\ HP \\ 100\ HP \\ 25\ HP \\ 100\ HP \\ 11\ HP \\ +\ \ 4\ HP \\ \hline 600\ HP \end{array}$$

$$600\ HP\left|\frac{0.745\,\text{kw}}{1\,HP}\right| = 447\ \text{kw}$$

6. $$\text{Specific Yield} = \frac{\text{Yield}}{\text{Drawdown}} = \frac{162\,\text{gpm}}{16\,\text{ft}} = 10.1\ \text{gpm/ft}$$

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11. Specific Yield = $\frac{\text{Yield}}{\text{Drawdown}}$

$$11.7 \frac{gpm}{ft} = \frac{265\ gpm}{D}$$

$$11.7 D = 265$$

$$D = 22.6\ ft$$

13. 79.12
+ 26.08
105.2 ft

14. TOTAL HEAD = STATIC HEAD + LOSSES
= 19 ft + 3.7 ft
= 22.7 ft

15. 104.2
− 84.5
19.7 ft

# Sidney's Big Book of Water and Wastewater Math

INDIGO WATER GROUP

## Unit Conversions to Know by Heart

1 inch = 2.54 centimeters
1 meter = 3.28 feet
1 mile = 5280 feet

1 acre = 43,560 $ft^2$
1 $m^2$ = 10.76 $ft^2$

1 gallon = 3.785 liters
1 $ft^3$ = 7.48 gallons
1 $m^3$ = 35.31 $ft^3$

1 ft water = 0.433 psi

1 gallon = 8.34 lbs when specific gravity is 1.0
1 kg = 2.2 lbs

1% = 10,000 mg/L
1 mg/L = 1 ppm
1 µg/L = 1 ppb

1 day = 1440 minutes
1 hp = 0.746 kW

1 gram = 15.43 grains
1 grain per gallon = 17.1 mg/L

## Water Formulas

pounds per day = (concentration in mg/L)*(flow rate in mgd)*(8.34)

chlorine dose = demand + residual

$$\text{velocity} = \frac{\text{flow}}{\text{area}} \qquad V = \frac{Q}{A}$$

$$\text{flow rate} = \frac{\text{volume}}{\text{time}} \qquad Q = \frac{V}{t}$$

$$\text{overflow rate} = \frac{\text{flow rate}}{\text{area}}$$

$$\text{weir loading rate} = \frac{\text{flow rate}}{\text{feet of weir}}$$

(concentration 1)*(volume 1) = (concentration 2)*(volume 2) $C_1V_1 = C_2V_2$

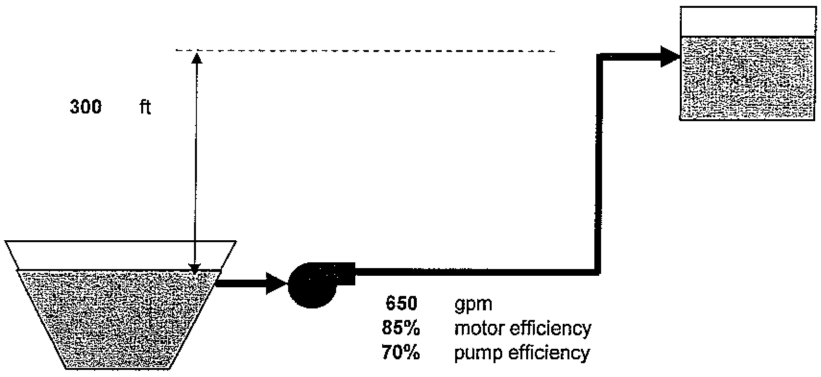
(conc. 1)*(volume 1) + (conc. 2)*(volume 2) = (conc. 3)*(volume 3)

$$C_1V_1 + C_2V_2 = C_3V_3$$

$$\text{horsepower} = \frac{\text{(flow in gpm)*(lift in feet)}}{3960}$$

# Pumps

Numbers in **RED** can be changed. Numbers in **BLUE** are calculated by the spreadsheet.



Water Horsepower = {(GPM x Pump head)/ 3,956} **49.3** hp

Brake Horsepower = Water Horsepower / % Pump Efficiency **70.4** hp

Electrical or Motor Horsepower = Brake Horsepower / % Motor E **82.8** hp

** Sometimes, this is called the wire to water horsepower.

Run Time **12** hours per day

**5** days per week

Electricty Cost

**0.09** $/kwh

Problem One: Water is being pumped from a reservoir uphill 300 to a storage tank. Calculate the Brake Horsepower if the pump rate is 650 gpm.

Answer: 70.4 hp

Problem Two: A 25 horsepower pump is used to dewater a lake. If the pump runs for 12 hours a day for 5 days a week, how much will it cost to run the pump per week? Assume energy costs of 0.09 dollars per kilowatt hour.

Answer: $100.71

| | | | | | |
|---|---|---|---|---|---|
| **25** hp | **0.746** kw | **0.09** $ | **12** hours | **5** days | **$100.71** |
| | 1 hp | 1 kw*h | 1 day | 1 week | week |

** Set it up this way because you need 25 horsepower per hour to run this pump.

| | | | | | |
|---|---|---|---|---|---|
| **25** ~~hp~~ | **0.746** ~~kw~~ | **0.09** $ | **12** ~~hours~~ | **5** ~~days~~ | **$100.71** |
| | 1 ~~hp~~ | 1 ~~kw*h~~ | 1 ~~day~~ | 1 week | week |

Problem Three: Calculate the water horsepower required for a pump to raise water 300 feet at a rate of 650 gallons per minute. If the pump runs for 12 hours a day for 5 days a week, how much will it cost to run the pump for one year? Assume energy costs of 0.09 dollars per kilowatt hour.

Answer: 49.3 hp

Answer: $10,327.21

| | | | | | | |
|---|---|---|---|---|---|---|
| **49.3** hp | **0.746** kw | **0.09** $ | **12** hours | **5** days | **52** weeks | **$10,327.21** |
| | 1 hp | 1 kw*h | 1 day | 1 week | 1 year | year |

# Pumps and Pressure

1. A pump station is used to lift water 50 feet above the pump station to a storage tank. If the pump is 4.2 hp and has a motor efficiency of 0.9 and a pump efficiency of 0.85 , how fast can the pump station pump water into the tank?

Answer: gpm

2. The pressure gage at the bottom of a tank reads 35 psi. How many feet of water are in the tank?
Answer: feet

3. Water is being pumped from a reservoir uphill 120 to a storage tank. Calculate the Brake Horsepower if the pump rate is 1200 gpm.

Answer: hp

4. A 25 horsepower pump is used to dewater a lake. If the pump runs for 8 hours a day for 7 days a week, how much will it cost to run the pump per week? Assume energy costs of 0.07 dollars per kilowatt hour.

Answer:

5. A water tank contains 80,000 gallons of water and is 80.85 feet deep. What is the water pressure at the bottom of the tank?

Answer: psi

6. Water is being pumped from a reservoir uphill 120 to a storage tank. Calculate the Brake Horsepower if the pump rate is 600 gpm.

Answer: hp

7. A 25 horsepower pump is used to dewater a lake. If the pump runs for 5 hours a day for 5 days a week, how much will it cost to run the pump per week? Assume energy costs of 0.07 dollars per kilowatt hour.
Answer:

8. The pressure gage at the bottom of a tank reads 20 psi. How many feet of water are in the tank?

Answer: feet

9. Calculate the water horsepower required for a pump to raise water 120 feet at a rate of 600 gallons per minute. If the pump runs for 5 hours a day for 5 days a week, how much will it cost to run the pump for one year? Assume energy costs of 0.07 dollars per kilowatt hour.

Answer: hp
Answer: $

10. A water tank contains 80,000 gallons of water and is 115.5 feet deep. What is the water pressure at the bottom of the tank?

Answer: psi

11. Calculate the water horsepower required for a pump to raise water 120 feet at a rate of 600 gallons per minute. If the pump runs for 24 hours a day for 7 days a week, how much will it cost to run the pump for one year? Assume energy costs of 0.09 dollars per kilowatt hour.

Answer: hp
Answer: $

12. Water is being pumped from a reservoir uphill 50 to a storage tank. Calculate the Brake Horsepower if the pump rate is 250 gpm.

Answer: hp

13. A pump station is used to lift water 500 feet above the pump station to a storage tank. If the pump is 49.6 hp and has a motor efficiency of 0.9 and a pump efficiency of 0.85 , how fast can the pump station pump water into the tank?

Answer: gpm

14. Calculate the water horsepower required for a pump to raise water 500 feet at a rate of 300 gallons per minute. If the pump runs for 24 hours a day for 7 days a week, how much will it cost to run the pump for one year? Assume energy costs of 0.09 dollars per kilowatt hour.

Answer: hp
Answer: $

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PUMPS & PRESSURE

1. $$HP = \frac{(gpm)(TDH, ft)}{(3960)(E_p)(E_m)}$$

$$4.2\ HP = \frac{(gpm)(50 ft)}{(3960)(0.85)(0.9)}$$

$$4.2\ hp = \frac{(gpm)(50 ft)}{3029.4}$$ ← simplify, then, cross multiply

$$(4.2 hp)(3029.4) = (gpm)(50 ft)$$

$$12723.48 = (gpm)(50 ft)$$ ← divide both sides by 50 ft

$$254.5 = gpm$$

2. $$35\ psi \left| \frac{1\ ft}{0.433\ psi} \right| = 80.8\ ft$$

3. $$HP = \frac{(gpm)(HEAD, ft)}{3960}$$ ← no efficiency terms were given, so don't assume any

$$HP = \frac{(1200 gpm)(120 ft)}{3960}$$

$$HP = 36$$

4. $$25\ HP \left| \frac{0.745\ kw}{1\ HP} \right| \frac{\$0.07}{1\ kwh} \left| \frac{8\ hrs}{1\ day} \right| \frac{7\ days}{week} \right| = 73.01\ \frac{\$}{week}$$

5. $$80.85\ ft \left| \frac{0.433\ psi}{1\ ft} \right| = 35\ psi$$

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SUBJECT ______

6. $$HP = \frac{(gpm)(TDH)}{3960}$$

$$HP = \frac{(600\,gpm)(120\,ft)}{3960}$$

$$HP = 18.2$$

7. $$25\,HP \Big| \frac{0.745\,kw}{1\,HP} \Big| \frac{\$0.07}{1\,kwh} \Big| \frac{5\,hrs}{1\,day} \Big| \frac{5\,days}{1\,week} \Big| = 32.59\,\frac{\$}{wk}$$

8. $$20\,psi \Big| \frac{1\,ft}{0.433\,psi} \Big| = 46.2\text{ feet}$$

9. $$HP = \frac{(gpm)(TDH,\,ft)}{3960}$$

$$HP = \frac{(600\,gpm)(120\,ft)}{3960}$$

$$HP = 18.18\,HP$$

$$18.18\,HP \Big| \frac{0.745\,kw}{1\,HP} \Big| \frac{\$0.07}{1\,kw\cdot h} \Big| \frac{5\,hrs}{1\,day} \Big| \frac{5\,days}{1\,week} \Big| \; 23.70\,\frac{\$}{week}$$

10. $$115.5\,ft \Big| \frac{0.433\,psi}{1\,ft} \Big| = 50\,psi$$

11. From #9, we know the pump HP is 18.18 HP

$$18.18\,HP \Big| \frac{0.745\,kW}{1\,HP} \Big| \frac{\$0.09}{1\,kw\cdot h} \Big| \frac{24\,hrs}{1\,day} \Big| \frac{7\,days}{1\,week} \Big| \frac{52\,weeks}{1\,year} \Big| =$$

$$\$10648.91/year$$

## Pump Problems

90. A centrifugal pump is pumping 200 gpm against a 40 ft total pumping head. The output power of the pump is approximately ______ hp.
  - a) 0.5
  - b) 2
  - c) 15
  - d) 121

91. A raw water pump with a 6" bore and a 3" stroke pumps 60 cycles/minute. What is the pumping rate in gpm?
  - a) 18 gpm
  - b) 26.75 gpm
  - c) 22.5 gpm
  - d) 14.3 gpm

92. What is the flow rate (gpm) from a pump with a discharge diameter of 6" and a velocity of 5 ft/sec?
  - a) 198 gpm
  - b) 440 gpm
  - c) 44 gpm
  - d) 338.5 gpm

93. What is the pumping rate in gpm of the following piston pump? Diameter = 10 inches, Stroke length = 6 inches, Strokes/min = 30
  - a) 293.6 gpm
  - b) 86.9 gpm
  - c) 45.5 gpm
  - d) 62.1 gpm

94. A centrifugal pump is pumping 200 gal/min against a 40-foot total pumping head. The approximate output power of is 2 HP. What will the output power be if the pumping head increased to 60 feet?
  - a) 1 hp
  - b) 2 hp
  - c) 3 hp
  - d) 8 hp

95. A single-piston reciprocating pump has a 6" diameter piston with a 6" length of stroke. It makes 16 discharge strokes/min, the pumping rate is _______gpm.

a) 6
b) 12
c) 25
d) 47

96. A pump delivers 240,000 gallons per day at a static head of 275 feet. Calculate the pressure equivalent to this head, expressed in pounds per square inch.

a) 275 psi
b) 119 psi
c) 550 psi
d) 635 psi

97. Determine the flow capacity of a pump in gpm if the pump lowers the water in a six-foot square clear well by 8 inches in 5 minutes.

a) 57.6 gpm
b) 92.4 gpm
c) 179.5 gpm
d) 35.9 gpm
e) 430 gpm

98. What horsepower must a pump deliver to water that must be lifted 90 feet? The flow is 40 gpm.

a) ‘1.0 HP
b) ‘50 HP
c) ‘0.9 HP
d) ‘60 HP
e) ‘76 HP

99. If the required water horsepower of a pump is 50 HP, what must the motor horsepower be if the efficiency of the pump is 75 percent and the efficiency of the motor is 90 percent?

a) 74 HP
b) 40.5 HP
c) 50 HP
d) 89 HP
e) 111 HP

100. How many kilowatt-hours per day are required by a pump with a motor horsepower of 50 horsepower when the pump operates 24 hours a day?

a) 716 kW-hr/day
b) 960 kW-hr/day
c) 894 kW-hr/day
d) 1,075 kW-hr/day
e) 1,287 kW-hr/day

## Jar Testing

101. Through jar testing, you have determined that your best Alum dose is 5 mg/L. Your liquid alum has a specific gravity of 1.31 and its strength is 49.8%. Your plant flow is 700 GPM. How many mL/min will your chemical feed pump need to pump to produce this residual?

a) 84.1 mL/min
b) 200 mL/min
c) 10.1 mL/min
d) 20.3 mL/min
e) 42.0 mL/min

## Miscellaneous

102. If the water rate is $5.50 for the first 500 cu ft and all water used over the minimum is billed at a rate of $0.25 per 100 cu ft, how much would a customer using 1200 cu ft be billed?

a) $5.25
b) $6.25
c) $6.75
d) $7.25

103. Calculate the percent reduction in flows achieved by an industrial water conservation program if water flows are reduced from 350 gpm to 220 gpm

a) 31%
b) 37%
c) 44%
d) 59%
e) 63%

## Pump Problems

90. $HP = \frac{(Q, gpm)(Head, ft)}{(3960)(efficiency)}$

$HP = \frac{(200 gpm)(40 ft)}{3960}$

$HP = 2.0$

91. Convert all dimensions to feet. Then, find the volume pumped per stroke.

$6 inches \left| \frac{1 foot}{12 inches} \right| = 0.5 ft \quad \therefore radius = 0.25 ft$

$3 inches \left| \frac{1 foot}{12 inches} \right| = 0.25 ft$

$Volume = \pi r^2 d$

$Volume = (3.14)(0.25 ft)^2(0.25 ft)$

$Volume = 0.049 ft^3$

$\frac{0.049 ft^3}{stroke} \left| \frac{60 strokes}{1 minute} \right| \frac{7.48 gallons}{1 ft^3} \Big| = 22 \frac{gallons}{min}$

92. $Velocity = \frac{Flow}{Area}$

diameter = 0.5 ft

radius = 0.25 ft

$\frac{5 ft}{sec} = \frac{Flow}{(\pi)(r^2)}$

$\frac{5 ft}{sec} = \frac{Flow}{(3.14)(0.25^2)}$

$5 = \frac{Flow}{0.19625}$

$0.981 \frac{ft^3}{sec} = Flow$

92. (cont.)

$$\frac{0.981 \text{ ft}^3}{\text{sec}} \Bigg| \frac{7.48 \text{ gallons}}{1 \text{ ft}^3} \Bigg| \frac{60 \text{ sec}}{1 \text{ min}} \Bigg| = 440 \frac{\text{gallons}}{\text{min}}$$

93. $$\frac{10 \text{ inches}}{} \Bigg| \frac{1 \text{ foot}}{12 \text{ inches}} \Bigg| = 0.83 \text{ ft} \quad \therefore \text{radius} = 0.42 \text{ ft}$$

$\text{Volume} = \pi r^2 d$

$V = (3.14)(0.42 \text{ ft})^2(0.5 \text{ ft})$

$V = (3.14)(0.42 \text{ft})(0.42 \text{ ft})(0.5 \text{ft})$

$V = 0.2769 \text{ ft}^3/\text{stroke}$

$$\frac{0.2769 \text{ ft}^3}{\text{stroke}} \Bigg| \frac{30 \text{ strokes}}{\text{minute}} \Bigg| \frac{7.48 \text{ gallons}}{1 \text{ ft}^3} \Bigg| = 62.1 \frac{\text{gallons}}{\text{minute}}$$

94. $$HP = \frac{(Q, \text{gpm})(\text{Head, ft})}{3960}$$

$$HP = \frac{(200 \text{ gpm})(60 \text{ ft})}{3960}$$

$HP = 3.03$

95. $\text{Volume} = \pi r^2 d$

$V = (3.14)(0.25\text{ ft})^2(0.5\text{ ft})$

$V = (3.14)(0.25\text{ ft})(0.25\text{ ft})(0.5\text{ ft})$

$V = 0.098125\text{ ft}^3$

$$\frac{0.098125\text{ ft}^3}{\text{stroke}} \bigg| \frac{16\text{ strokes}}{\text{minute}} \bigg| \frac{7.48\text{ gallons}}{1\text{ ft}^3} \bigg| = 11.74\ \frac{\text{gallons}}{\text{min}}$$

96. $$275\text{ ft head} \bigg| \frac{0.433\text{ psi}}{1\text{ ft head}} \bigg| = 119\text{ psi}$$

97. $Q = \dfrac{\text{Volume}}{\text{time}}$ $\qquad$ $\text{Volume} = (l)(w)(d)$

$V = (6\text{ ft})(6\text{ ft})(8\text{ inches})$

$V = (6\text{ ft})(6\text{ ft})(0.67\text{ ft})$

$V = 24\text{ ft}^3$

$Q = \dfrac{24\text{ ft}^3}{5\text{ minutes}}$

$Q = 4.8\text{ ft}^3/\text{min}$

$$\frac{4.8\text{ ft}^3}{\text{min}} \bigg| \frac{7.48\text{ gallons}}{1\text{ ft}^3} \bigg| = 35.9\ \frac{\text{gallons}}{\text{minute}}$$

98. $HP = \dfrac{(Q,\text{gpm})(\text{Head},\text{ft})}{3960}$

$HP = \dfrac{(40\text{ gpm})(90\text{ ft})}{3960}$

$HP = 0.90$

99. If the motor needs to be 50 HP at 100% efficiency, then it needs be larger as efficiency decreases.

$$50\ HP = \frac{(Q)(head)}{3960}$$

$$198000 = (Q)(head)$$

$$HP = \frac{(Q)(head)}{(3960)(E_{motor})(E_{pump})}$$

$$HP = \frac{198000}{(3960)(0.90)(0.75)}$$

$$HP = 74$$

100. $\frac{50\ HP}{hour} \Big| \frac{0.745\ kWh}{1\ HP} \Big| \frac{24\ hours}{1\ day} \Big| = 894\ \frac{kW\text{-}hr}{day}$

101. $ppd\ Alum = (mg/L)(Q, mgd)(8.34)$

$\frac{700\ gallons}{minute} \Big| \frac{1\ MG}{1000000\ gal} \Big| \frac{1440\ min}{1\ day} \Big| = 1.008\ mgd$

$$ppd\ Alum = (5\ mg/L)(1.008\ mgd)(8.34)$$

$$ppd\ Alum = 42.0$$

$$ppd\ Alum = (mg/L)(Q, mgd)(8.34)$$

$$42.0\ ppd = (49.8\%)(10{,}000)(Q)(8.34)(1.31)$$

$$0.000007719\ mgd = Q$$

$$7.72\ gpd = Q$$

101 (cont.)

$$\frac{7.72\text{ gallons}}{\text{day}}\left|\frac{1\text{ day}}{1440\text{ min}}\right|\frac{3.785\text{ L}}{1\text{ gallon}}\left|\frac{1000\text{ mL}}{1\text{ L}}\right| = 20.3\ \frac{\text{mL}}{\text{min}}$$

MISC.

102.

$$\begin{array}{r l} 1200\text{ cuft} & \\ \underline{-500\text{ cuft}} & \leftarrow \text{charged } \$5.50 \\ 700\text{ cuft} & \leftarrow \text{charged } (7)(0.25) = \$1.75 \end{array}$$

$$\text{TOTAL CHARGE} = \begin{array}{r} \$5.50 \\ \underline{+\ \$1.75} \\ \$7.25 \end{array}$$

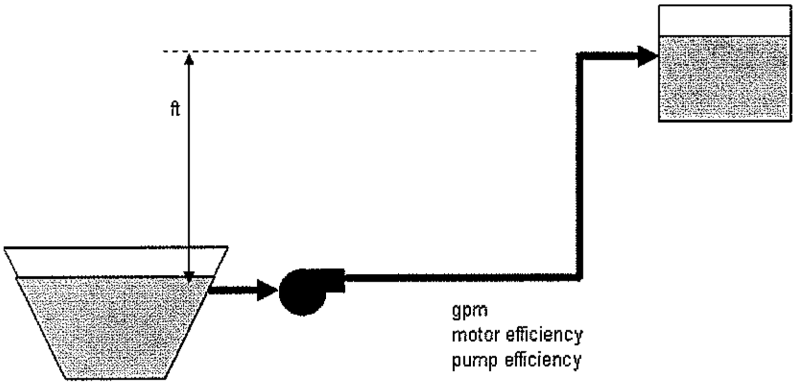
103.

$$\%\text{ Reduction} = \left[\frac{350\text{gpm} - 220\text{gpm}}{350\text{gpm}}\right] * 100$$

$$\%\text{ Reduction} = \left[\frac{130\text{ gpm}}{350\text{gpm}}\right] * 100$$

$$\%\text{ Reduction} = 37$$

## PUMPS



1. A centrifugal pump is pumping 200 gpm against a 40 ft total pumping head. The output power of the pump is approximately ______ hp.
   a) 0.5
   b) 2
   c) 15
   d) 121

2. A sludge pump with a 6" bore and a 3" stroke pumps 60 cycles/minute. What is the pumping rate in gpm?
   a) 22 gpm
   b) 18 gpm
   c) 27 gpm
   d) 35 gpm

3. What is the flow rate (gpm) from a pump with a discharge diameter of 6" and a velocity of 5 ft/sec?
   a) 440 gpm
   b) 198 gpm
   c) 44 gpm
   d) 338.5 gpm

4. What is the pumping rate in gpm of the following piston pump? Diameter = 10 inches, Stroke length = 6 inches, Strokes/min = 30
   a) 60.6 gpm
   b) 293.6 gpm
   c) 86.9 gpm
   d) 45.5 gpm

5. A single-piston reciprocating pump has a 6" diameter piston with a 6" length of stroke. It makes 16 discharge strokes/min, the pumping rate is ______gpm.
  a) 6
  b) 12
  c) 25
  d) 47

6. A centrifugal pump is pumping 650 gal/min against a 32-foot total pumping head. What is the approximate output power of the pump?
  a) 1 hp
  b) 5 hp
  c) 3 hp
  d) 8 hp
?Operations Forum May 1997

7. A pump delivers 240,000 gallons per day at a static head of 275 feet. Calculate the pressure equivalent to this head, expressed in pounds per square inch.
  a) 119 psi
  b) 275 psi
  c) 550 psi
  d) 635 psi
?WEF/ABC 2002 Guide

8. Water is being pumped from a reservoir uphill 120 to a storage tank. Calculate the Brake Horsepower if the pump rate is 1200 gpm.
a. 15
b. 36
c. 120
d. 8

9. A 25 horsepower pump is used to dewater a lake. If the pump runs for 8 hours a day for 7 days a week, how much will it cost to run the pump per week? Assume energy costs of 0.07 dollars per kilowatt hour.
a. $27.50
b. $92.15
c. $73.11
d, $112.35

10. Calculate the water horsepower required for a pump to raise water 120 feet at a rate of 1200 gallons per minute. If the pump runs for 8 hours a day for 7 days a week, how much will it cost to run the pump for one year? Assume energy costs of 0.07 dollars per kilowatt hour.
a. $15.03
b. $105.27
c. $5,489.00
d. $489.12

JOB Pumps JOB NO. 116
SHEET NO. ______ OF ______
CALCULATED BY ______ DATE ______
CHECKED BY ______ DATE ______
SUBJECT ______

$$HP = \frac{(gpm)(\text{Total Dynamic Head, ft})}{(3960)}$$

$$BHP = \frac{(gpm)(\text{Total Dynamic Head, ft})}{(3960)(\text{Pump Efficiency})(\text{Motor Efficiency})}$$

TOTAL DYNAMIC HEAD = FT OF LIFT + FRICTION LOSSES

1. $$HP = \frac{(gpm)(\text{head, ft})}{3960 \times E_m}$$

$$HP = \frac{(200\,gpm)(40\,ft)}{3960}$$

$$HP = 2$$

2. BORE = 6" = 0.5 ft = diameter
STROKE = 3" = 0.25 ft

$$\text{Volume per Stroke} = \pi r^2 h$$
$$= (3.14)(0.25\,ft)(0.25\,ft)(0.25\,ft)$$
$$= 0.049\,ft^3$$

$$\frac{0.049\,ft^3}{stroke} \Bigg| \frac{7.48\,gal}{1\,ft^3} \Bigg| \frac{60\,strokes}{1\,min} \Bigg| \; 22.0\,\frac{gal}{min}$$

3. $$\text{Velocity} = \frac{\text{Flow}}{\text{Area}}$$

$$\frac{5\,ft}{sec} = \frac{\text{Flow}}{0.196\,ft^2}$$

$$0.98\,ft^3/sec = \text{Flow}$$

$$\text{Area} = \pi r^2$$
$$= (3.14)(0.25\,ft)(0.25\,ft)$$
$$= 0.196\,ft^2$$

JOB Pumps JOB NO. 117
SHEET NO. OF
CALCULATED BY DATE
CHECKED BY DATE
SUBJECT

3. (cont.) $$0.98\,\frac{ft^3}{sec}\Big|\frac{7.48\ gal}{1\ ft^3}\Big|\frac{60\ sec}{1\ min}\Big| = 439.8\ \frac{gal}{min}$$

4. DIAMETER = 10 inches = 0.83 feet
STROKE LENGTH = 6 inches = 0.5 feet

VOLUME PER STROKE $= \pi r^2 h$
$= (3.14)(0.415\ ft)(0.415\ ft)(0.5\ ft)$
$= 0.27\ ft^3$

$$\frac{0.27\ ft^3}{stroke}\Big|\frac{30\ strokes}{1\ min}\Big|\frac{7.48\ gal}{1\ ft^3}\Big| = 60.6\ \frac{gal}{min}$$

5. DIAMETER = 6" = 0.5 ft
STROKE LENGTH = 6" = 0.5 ft

VOLUME PER STROKE $= \pi r^2 h$
$= (3.14)(0.25\ ft)(0.25\ ft)(0.5\ ft)$
$= 0.098\ ft^3$

$$\frac{0.098\ ft^3}{stroke}\Big|\frac{16\ strokes}{1\ min}\Big|\frac{7.48\ gal}{1\ ft^3}\Big| = 11.7\ \frac{gal}{min}$$

6. $$HP = \frac{(gpm)(head, ft)}{3960}$$
$$HP = \frac{(650\ gpm)(32\ ft)}{3960}$$
$$HP = 5.25$$

JOB Pumps JOB NO. 118

SHEET NO. OF

CALCULATED BY DATE

CHECKED BY DATE

SUBJECT

7. Convert feet to psi

$$275\text{ feet}\,\Big|\,\frac{0.433\text{ psi}}{1\text{ ft}}\,\Big| = 119\text{ psi}$$

8.
$$HP = \frac{(gpm)(Head,\ ft)}{3960}$$
$$HP = \frac{(1200\text{ gpm})(120\text{ ft})}{3960}$$
$$HP = 36$$

9.
$$25\text{ hp}\,\Big|\,\frac{0.746\text{ kw}}{\text{hp-h}}\,\Big|\,\frac{8\text{ hr}}{\text{day}}\,\Big|\,\frac{7\text{ day}}{\text{week}}\,\Big| = 1044\text{ kw/week}$$

$$\frac{1044\text{ kw}}{\text{week}}\,\Big|\,\frac{0.07\text{ \$}}{1\text{ kw}}\,\Big| = \$73.11$$

10. FROM #8, WE KNOW THAT THE PUMP IS 36 HP

$$36\text{ HP}\,\Big|\,\frac{0.746\text{ kw}}{1\text{ hp-h}}\,\Big|\,\frac{8\text{ hr}}{1\text{ day}}\,\Big|\,\frac{365\text{ day}}{1\text{ year}}\,\Big|\,\frac{0.07\text{ \$}}{1\text{ kw}}\,\Big| = \$5{,}489$$

# Sidney's Big Book of Water and Wastewater Math

INDIGO WATER GROUP

## Unit Conversions to Know by Heart

1 inch = 2.54 centimeters
1 meter = 3.28 feet
1 mile = 5280 feet

1 acre = 43,560 ft$^2$
1 m$^2$ = 10.76 ft$^2$

1 gallon = 3.785 liters
1 ft$^3$ = 7.48 gallons
1 m$^3$ = 35.31 ft$^3$

1 ft water = 0.433 psi

1 gallon = 8.34 lbs when specific gravity is 1.0
1 kg = 2.2 lbs

1% = 10,000 mg/L
1 mg/L = 1 ppm
1 µg/L = 1 ppb

1 day = 1440 minutes
1 hp = 0.746 kW

1 gram = 15.43 grains
1 grain per gallon = 17.1 mg/L

## Water Formulas

pounds per day = (concentration in mg/L)*(flow rate in mgd)*(8.34)

chlorine dose = demand + residual

$$\text{velocity} = \frac{\text{flow}}{\text{area}} \qquad V = \frac{Q}{A}$$

$$\text{flow rate} = \frac{\text{volume}}{\text{time}} \qquad Q = \frac{V}{t}$$

$$\text{overflow rate} = \frac{\text{flow rate}}{\text{area}}$$

$$\text{weir loading rate} = \frac{\text{flow rate}}{\text{feet of weir}}$$

(concentration 1)*(volume 1) = (concentration 2)*(volume 2) $C_1V_1 = C_2V_2$

(conc. 1)*(volume 1) + (conc. 2)*(volume 2) = (conc. 3)*(volume 3)

$$C_1V_1 + C_2V_2 = C_3V_3$$

$$\text{horsepower} = \frac{\text{(flow in gpm)*(lift in feet)}}{3960}$$

# Dilutions

# DILUTIONS

## 1. Making a standard.

A. Decide what you want.
B. Figure out what you have.
C. Use this formula to figure out dilution.

$$C_1V_1 = C_2V_2$$

$$\left.\begin{array}{l}\text{where } C_1 = \text{starting concentration} \\ V_1 = \text{volume you will need to dilute}\end{array}\right\} \text{have}$$

$$\left.\begin{array}{l}C_2 = \text{desired concentration} \\ V_2 = \text{volume desired}\end{array}\right\} \text{want}$$

Example: To calibrate an instrument, we need a 10 mg/L standard solution. We only need 100 mLs of the standard. In the chemical cabinet, there is a 1 Liter bottle of a 1000 mg/L stock solution.

$$C_1V_1 = C_2V_2$$
$$(1000\ \text{mg/L})(V_1) = (10\ \text{mg/L})(100\ \text{mLs})$$
$$V_1 = 1\ \text{mL}$$

Add 1 mL of stock solution to a 100 mL volumetric flask and bring to volume.

# DILUTIONS

2. Mixing two solutions together.

A. Figure out volumes and concentrations for both starting solutions.

B. Calculate new concentration by

$$\underbrace{C_1V_1}_{\text{starting solution 1}} + \underbrace{C_2V_2}_{\text{starting solution 2}} = \underbrace{C_3V_3}_{\text{final solution}}$$

NOTE THAT $V_3 = V_1 + V_2$

$$C_1V_1 + C_2V_2 = C_3(V_1 + V_2)$$

C. Enter all known information and solve for $C_3$

Example:

Plant influent $Q = 2.0$ MGD, $NH_3\text{-}N = 30$ mg/L
Septic haulers 10 trucks at 50,000 gallons total
$NH_3\text{-}N = 1200$ mg/L
Find new influent ammonia concentration.

## DILUTIONS

$$C_1V_1 + C_2V_2 = C_3(V_1 + V_2)$$

$$(2\text{ MGD})(30\text{ mg/L}) + (50{,}000\text{ gal/day})(1200\text{ mg/L}) = C_3(V_1 + V_2)$$

$$\updownarrow$$

convert to MGD

$$\frac{50{,}000\text{ gal}}{\text{day}}\left|\frac{1\text{ MG}}{1{,}000{,}000\text{ gal}}\right| = 0.05\text{ MGD}$$

$$(2\text{ MGD})(30\text{ mg/L}) + (0.05\text{ MGD})(1200\text{ mg/L}) = C_3(2\text{ MGD} + 0.05\text{ MGD})$$

$$60 + 60 = C_3(2.05)$$

$$120 = C_3(2.05)$$

$$C_3 = 58.5\text{ mg/L}$$

NOTE: Formula only works for parameters that are "conserved". In other words, parameters that aren't changed in the mixing process.

| Conserved | Not Conserved |
|---|---|
| TSS | Alkalinity |
| $BOD_5$ | pH |
| $NH_3$-N | |
| $NO_3$-N | |
| $NO_2$-N | |

# Dilutions

1. A wastewater treatment plant operator is preparing to run the Hach Nessler Ammonia test. For the test, they need a 20 mg/L standard. Looking around the laboratory, they find a 150 mL volumetric flask and a stock standard solution. The stock concentration is 1000 mg/L. How much stock standard should be added to the volumetric flask to achieve the desired concentration? Assume that the remaining volume of the flask will be filled with purified water.

Answer: 3.0 mL

2. An arsenic standard is left sitting out on the counter without a lid for several days. In the beginning, the bottle had 150 mL of a mg/L solution. After four days, the bottle only contained 125 mL. What was the concentration of arsenic after four days?

Answer: 24 mg/L

3. Some Polymer is being added to precipitate phosphorus. It is added in the pipeline between the aeration basins and secondary clarifiers. The target dose is 25 mg/L and the influent flow rate is 7.74 cfs. If the raw chemical in the feeder tank is 20000 mg/L, what should the pump rate be, in gpm, to acheive the desired dose?

Answer: 4.3 gpm

4. For the chemical dosing situation described in Problem 3, how many pounds of DRY chemical are added to the wastewater per week? Assume the pump runs 24 hours per day, seven days a week.

Answer: 7297.495 pounds per week
Calculate the millions of gallons of chemical solution added per week. Then, calculate pounds.

5. Chlorine is added to a wastewater plant effluent as a disinfectant. The effluent flow rate is 3472.22 gpm and the desired residual is 25 mg/L. If the wastewater has a demand of 12 mg/L and the chlorine is delivered as a hypochorite soluion with 2 percent available chlorine, where should the pump rate be set to acheive the desired residual?

Answer: 6.42 gpm
Don't forget to add the demand to your residual before calculating dose!

6. Ferric chloride is being added as a coagulant to the influent to a secondary clarifier. Sampling shows that the concentration of ferric in the clarifier floc well is 25 ppm. A quick check of the chemical metering pump shows that it is operating at a flow rate of 4.3 gpm. If the flow through the WWTP is 7.74 cfs, what is the concentration of raw chemical in the dosing tank?

Answer: 2.00 %
Same problem, just backwards to find the tank concentration.

Dilutions

** most chemical dosing problems can be solved by using the same formulas that we use to calculate dilutions. There are two formulas.

$C1V1 = C2V2$ which is used when a small volume of one solution will be added to another.

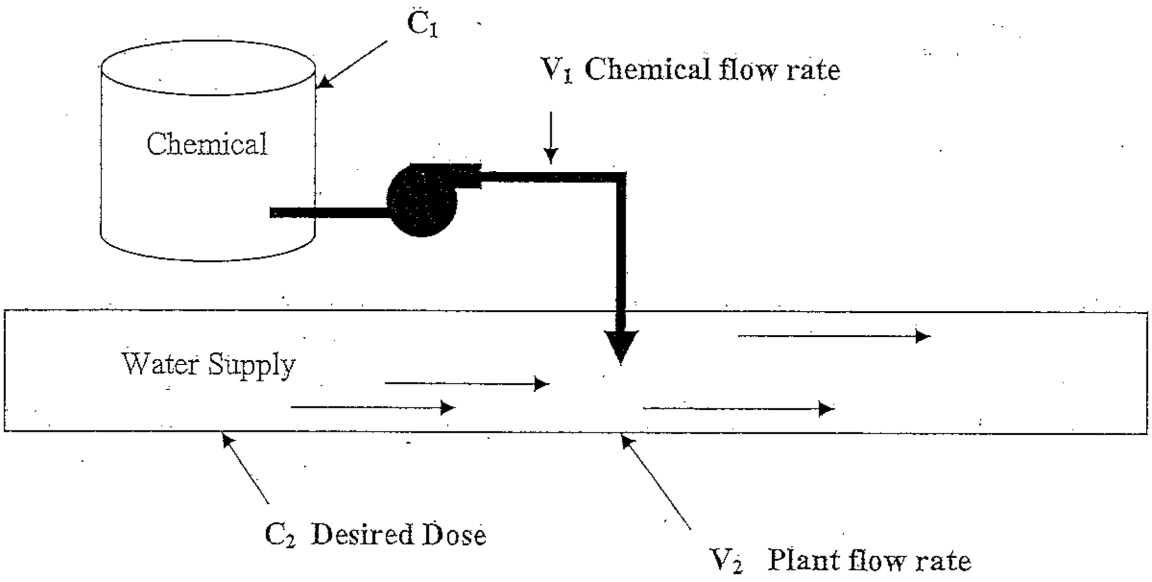
$C1V1 + C2V2 = C3V3$ which is used when two solutions are mixed together.

54. You are preparing a stock solution using dry sodium bicarbonate. Your desired strength is 5,000 mg/L so that 1 ml of stock solution per 1,000 ml sample water produces 5mg/L. How many dry grams must you add to your 1 Liter of stock solution dilution water?

a) 0.5
b) 5
c) 500
d) 0.05

55. You have a 1000 mg/L solution of Arsenic. To calibrate the instrument, you need 250 mL of a 10 mg/L solution. How many milliliters of the stock solution should be diluted to make 250 mLs?

a) 2.5
b) 5.0
c) 15.0



56. A water treatment plant adds ferric chloride as a coagulant. The raw water enters the plant at 10 mgd. Jar testing shows that the optimum ferric dose is 200 mg/L. If the ferric chloride is delivered as a 47% solution, what should the chemical delivery pump rate be? Express your answer in gpm.

a) 2.96
b) 4255
c) 5.31
d) 25.8

57. There are two raw water lines entering a treatment plant. One line carries a flow rate of 500 gal/min with a TDS concentration of 1500 mg/l, and the other has a flow rate of 6 MGD with a 250 mg/l TDS. What is the actual combined TDS concentration entering the plant? Round off answer to nearest full unit.

a) 700 mg/l
b) 384 mg/l
c) 420 mg/l
d) 1200 mg/L

58. Two wells are used to satisfy demand during the summer months. One well produces water that contains 22 mg/L of arsenic. The other well produces water that contains 3 mg/L of arsenic. If the total demand for water is 400 gpm and the target arsenic concentration in the finished water is 8 mg/L, what is the highest pumping rate possible for the first well?

a) 252 gpm
b) 105 gpm
c) 295 gpm
d) 160 gpm

59. Liquid polymer is delivered as an 8 percent solution. How many gallons of liquid polymer should be mixed in a tank to produce 150 gallons of 0.6 percent polymer solution?

a) 2.5 gallons
b) 7.5 gallons
c) 17.5 gallons
d) 22.5 gallons
e) 11.3 gallons

# DILUTIONS

54. $\frac{5000\text{ mg}}{L} \Big| \frac{1\text{ gram}}{1000\text{ mg}} \Big| = 5\text{ grams}/\text{Liter}$

55. $\overbrace{C_1 V_1}^{\text{have}} = \overbrace{C_2 V_2}^{\text{want}}$

$(1000\text{ mg/L})(V_1) = (10\text{ mg/L})(250\text{mL})$

$1000\ V_1 = 2500$

$V_1 = 2.5\ \underline{\underline{\text{mL}}}$

units must be mL since $V_2$ was also in mL

56. This problem can be done in two ways; by finding the total lbs of Fe needed and then calculating the feed rate OR the problem can be set up as a dilution

A) $\text{ppd} = (\text{mg/L})(Q)(8.34)$

$\text{ppd} = (200\text{ mg/L})(\overset{\text{oops!}}{\cancel{10,000}})(10\text{ MGD})(8.34)$

$\text{ppd} = 16680$

NOTE 1% = 10,000 mg/L

$\text{ppd} = (\text{mg/L})(Q)(8.34)$

$16680\text{ ppd} = (10,000)(47\%)(Q)(8.34)$

$Q = 0.004255\text{ MGD}$

$Q = 4255\text{ gpd}$

$Q = 2.96\text{ gpm}$

B) we can also set this up as a dilution

$$\overbrace{C_1 V_1}^{\text{have}} = \overbrace{C_2 V_2}^{\text{want}}$$

$$(47\%)(V_1) = (200\ \text{mg/L})(10\ \text{mgd})$$

I need to do some unit conversions

$$47\% \left| \frac{10{,}000\ \text{mg/L}}{1\%} \right| = 47{,}0000\ \text{mg/L}$$

$$\frac{10\ \text{MG}}{\text{day}} \left| \frac{1000000\ \text{gal}}{1\ \text{MG}} \right| \frac{1\ \text{day}}{1440\ \text{min}} \right| = 6944\ \text{gpm}$$

So ——

$$(C_1)(V_1) = (C_2)(V_2)$$

$$(470{,}000\ \text{mg/L})(V_1) = (200\ \text{mg/L})(6944\ \text{gpm})$$

$$(470000)(V_1) = 1388800$$

$$V_1 = 2.95\ \text{gpm}$$

57. Since we are blending two large volumes, we need a different formula.

$$\underbrace{C_1V_1}_{\text{stream } 1} + \underbrace{C_2V_2}_{\text{stream } 2} = \underbrace{C_3V_3}_{\text{combo volume}}$$

we know that $V_3 = V_1 + V_2$

$$C_1V_1 + C_2V_2 = C_3V_3$$

$$(1500\,^{mg/L})(500\text{ gal/min}) + (250\,^{mg/L})(6\text{ MGD}) = C_3(6\text{ MGD} + 500\text{ gpm})$$

units don't match! convert one.

$$\frac{500\text{ gal}}{\text{min}}\left|\frac{1440\text{ min}}{1\text{ day}}\right|\frac{1\text{ MG}}{1000000\text{ gal}}\right| = 0.72\text{ MGD}$$

$$C_1V_1 + C_2V_2 = C_3V_3$$

$$(1500\,^{mg/L})(0.72\text{ mgd}) + (250\,^{mg/L})(6\text{ mgd}) = C_3(6\text{ mgd} + 0.72\text{ mgd})$$

$$1080 + 1500 = C_3(6.72)$$

$$2580 = C_3(6.72)$$

$$384\text{ mg/L} = C_3$$

58. This uses the same formula as #57, but is slightly more complicated.

$$C_1 V_1 + C_2 V_2 = C_3 V_3$$
$$(22\,mg/L)(V_1) + (3\,mg/L)(V_2) = (8\,mg/L)(400gpm)$$

we don't know $V_1$ or $V_2$, but we do know that

$$V_1 + V_2 = V_3$$
$$V_1 + V_2 = 400gpm$$
$$V_1 = 400gpm - V_2$$

$$C_1 V_1 + C_2 V_2 = C_3 V_3$$
$$(22\,mg/L)(400gpm - V_2) + (3\,mg/L)(V_2) = (8\,mg/L)(400gpm)$$
$$8800 - 22V_2 + 3V_2 = 3200$$
$$8800 - 19V_2 = 3200$$
$$5600 - 19V_2 = 0$$
$$5600 = 19V_2$$
$$295\,gpm = V_2$$

Whew!

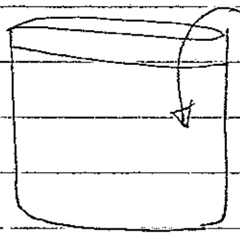
59. This is a simple dilution.

$$C_1 V_1 = C_2 V_2$$

$$(8\%)(V_1) = (0.6\%)(150 \text{ gallons})$$

$$(8\%)(V_1) = 90$$

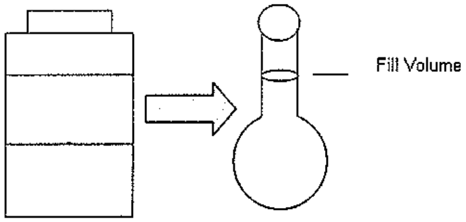
$$V_1 = 11.25 \text{ gallons}$$



add 11.25 gallons polymer and water up to the 150 gallon mark.

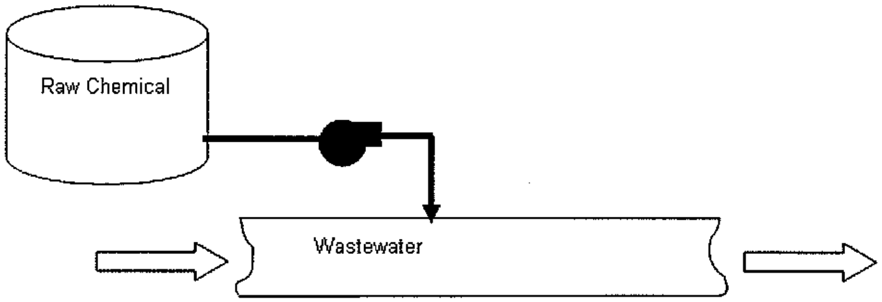
## DILUTIONS

1. There are two influent lines entering a treatment plant. One line carries a flow rate of 500 gal/min with a BOD concentration of 1500 mg/l, and the other has a flow rate of 6 MGD with a 250 mg/l BOD. What is the actual combined BOD concentration entering the plant? Round off answer to nearest full unit.
   a) 700 mg/l
   b) 384 mg/l
   c) 420 mg/l
   d) 1200 mg/L



2. A wastewater treatment plant operator is preparing to run the Hach Nessler Ammonia test. For the test, they need a 20 mg/L standard. Looking around the laboratory, they find a 150 mL volumetric flask and a stock standard solution. The stock concentration is 1000 mg/L. How much stock standard should be added to the volumetric flask to achieve the desired concentration? Assume that the remaining volume of the flask will be filled with purified water.

3. An arsenic standard is left sitting out on the counter without a lid for several days. In the beginning, the bottle had 150 mL of a 500 mg/L solution. After four days, the bottle only contained 125 mL. What was the concentration of arsenic after four days?



4. Some polymer is being added to precipitate phosphorus. It is added in the pipeline between the aeration basins and secondary clarifiers. The target dose is 25 mg/L and the influent flow rate is 7.74 cfs. If the raw chemical in the feeder tank is 20000 mg/L, what should the pump rate be, in gpm, to acheive the desired dose?

5. For the chemical dosing situation described in Problem 4, how many pounds of DRY chemical are added to the wastewater per week? Assume the pump runs 24 hours per day, seven days a week.

JOB DILUTIONS JOB NO. 44

SHEET NO. OF

CALCULATED BY DATE

CHECKED BY DATE

SUBJECT

1. $C_1V_1 + C_2V_2 = C_3V_3$

$(1500 \, ^{mg/L})(500 \, gpm) + (6 \, mgd)(250 \, ^{mg/L}) = C_3V_3$

UNITS DON'T MATCH, SO CONVERT

$\frac{6 \, MG}{D} \Big| \frac{1 \, DAY}{1440 \, min} \Big| \frac{1,000,000 \, gal}{1 \, MG} \Big| = 4167 \, gpm$

$(1500 \, ^{mg/L})(500 \, gpm) + (4167 \, gpm)(250 \, ^{mg/L}) = (4167 + 500 \, gpm)(C_3)$

$750000 + 1041750 = (4667)(C_3)$

$1791750 = (4667)(C_3)$

$384 \, ^{mg/L} = C_3$

2. $C_1V_1 = C_2V_2$

$(1000 \, mg/L)(V_1) = (20 \, ^{mg/L})(150 \, mL)$

$1000 \, V_1 = 3000$

$V_1 = 3 \, mL$

3. $C_1V_1 = C_2V_2$

$(500 \, ^{mg/L})(150 \, mL) = (C_2)(125 \, mL)$

$75000 = (C_2)(125)$

$600 \, ^{mg/L} = C_2$

4. $C_1V_1 = C_2V_2$

$(20{,}000 \, mg/L)(V_1) = (25 \, ^{mg/L})(7.74 \, cfs)$

$(20{,}000)(V_1) = 193.5$

$V_1 = 0.009675 \, cfs$

$\frac{0.009675 \, cf}{sec} \Big| \frac{60 \, sec}{1 \, min} \Big| \frac{7.48 \, gal}{1 \, cf} \Big| = 4.34 \, gpm$

JOB DILUTIONS JOB NO. 45
SHEET NO. OF
CALCULATED BY DATE
CHECKED BY DATE
SUBJECT

5. ppd = (mg/L)(Q, mgd)(8.34)

$$\left.\frac{4.34\ \text{gal}}{\text{min}}\right|\left.\frac{1440\ \text{min}}{1\ \text{day}}\right|\left.\frac{1\ \text{MG}}{1000000\ \text{gal}}\right| = 0.00625\ \frac{\text{MG}}{\text{day}}$$

ppd = (25 mg/L)(0.00625 MGD)(8.34)
ppd = 1.30

pounds per week = (7)(1.30) = 9.12

# Sidney's Big Book of Water and Wastewater Math

INDIGO WATER GROUP

## Unit Conversions to Know by Heart

1 inch = 2.54 centimeters
1 meter = 3.28 feet
1 mile = 5280 feet

1 acre = 43,560 $ft^2$
1 $m^2$ = 10.76 $ft^2$

1 gallon = 3.785 liters
1 $ft^3$ = 7.48 gallons
1 $m^3$ = 35.31 $ft^3$

1 ft water = 0.433 psi

1 gallon = 8.34 lbs when specific gravity is 1.0
1 kg = 2.2 lbs

1% = 10,000 mg/L
1 mg/L = 1 ppm
1 µg/L = 1 ppb

1 day = 1440 minutes
1 hp = 0.746 kW

1 gram = 15.43 grains
1 grain per gallon = 17.1 mg/L

## Water Formulas

pounds per day = (concentration in mg/L)*(flow rate in mgd)*(8.34)

chlorine dose = demand + residual

$$\text{velocity} = \frac{\text{flow}}{\text{area}} \qquad V = \frac{Q}{A}$$

$$\text{flow rate} = \frac{\text{volume}}{\text{time}} \qquad Q = \frac{V}{t}$$

$$\text{overflow rate} = \frac{\text{flow rate}}{\text{area}}$$

$$\text{weir loading rate} = \frac{\text{flow rate}}{\text{feet of weir}}$$

(concentration 1)*(volume 1) = (concentration 2)*(volume 2) $C_1V_1 = C_2V_2$

(conc. 1)*(volume 1) + (conc. 2)*(volume 2) = (conc. 3)*(volume 3)

$$C_1V_1 + C_2V_2 = C_3V_3$$

$$\text{horsepower} = \frac{\text{(flow in gpm)*(lift in feet)}}{3960}$$

# Chemical Dosing and Disinfection

Disinfection

60. The finished water chlorine demand is 12 mg/l, the target chlorine residual is 1.2 mg/l, and the plant flow is 5.6 MGD. How many lbs/day of 65% hypochlorite solution will be required?
a) 776 lbs/day
b) 948 lbs/day
c) 113 lbs/day
d) 514 lbds/day

61. If chlorine costs $0.21/lb, what is the daily cost to chlorinate a 5 MGD flow rate at a chlorine dosage of 2.6 mg/l?
a) $22.77
b) $18.95
c) $31.22
d) $21.34

62. If a 1-mgd plant has an chlorine demand of 4.5 mg/l and maintains a residual of 1.0 mg/l, what is the estimated required chlorine feed rate in pounds per day?
a) 38
b) 46
c) 51
d) 68
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63. Determine the required chlorinator setting in lb/day given: Steady flow rate of 5.5 MGD, Target chlorine residual = 2.5 mg/l, Average chlorine demand = 2.5 mg/l
a) 251 lbs/day
b) 195 lbs/day
c) 213 lbs/day
d) 229 lbs/day

64. How many lbs of chlorine gas are required to treat 4,000,000 gal of water at a dosage of 2 mg/l?
a) 61
b) 65
c) 67
d) 69

65. How many pounds of calcium hypochlorite are there in 15 lbs of 65% calcium hypochlorite solution?
a) 9.75 pounds
b) 24.75 pounds
c) 5.25 pounds
d) 23.07 pounds

66. To accurately obtain a chlorine residual from your system you are sampling at a customer tap. You would like to flush twice the volume of the service line before sampling. The service line is 3/4" and approximately 200 feet from the main. How many gallons must you flush?
a) 610
b) 4.6
c) 61
d) 46
e) 0.61

67. How many lbs/day chlorine will be used if the flow is 7,000,000 gpd and a uniform dose of 1.2 mg/l is applied?
a) 15 lb
b) 22 lb
c) 70 lb
d) 26 lb

68. One gallon of sodium hypochlorite laundry bleach (with 5.25% available chlorine) contains:
a) 0.44 pounds of active chlorine
b) 0.053 pounds of active chlorine
c) 4.38 pounds of active chlorine
d) 0.39 pounds of active chlorine

69. How many pounds of sodium hypochorite solution will be needed to provide 25 pounds of available chlorine if the sodium hypochlorite solution contains 8 percent available chlorine by weight?
a) 312.5 pounds
b) 27.0 pounds
c) 16.68 pounds
d) 200 pounds

70. How many pounds of 65-percent available chlorine equal 2 pounds of 100 percent chlorine.
a) 1.30 pounds
b) 3.08 pounds
c) 5.28 pounds
d) 308 pounds

71. How many pounds of 70-percent available chlorine equal 2 pounds of 100 percent chlorine?

- a) 1.40 pounds
- b) 2.80 pounds
- c) 1.35 pounds
- d) 2.86 pounds

72. If 1,000,000 bacteria are exposed to a disinfectant and 90 percent are destroyed every hour, then fewer than 5 bacteria will remain after

- a) 3 hours
- b) 6 hours
- c) 4 hours
- d) 5 hours
- e) 7 hours
- f) 24 hours

73. Determine the chlorinator setting in pounds per 24 hours if a well pump delivers 300 gpm and the desired chlorine dose is 2.0 mg/L.

- a) 6.5 ppd
- b) 12.0 ppd
- c) 7.2 ppd
- d) 4.8 ppd

74. How much sodium hypochlorite, in gallons, is required to obtain a residual of 100 mg/L in a well? The casing diameter is 18 inches and the length of water filled casing is 80 feet. Sodium hypochlorite contains 5.25% available chlorine. Assume a demand of 15 mg/L.

- a) '23.0 gallons
- b) '2.0 gallons
- c) '16.8 gallons
- d) '2.3 gallons

# DISINFECTION

60. DOSE = DEMAND + RESIDUAL
DOSE = (12.0 mg/L + 1.2 mg/L)
DOSE = 13.2 mg/L

ppd $Cl_2$ = (mg/L)(Q)(8.34)
ppd $Cl_2$ = (13.2 mg/L)(5.6 mgd)(8.34)
ppd $Cl_2$ = 616.5

$$616.5 \text{ ppd } Cl_2 \left| \frac{1 \text{ lb soln}}{0.65 \text{ lb } Cl_2} \right| = 948 \text{ ppd soln.}$$

61. ppd = (mg/L)(Q)(8.34)
ppd = (2.6 mg/L)(5 mgd)(8.34)
ppd = 108.42

$$\frac{108.42 \text{ lbs}}{\text{day}} \left| \frac{0.21\ \$}{1 \text{ lb}} \right| = \$22.77/\text{day}$$

62. ppd = (mg/L)(Q)(8.34)
ppd = (4.5 + 1.0 mg/L)(1 mgd)(8.34)
ppd = (5.5)(1)(8.34)
ppd = 45.87

63. $ppd = (mg/L)(Q)(8.34)$

$ppd = (2.5 + 2.5 \; mg/L)(5.5 \; mgd)(8.34)$

$ppd = (5)(5.5)(8.34)$

$ppd = 229$

64. $ppd = (mg/L)(Q)(8.34)$

$ppd = (2 \; mg/L)(4 \; mgd)(8.34)$

$ppd = 66.7$

*NOTE: FOR THIS FORMULA TO WORK, FLOW MUST BE IN MGD

65. $$15 \text{ lbs Hypo Soln} \left| \frac{\overset{\text{chemical}}{0.65 \text{ lbs}}}{1 \text{ lb Soln}} \right| = 9.75 \text{ lbs}$$

66. We need to find the volume of the pipe in cubic feet, then convert to gallons.

$$\frac{3}{4} \text{ inch} = 0.75 \text{ inch}$$

$$0.75 \text{ inch} \left| \frac{1 \text{ foot}}{12 \text{ inches}} \right| = 0.0625 \text{ ft}$$ so radius = 0.03125 ft

$Volume = \pi r^2 d$

$V = (3.14)(0.03125')^2(200')$

$V = (3.14)(0.03125')(0.03125')(200')$

$V = 0.613 \text{ ft}^3$

$$0.613 \text{ ft}^3 \left| \frac{7.48 \text{ gallons}}{1 \text{ ft}^3} \right| = 4.6 \text{ gallons}$$

67. $ppd = (mg/L)(Q)(8.34)$
$ppd = (1.2\,mg/L)(7\,mgd)(8.34)$
$ppd = 70$

68. $\left.1\text{ gal bleach}\,\right|\,\frac{8.34\text{ lbs}}{1\text{ gallon}}\,\left|\,\frac{0.0525\text{ lbs } Cl_2}{1\text{ lb bleach}}\right| = 0.44\text{ lbs}$

69. $\left.25\text{ lbs } Cl_2\,\right|\,\frac{1\text{ lb NaOHCl}}{0.08\text{ lbs } Cl_2}\right| = 312.5\text{ lbs hypochlorite}$

70. $\left.2\text{ lbs } Cl_2\,\right|\,\frac{1\text{ lb NaOHCl}}{0.65\text{ lbs } Cl_2}\right| = 3.07\text{ lbs hypochlorite}$

71. $\left.2\text{ lbs } Cl_2\,\right|\,\frac{1\text{ lb NaOHCl}}{0.70\text{ lbs } Cl_2}\right| = 2.86\text{ lbs hypochlorite}$

72. 1,000,000
x 0.90
900,000 destroyed in first hour
so 100000 remain

We are getting one order of magnitude removal per hour

1,000,000
6 5 4 3 2 1

after 6 hours,
1 bacteria will remain

73. $ppd = (\text{mg/L})(Q, \text{mgd})(8.34)$

Our flow rate is in gpm, so we need to convert to mgd

$$\frac{300 \text{ gallons}}{\text{minute}} \Bigg| \frac{1440 \text{ minutes}}{1 \text{ day}} \Bigg| \frac{1 \text{ MG}}{1000000 \text{ gallons}} \Bigg| = 0.432 \text{ mgd}$$

$$ppd = (\text{mg/L})(Q)(8.34)$$
$$ppd = (2.0 \text{ mg/L})(0.432 \text{ mgd})(8.34)$$
$$ppd = 7.2$$

74. First, we need to find the volume of the well in gallons. Then, we can solve this problem using the dilution formula.

$$\frac{18 \text{ inches}}{} \Bigg| \frac{1 \text{ foot}}{12 \text{ inches}} \Bigg| = 1.5 \text{ feet} \quad \therefore \text{radius} = 0.75 \text{ ft}$$

$$\text{Volume} = \pi r^2 d$$
$$\text{Volume} = (3.14)(0.75 \text{ ft})^2(80 \text{ ft})$$
$$\text{Volume} = (3.14)(0.75 \text{ ft})(0.75 \text{ ft})(80 \text{ ft})$$
$$\text{Volume} = 141.3 \text{ ft}^3$$

$$\frac{141.3 \text{ ft}^3}{} \Bigg| \frac{7.48 \text{ gal}}{1 \text{ ft}^3} \Bigg| = 1056.9 \text{ gallons}$$

74. (cont.) $C_1 V_1 = C_2 V_2$

$$(5.25\%)(10{,}000)(V_1) = (100 \text{ mg/L} + 15 \text{ mg/L})(1056.9 \text{ gallons})$$

$$(52500 \text{ mg/L})(V_1) = (115 \text{ mg/L})(1056.9 \text{ gallons})$$

$$V_1 = 2.3 \text{ gallons}$$

## CHEMICAL DOSING and DISINFECTION

1. The effluent chlorine demand is 12 mg/l, the target chlorine residual is 1.2 mg/l, and the plant flow is 5.6 MGD. How many lbs/day of 65% hypochlorite solution will be required?
   a) 776 lbs/day
   b) 948 lbs/day
   c) 113 lbs/day

2. If chlorine costs $0.21/lb, what is the daily cost to chlorinate a 5 MGD flow rate at a chlorine dosage of 2.6 mg/l?
   a) $22.77
   b) $18.95
   c) $31.22
   d) $21.34

3. Determine the required chlorinator setting in lb/day given: Steady flow rate of 5.5 MGD, Target chlorine residual = 2.5 mg/l, Average chlorine demand = 2.5 mg/l
   a) 251 lbs/day
   b) 195 lbs/day
   c) 213 lbs/day
   d) 229 lbs/day

4. How many lbs of chlorine gas are required to treat 4,000,000 gal of wastewater at a dosage of 2 mg/l
   a) 61
   b) 65
   c) 67
   d) 69

5. If a 1-mgd plant has an effluent chlorine demand of 4.5 mg/l and maintains a residual of 1.0 mg/l, what is the estimated required chlorine feed rate in pounds per day?
   a) 38
   b) 46
   c) 51
   d) 68

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6. How many lbs/day chlorine will be used if the flow is 7,000,000 gpd and a uniform dose of 1.2 mg/l is applied?
   a) 70 lb
   b) 15 lb
   c) 22 lb
   d) 26 lb

7. 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: design flow = 5 mgd; chlorine dosage rate = 4 mg/l; chlorine residual = 0.9 mg/l

a) 25 lb/d
b) 100 lb/d
c) 167 lb/d
d) 267 lb/d

?Operations Forum December 1998

JOB CHEMICAL DOSING JOB NO. 97
SHEET NO. & DISINFECTION OF
CALCULATED BY DATE
CHECKED BY DATE
SUBJECT

1. ppd = (mg/L)(Q, mgd)(8.34)
ppd = (12 mg/L + 1.2 mg/L)(5.6 mgd)(8.34)
ppd = (13.2 mg/L)(5.6 mgd)(8.34)
ppd = 616.5 ppd

$$616.5 \text{ ppd } Cl_2 \left| \frac{1 \text{ lb NaOHCl}}{0.65 \text{ lb } Cl_2} \right| = 948 \text{ ppd NaOHCl}$$

2. ppd = (mg/L)(Q, mgd)(8.34)
ppd = (2.6 mg/L)(5 mgd)(8.34)
ppd = 108.42 ppd

$$\frac{108.42 \text{ lbs}}{\text{day}} \left| \frac{0.21 \ \$}{1 \text{ lb}} \right| = \$22.77/\text{day}$$

3. ppd = (mg/L)(Q, mgd)(8.34)
ppd = (2.5 + 2.5 mg/L)(5.5 mgd)(8.34)
ppd = 229

4. ppd = (2 mg/L)(4 mgd)(8.34)
ppd = 66.72

5. ppd = (4.5 + 1.0 mg/L)(1 mgd)(8.34)
ppd = (5.5 mg/L)(1 mgd)(8.34)
ppd = 45.87

6. ppd = (1.2 mg/L)(7 mgd)(8.34)
ppd = 70.06

JOB DISINFECTION JOB NO. 98

SHEET NO. OF

CALCULATED BY DATE

CHECKED BY DATE

SUBJECT

7. SULFUR DIOXIDE DOSE = 0.9 mg/L + 1.5 mg/L

= 2.4 mg/L

ppd = (mg/L)(Q, mgd)(8.34)

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

ppd = 100.08

The calculated pure chemical dose for a chemical solution is 3.56 pounds. The chemical manufacturer has indicated on the chemical container label that the chemical purity or percent active chemical is 91 percent. Calculate the pounds of chemical from the container that must be added to water to produce the desired percent solution or concentration.

**Known**

Pure Chemical, lbs = 3.56 lbs
Active Chemical, % = 91%

**Unknown**

Actual Chemical Required, lbs

Calculate the pounds of chemical from the container that must be added to the water.

$$\text{Actual Chemical Required, lbs} = \frac{(\text{Pure Chemical, lbs})(100\%)}{\text{Active Chemical, \%}}$$

$$= \frac{(3.56 \text{ lbs})(100\%)}{91\%}$$

$$= 3.91 \text{ lbs}$$

$$= 3 \text{ lbs} + (0.91 \text{ lbs})(16 \text{ oz/lb})$$

$$= 3 \text{ lbs, } 15 \text{ oz}$$

An industrial wastewater with a pH of 10.8 flows from an equalization tank to a neutralization mixing tank at a rate of 9 GPM. Lab tests indicate that a 100 m*L* sample of the waste requires 11.3 m*L* of 0.5 *N* sulfuric acid to lower the pH to 7.0. Determine the setting in gallons per day on a chemical feed pump which is pumping 2 *N* sulfuric acid to the neutralization mixing tank.

**Known**

Waste Flow, GPM = 9 GPM
Waste Sample, m*L* = 100 m*L*
Acid Vol, m*L* = 11.3 m*L*
Acid, *N* = 0.5 *N*
Acid Feed, *N* = 2 *N*

**Unknown**

Acid Feed, GPD

Determine normality of waste.

Millequivalents = (m*L*)(*N*)

$$\text{Waste Normality} = \frac{(\text{Acid Vol, m}L)(\text{Acid, } N)}{\text{Waste Sample, m}L}$$

$$= \frac{(11.3 \text{ m}L)(0.5\ N)}{100 \text{ m}L}$$

$$= 0.0565\ N$$

Calculate the flow to be delivered by the chemical feed pump.

$$\text{Acid Feed, GPD} = \frac{(\text{Waste Flow, GPM})(\text{Waste Normality})(60 \text{ min/hr})(24 \text{ hr/day})}{\text{Acid Feed, } N}$$

$$= \frac{(9 \text{ GPM})(0.0565\ N)(60 \text{ min/hr})(24 \text{ hr/day})}{2\ N}$$

$$= 366 \text{ GPD}$$

Complexed copper is being removed in a plating wastestream by hydroxide precipitation. Laboratory results indicate that 10 milliliters of four percent or one normal sodium hydroxide will increase the pH of one liter of wastewater to 12 and precipitate the copper. Determine the setting on the sodium hydroxide feed pump in gallons per day to treat a complexed copper wastewater flow of 12 GPM.

| **Known** | **Unknown** |
|---|---|
| Lab Results | NaOH Feed, GPD |
| 10 m*L* NaOH/*L* wastewater | |
| Copper Flow, GPM = 12 GPM | |

Calculate the sodium hydroxide feed rate in gallons per day.

$$\text{NaOH Feed, GPD} = \frac{(\text{Copper Flow, gal/min})(\text{m}L\text{ NaOH})(60\text{ min/hr})(24\text{ hr/day})}{(1{,}000\text{ m}L/L)(1\ L\text{ copper})}$$

$$= \frac{(12\text{ GPM copper})(10\text{ m}L\text{ NaOH})(60\text{ min/hr})(24\text{ hr/day})}{(1{,}000\text{ m}L/L)(1\ L\text{ copper})}$$

$$= 173\text{ GPD}$$

How much sulfur dioxide is required to treat 1,100 gallons of chromic acid containing 1,400 mg/*L* of hexavalent chromium? Assume that one pound of hexavalent chromium is reduced to the trivalent state by the addition of three pounds of sulfur dioxide.

| **Known** | **Unknown** |
|---|---|
| Waste, gal = 1,100 gal | Dosage, lbs $SO_2$ |
| Conc, mg/*L* = 1,400 mg $Cr^{6+}/L$ | |
| Treat, lbs/lb = 3 lbs $SO_2$/lb $Cr^{6+}$ | |

1. Calculate the pounds of $Cr^{6+}$ to be treated.

$$Cr^{6+}\text{ Treated, lbs} = (\text{Waste, MG})(Cr^{6+}, \text{mg}/L)(8.34\text{ lbs/gal})$$

$$= (0.0011\text{ MG})(1{,}400\text{ mg}/L)(8.34\text{ lbs/gal})$$

$$= 12.8\text{ lbs }Cr^{6+}$$

2. Calculate the dosage of sulfur dioxide.

$$\text{Dosage, lbs }SO_2 = (Cr^{6+}\text{ Treated, lbs})(\text{Treatment, lbs }SO_2/\text{lb }Cr^{6+})$$

$$= (12.8\text{ lbs }Cr^{6+})(3\text{ lbs }SO_2/\text{lb }Cr^{6+})$$

$$= 38.4\text{ lbs }SO_2$$

A cyanide-bearing waste is to be treated by a continuous flow process using the alkaline chlorination method. The cyanide holding tank contains 6,000 gallons with a cyanide concentration of 15 mg/*L*. Seven pounds of caustic soda and eight pounds of chlorine are required to oxidize one pound of cyanide to nitrogen gas. The cyanide wastes are delivered to a mixing tank by a 25 GPM pump.

a. What should be the setting on the hypochlorinator in gallons per day if the hypochlorite solution is 2.0 percent chlorine?

b. What should be the setting on the caustic feed pump in gallons per day if the caustic soda is a 10 percent solution?

| Known | | Unknown |
|---|---|---|
| Cyanide Vol, gal | = 6,000 gal | Hypochlorinator, GPD |
| Cyanide Conc, mg/*L* | = 15 mg/*L* | Caustic Pump, GPD |
| Cyanide Flow, GPM | = 25 GPM | |
| Chlorine Dose, lb/lb | = 8 lbs Cl/lb CN | |
| Caustic Dose, lb/lb | = 7 lbs NaOH/lb CN | |
| Hypochlorite, % Cl | = 2% | |
| Caustic Soda, % | = 10% | |

1. Calculate the cyanide feed rate in pounds per day.

$$\text{Cyanide, lbs/day} = \frac{(\text{Flow, GPM})(\text{Cyanide Conc, mg}/L)(8.34\text{ lbs/gal})}{694\text{ GPM/MGD}}$$

$$= \frac{(25\text{ GPM})(15\text{ mg}/L)(8.34\text{ lbs/gal})}{694\text{ GPM}}$$

$$= 4.5\text{ lbs/day}$$

2. Determine the chlorine feed rate in pounds per day.

$$\text{Chlorine Feed, lbs/day} = (\text{Cyanide, lbs/day})(\text{Chlorine Dose, lb/lb})$$

$$= (4.5\text{ lbs CN/day})(8\text{ lbs Cl/lb CN})$$

$$= 36\text{ lbs Cl/day}$$

$$\text{Caustic Feed, lbs/day} = (\text{Cyanide, lbs/day})(\text{Caustic Dose, lb/lb})$$

$$= (4.5\text{ lbs CN/day})(7\text{ lbs NaOH/lb CN})$$

$$= 31.5\text{ lbs caustic/day}$$

3. Determine the hypochlorinator setting in gallons per day.

$$\text{Hypochlorinator, GPD} = \frac{(\text{Chlorine Feed, lbs/day})(100\%)}{(8.34\text{ lbs/gal})(\text{Hypochlorite, }\%)}$$

$$= \frac{(36\text{ lbs/day})(100\%)}{(8.34\text{ lbs/gal})(2\%)}$$

$$= 216\text{ GPD}$$

4. Determine the caustic pump setting in gallons per day.

$$\text{Caustic Pump, GPD} = \frac{(\text{Caustic Feed, lbs/day})(100\%)}{(8.34\text{ lbs/gal})(\text{Caustic, }\%)}$$

$$= \frac{(31.5\text{ lbs/day})(100\%)}{(8.34\text{ lbs/gal})(10\%)}$$

$$= 38\text{ GPD}$$

JAR TEST

Collected 2000 mL of wastewater. Optimum dose from the jar test was 5 mL of a 1,000 mg/L stock solution of ferric chloride. What should my chemical feed rate be in ppd if my plant flow rate is 208 gpm?

FIRST, Calculate the concentration of chemical in the jar test.

$$C_1V_1 = C_2V_2$$
$$C_1(2000\text{ mL}) = (5\text{ mL})(1000\text{ mg/L})$$
$$C_1 = 2.5\text{ mg/L}$$

THEN, Calculate the total pounds.

$$ppd = (\text{mg/L})(\underset{\uparrow}{\text{MGD}})(8.34)$$

uh oh, my flow rate is in gpm. Convert.

$$\frac{200\text{ gallons}}{\text{minute}}\left|\frac{60\text{ minutes}}{1\text{ hour}}\right|\frac{24\text{ hours}}{1\text{ day}}\left|\frac{1\text{ MG}}{10^6\text{ gallons}}\right| = 0.288\text{ MGD}$$

$$ppd = (2.5\text{ mg/L})(0.288\text{ MGD})(8.34)$$
$$ppd = 6.0$$

Chemical Dosing and Contaminant Removal

75. A chemical feed pump has been rebuilt and must be calibrated for maximum pump rate. If it takes 1 hour and 15 minutes to fill a 10-ft X 5-ft X 10-ft rectangular tank, what is the maximum pump rate in gal/min?

a) 67 gal/min
b) 50 gal/min
c) 45 gal/min
d) 38 gal/min

Operations Forum March 1998

76. A test on a water supply showed a hardness of 232 mg/L. A certain dosage of polyphosphates will theoretically reduce this hardness by 21 percent. What should the water hardness be after treatment?

a) 49 mg/L
b) 211 mg/L
c) 183 mg/L
d) 174 mg/L

77. A water company uses an average of 600 gpm. The water contains 0.30 mg/L of manganese and 0.06 mg/L of iron. How many pounds of iron and manganese combined are pumped into the distribution system in a year?

a) 950 pounds
b) 2.52 pounds
c) 789 pounds
d) 400 pounds

78. After calibrating a chemical feed pump in your plant you have determined that its maximum feed rate is 178 mL/min. If this pump ran continuously at this rate how many gallons would it pump in 1 full day ?

a) 10.7 gallons
b) 25.6 gallons
c) 256 Gal
d) 67.7 gallons
e) 17.8 gallons

79. Your chemical supplier charges you $1.28 / gallon of caustic soda. You have determined you will need approximately 60.1 (55 Gal) drums per year, what would be your annual budget cost for this item ?

a) $14,932.00
b) $8,833.29
c) $3,305.50
d) $4,231.04
e) $6,819.71

80. Your water plant feeds 25% caustic soda (containing 2.67 lbs.dry/gallon) for final pH adjustment. Historic records show your average dose is 6.5 mg/L and average flow is 310 GPM. At this rate how many 55 gallon drums will you use in 1 year?

a) 24.2 drums
b) 60.1 drums
c) 88.3 drums
d) 120 drums
e) 33.1 drums

81. An iron removal plant treats water with an average iron concentration of 3 ppm. If the process removes 90% of the iron and the daily pumpage is 1.5 million gallons, how many pounds of iron are removed per week? Assume 7 day operation.

a) 236 pounds per week
b) 3.75 pounds per week
c) 263 pounds per week
d) 27 pounds per week

82. How many pounds of copper sulfate will be needed to dose a reservoir with 0.6 mg/L copper? The reservoir volume is 30 million gallons. The copper sulfate is 25 percent copper. Select the closest answer.

a) 335 pounds
b) 400 pounds
c) 500 pounds
d) 600 pounds
e) 725 pounds

83. Determine the setting on a dry alum feeder in pounds per day when the flow is 1.2 mgd. Jar tests indicate that the best alum dose is 9 mg/L.

- a) 70 lbs/day
- b) 75 lbs/day
- c) 90 lbs/day
- d) 100 lbs/day
- e) 130 lbs/day

84. The average daily flow for a water treatment plant is 0.95 mgd. Jar tests indicate that the best polymer dosage is 2.2 mg/L. How many pounds of polymer will be used in 30 days?

- a) 260 lbs
- b) 340 lbs
- c) 523 lbs
- d) 412 lbs
- e) 437 lbs

85. A water treatment plant used 24 pounds of cationic polymer to treat 1.4 million gallons of water during a 24-hour period. What was the polymer dosage in mg/L?
5 mg/L

- a) '18 mg/L
- b) '2.0 mg/L
- c) '36 mg/L
- d) '48 mg/L

86. Liquid alum delivered to a water treatment plant contains 642.3 milligrams of aluminum per milliliter of liquid solution. Jar tests indicate that the best alum dose is 9 mg/L. Determine the setting on the liquid alum feeder in milliliters per minute when the plant flow is 3.2 mgd.

- a) 118 mL/min
- b) 72 mL/min
- c) 80 mL/min
- d) 90 mL/min
- e) 105 mL/min

87. A flow of 1.2 mgd will be treated with an 18-percent solution of hydrofluosilicic acid. The raw water does not contain any fluoride and the desired fluoride concentration is 1.4 mg/L. Assume that the hydrofluosilicic weighs 9.5 pounds per gallon and 79.2 percent of the solution is available fluoride. Calculate the hydrofluosilicic acid feed rate in gallons per day.

a) 5.8 gpd
b) 10.3 gpd
c) 11.6 gpd
d) 12.9 gpd
e) 14.5 gpd

88. A flow of 180 gpm will be treated with a 2.5 percent solution of sodium fluoride. The raw water contains 0.3 mg/L of fluoride ion and the desired fluoride ion concentration is 1.4 mg/L. Calculate the sodium fluoride feed rate in gallons per day. Assume the sodium floride contains 43.4 percent fluoride.

a) 26.3 gpd
b) 2.4 gpd
c) 3.3 gpd
d) 14 gpd
e) 23 gpd

89. The raw water alkalinity is 50 mg/L as calcium carbonate. The water is treated by adding 15 mg/L of alum. What is the alkalinity concentration of the finished water?

a) 35.0 mg/L
b) 57.5 mg/L
c) 65.0 mg/L
d) 42.5 mg/L

Note: Alum consumes 0.5 mg/L of alkalinity for every 1.0 mg/L of alum added.

Here's the table. A sample question might read:

A plant has a raw water TOC of 5 mg/L and an alkalinity of 95 mg/L. According to the Enhanced Coagulation technique how much TOC must be removed (percentage) from the water prior to final disinfection and what will the final TOC level be in mg/L?

Answer: must remove 35% and final TOC will be 3.25 mg/L.

(Enhanced Coagulation came out of the 1998 Stage I DBP Rule)

| | Source Water Alkalinity mg/L as CaCO3 | | |
|---|---|---|---|
| Source Water TOC, mg/L | 0-60 | >60 -120 | > 120 |
| > 2.0 - 4.0 | 35 | 25 | 15 |
| >4.0 - 8.0 | 45 | 35 | 25 |
| > 8.0 | 50 | 40 | 30 |
| Source: Water Quality and Treatment, AWWA, 1999 | | | |

75. $\text{Volume} = (l)(w)(d)$

$V = (10')(5')(10')$

$V = 500\ \text{ft}^3$

$$\frac{500\ \text{ft}^3}{} \left| \frac{7.48\ \text{gallons}}{1\ \text{ft}^3} \right| = 3740\ \text{gallons}$$

$$Q = \frac{V}{t}$$

$$Q = \frac{3740\ \text{gallon}}{60+15\ \text{minutes}}$$

$$Q = \frac{3740\ \text{gallons}}{75\ \text{minutes}}$$

$$Q = 49.9\ \text{gpm}$$

76. $(232\ \text{mg/L})(100-21\%) = \text{new hardness}$

$(232\ \text{mg/L})(79\%) =$ $\quad\downarrow$

$(232\ \text{mg/L})(0.79) =$

$183\ \text{mg/L} =$

77. $$\frac{600\ \text{gallons}}{\text{min}} \left| \frac{1\ \text{MG}}{1000000\ \text{gallons}} \right| \frac{1440\ \text{min}}{1\ \text{day}} \right| = 0.864\ \text{mgd}$$

$ppd = (0.864\ \text{mgd})(0.30 + 0.06\ \text{mg/L})(8.34)$

$ppd = 2.594$

$ppy = (ppd)(365)$

$ppy = (2.594)(365)$

$ppy = 947$

78. $$\begin{array}{c|c|c|c|}\text{178 mL} & \text{1 L} & \text{1 gallon} & \text{1440 min} \\ \hline \text{min} & \text{1000 mL} & \text{3.785 L} & \text{1 day}\end{array} = \text{67.7 gallons}$$

79. $$\begin{array}{c|c|c|}\text{60.1 }\overset{55}{\text{gallon}}\text{drums} & \text{55 gallons} & \text{\$1.28} \\ \hline & \text{1 drum} & \text{1 gallon}\end{array} = \text{\$4,231.04}$$

80. find the total pounds per day. Then use unit conversions to find the number of drums.

$$\begin{array}{c|c|c|}\text{310 gallons} & \text{1440 min} & \text{1 MG} \\ \hline \text{minute} & \text{1 day} & \text{1000000 gallons}\end{array} = \text{0.4464 mgd}$$

ppd = (mg/L)(Q)(8.34)
ppd = (0.4464 mgd)(6.5 mg/L)(8.34)
ppd = 24.2

$$\begin{array}{c|c|c|c|}\text{24.2 pounds} & \text{365 days} & \text{1 gallon} & \text{1 drum} \\ \hline \text{day} & \text{1 year} & \text{2.67 lbs} & \text{55 gallons}\end{array} = \text{60.1 drums}$$

81. ppd = (mg/L)(Q)(8.34)
ppd = (3 mg/L)(0.90)(1.5 mgd)(8.34)
ppd = 33.8

$$\begin{array}{c|c|}\text{33.8 pounds} & \text{7 days} \\ \hline \text{day} & \text{1 week}\end{array} = \text{236 ppw}$$

82. ppd = (mg/L)(Q)(8.34)
ppd Cu = (0.6 mg/L)(30 mg)(8.34)
ppd Cu = 150.12

$$150.12 \text{ lbs Cu} \left| \frac{1 \text{ lb } CuSO_4}{0.25 \text{ lbs Cu}} \right| = 600 \text{ pounds}$$

83. ppd = (mg/L)(Q)(8.34)
ppd = (9 mg/L)(1.2 mgd)(8.34)
ppd = 90

84. ppd = (mg/L)(Q)(8.34)
ppd = (2.2 mg/L)(0.95 mgd)(8.34)
ppd = 17.4

$$\left(\frac{17.4 \text{ lbs}}{\text{day}}\right)\left(30 \text{ days}\right) = 523 \text{ lbs}$$

85. ppd = (mg/L)(Q)(8.34)
24 ppd = (mg/L)(1.4 mgd)(8.34)
2.0 = mg/L

86. We can use the dilution equation to solve this problem, but first we need common units

$$\frac{3.2\ \text{MG}}{\text{day}} \Big| \frac{1\ \text{day}}{1440\ \text{min}} \Big| \frac{1000000\ \text{gal}}{1\ \text{MG}} \Big| \frac{3.785\ \text{L}}{1\ \text{gal}} \Big| \frac{1000\ \text{mL}}{1\ \text{L}} \Big| = 8411111\ \frac{\text{mL}}{\text{min}}$$

$$C_1 V_1 = C_2 V_2$$

$$(642.3\ \text{mg/mL})(V_1) = (9\ \text{mg/L})(8411111\ \text{mL/min})$$

$$\uparrow\ \frac{\text{mg}}{\text{mL}} = \frac{\text{grams}}{\text{Liter}}$$

$$(642300\ \text{mg/L})(V_1) = (9\ \text{mg/L})(8411111\ \text{mL/min})$$

$$V_1 = 118\ \text{mL/min}$$

87. Begin by finding the dose of fluoride needed in ppd.

$$\text{ppd} = (\text{mg/L})(Q)(8.34)$$

$$\text{ppd} = (1.4\ \text{mg/L})(1.2\ \text{mgd})(8.34)$$

$$\text{ppd} = 14.0$$

Then, find the feed rate of hydrofluosilicic acid using the same equation

$$\text{ppd} = (\text{mg/L})(Q)(\overset{9.5}{\cancel{8.34}}) \leftarrow \text{the new density given to us}$$

$$14.0 = (79.2\%)(10{,}000)(Q)(9.5)(0.18)$$

$$Q = 0.0000103\ \text{mgd}$$

$$Q = 10.3\ \text{gpd}$$

88. $\frac{180\text{ gallons}}{\text{minute}}\Big|\frac{1\text{ MG}}{1000000\text{ gallons}}\Big|\frac{1440\text{ min}}{1\text{ day}}\Big| = 0.2592\text{ mgd}$

ppd = (mg/L)(Q)(8.34)
ppd = (1.4 − 0.3 mg/L)(0.2592 mgd)(8.34)
ppd = 2.38

ppd = (mg/L)(Q)(8.34)
2.38 ppd = (2.5%)(10,000)(0.434)(Q)(8.34)
Q = 0.0000263 mgd
Q = 26.3 gpd

89. $15\text{ mg/L Alum}\Big|\frac{0.5\text{ mg Alk}}{1\text{ mg Alum}}\Big| = 7.5\text{ mg/L Alkalinity Used}$

$$\begin{array}{r} 50\text{ mg/L} \\ -7.5\text{ mg/L} \\ \hline 42.5\text{ mg/L alkalinity remaining} \end{array}$$

# Sidney's Big Book of Water and Wastewater Math

INDIGO WATER GROUP

## Unit Conversions to Know by Heart

1 inch = 2.54 centimeters
1 meter = 3.28 feet
1 mile = 5280 feet

1 acre = 43,560 $ft^2$
1 $m^2$ = 10.76 $ft^2$

1 gallon = 3.785 liters
1 $ft^3$ = 7.48 gallons
1 $m^3$ = 35.31 $ft^3$

1 ft water = 0.433 psi

1 gallon = 8.34 lbs when specific gravity is 1.0
1 kg = 2.2 lbs

1% = 10,000 mg/L
1 mg/L = 1 ppm
1 µg/L = 1 ppb

1 day = 1440 minutes
1 hp = 0.746 kW

1 gram = 15.43 grains
1 grain per gallon = 17.1 mg/L

## Water Formulas

pounds per day = (concentration in mg/L)*(flow rate in mgd)*(8.34)

chlorine dose = demand + residual

$$\text{velocity} = \frac{\text{flow}}{\text{area}} \qquad V = \frac{Q}{A}$$

$$\text{flow rate} = \frac{\text{volume}}{\text{time}} \qquad Q = \frac{V}{t}$$

$$\text{overflow rate} = \frac{\text{flow rate}}{\text{area}}$$

$$\text{weir loading rate} = \frac{\text{flow rate}}{\text{feet of weir}}$$

(concentration 1)*(volume 1) = (concentration 2)*(volume 2) $C_1V_1 = C_2V_2$

(conc. 1)*(volume 1) + (conc. 2)*(volume 2) = (conc. 3)*(volume 3)

$$C_1V_1 + C_2V_2 = C_3V_3$$

$$\text{horsepower} = \frac{(\text{flow in gpm})*(\text{lift in feet})}{3960}$$

# Activated Sludge

## F:M, MCRT, SRT, Space Loading, and more!

**Activated Sludge Problems**

Q = 20 MGD
BOD5 = 250 mg/L
NH3-N = 30 mg/L

Effluent TSS is negligible

A-basin = 6 MG
MLSS = 3000 mg/L
Clarifier = 2 MG
Core SS = 600 mg/L
WAS = 7500 mg/L
WAS = 110 gpm

1. Calculate the hydraulic retention time of the aeration basin. Then, calculate the hydraulic retention time of the clarifier. Express your answers in hours.

2. Calculate the Space Loading to the Aeration Basins:

3. Calculate the F:M.

4. Calculate the SRT and the MCRT for this system. How much do they differ?

5. Calculate the total oxygen (not air) demand on the system in one day. Use a value of 1.2 lbs of oxygen per pound of BOD and 4.33 lbs of oxygen per pound of ammonia.

6. If my target MCRT is 10 days, what should my wasting rate be adjusted to? Up or down?

7. 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 in the other three basins, what is the new food to microorganism ratio?

8. Iif each of the aeration basins is 16 feet deep and 33 feet wide, how long is each basin? Round to the nearest whole foot.

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

Express your result in gpd/sft.

1. $Q = \frac{V}{t}$

$20\text{ MGD} = \frac{6\text{ MG}}{t}$

$(20\text{ MGD})(t) = 6\text{ MG}$

$t = 0.30\text{ days}$

$0.30\text{ days}\left|\frac{24\text{ hours}}{1\text{ day}}\right| = 7.2\text{ hours}$

∴ HRT for aeration basins is 7.2 hours

$Q = \frac{V}{t}$

$20\text{ MGD} = \frac{2\text{ MG}}{\text{time}}$

$(20\text{ MGD})(t) = 2\text{ MG}$

$t = 0.10\text{ days}$

$0.10\text{ days}\left|\frac{24\text{ hours}}{1\text{ day}}\right| = 2.4\text{ hours}$

∴ HRT for the clarifiers is 2.4 hours.

2. $\text{Space Loading} = \frac{\text{lbs BOD}_5}{1000\text{ cuft a-basin}}$

First, I need to know the volume of the aeration basins in cuft. Convert.

$6\text{ MG}\left|\frac{1000000\text{ gallon}}{1\text{ MG}}\right|\frac{1\text{ cuft}}{7.48\text{ gallons}}\right| = 802139\text{ cuft}$

Divide by 1000 to get $802.139 \cdot 1000\text{ cuft}$

$$\text{Space Loading} = \frac{\text{lbs of BOD}}{1000 \text{ cuft basin}}$$

$$\text{Space Loading} = \frac{(250^{\text{mg/L}})(20 \text{ MGD})(8.34)}{802.139 \cdot 1000 \text{ cuft}}$$

$$\text{Space Loading} = \frac{41700}{802.139}$$

$$\text{Space Loading} = 51.99 \text{ lbs}/1000 \text{ cuft}$$

3. $$\frac{F}{m} = \frac{\text{lbs BOD}_5}{\text{lbs MLSS}}$$

$$\frac{F}{m} = \frac{(250^{\text{mg/L}})(20 \text{ MGD})(8.34)}{(3000^{\text{mg/L}})(6 \text{ MGD})(8.34)}$$

$$\frac{F}{m} = \frac{41700}{1050120}$$

$$\frac{F}{m} = 0.28$$

4. $$\text{SRT} = \frac{\text{lbs of MLSS in aeration basin}}{\text{lbs wasted}}$$

$$\text{SRT} = \frac{(3000^{\text{mg/L}})(6 \text{ MGD})(8.34)}{(7500^{\text{mg/L}})(110 \text{ gpm})(8.34)}$$

Uh oh! My units don't match. I need to convert.

$$\frac{110 \text{ gallons}}{\text{minute}} \left| \frac{60 \text{ minutes}}{1 \text{ hour}} \right| \frac{24 \text{ hours}}{1 \text{ day}} \left| \frac{1 \text{ MG}}{1000000 \text{ gallons}} \right| \frac{\text{MG}}{\text{day}}$$

= 0.1584 MGD

$$SRT = \frac{(3000 \text{ mg/L})(6 \text{ MGD})(8.34)}{(7500 \text{ mg/L})(0.1584 \text{ MGD})(8.34)}$$

SRT = 15.15 days

Good! How about MCRT?

$$MCRT = \frac{(\text{lbs MLSS in basin}) + (\text{lbs MLSS in clarifier})}{\text{lbs wasted}}$$

$$MCRT = \frac{(3000 \text{ mg/L})(6 \text{ MGD})(8.34) + (600 \text{ mg/L})(2 \text{ MGD})(8.34)}{(7500 \text{ mg/L})(0.1584 \text{ MGD})(8.34)}$$

$$MCRT = \frac{150120 + 10008}{9908}$$

MCRT = 16.16 days

BIG BLANKETS MEAN
BIGGER DIFFERENCES
BETWEEN SRT AND
MCRT.

5. FIRST, Find pounds of BOD and ammonia coming into the plant.

ppd BOD = (250 mg/L)(20 MGD)(8.34)
ppd BOD = 41700

ppd $NH_3$-N = (30 mg/L)(20 MGD)(8.34)
ppd $NH_3$-N = 5004

THEN, calculate pounds of oxygen needed for each.

$$41700 \text{ pounds BOD} \left| \frac{1.2 \text{ pounds}}{1 \text{ pound BOD}} \right| = 50040 \text{ lbs oxygen}$$

$$5004 \text{ pounds } NH_3 \left| \frac{4.33 \text{ pounds } O_2}{1 \text{ pound } NH_3} \right| = 21667 \text{ lbs oxygen}$$

TOTAL OXYGEN DEMAND = 50040 + 21667
= 71707 ppd

6. $$MCRT = \frac{\text{lbs MLSS total}}{\text{lbs wasted}}$$

$$10 \text{ days} = \frac{(3000 \text{ mg/L})(6 \text{ mgD})(8.34) + (600 \text{ mg/L})(2 \text{ mGD})(8.34)}{\text{lbs wasted}}$$

$$10 \text{ days} = \frac{150120 + 10008}{\text{lbs wasted}}$$

$$10 \text{ days} = \frac{160128 \text{ lbs}}{\text{lbs wasted}}$$

$$\frac{\text{lbs wasted}}{\text{day}} = 16012.8$$

To convert this to a pumping rate, use the same ppd formula.

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

$$16012.8 \text{ ppd} = (7500 \text{ mg/L})(\text{MGD})(8.34)$$

$$0.256 \text{ MGD} = \text{flow rate}$$

$$\frac{0.256 \text{ mg}}{\text{day}} \Big| \frac{1 \text{ day}}{24 \text{ hrs}} \Big| \frac{1 \text{ hr}}{60 \text{ min}} \Big| \frac{1000000 \text{ gal}}{1 \text{ mg}} \Big| = 178 \frac{\text{gallons}}{\text{min}}$$

7. $\frac{6 \text{ mg}}{4 \text{ basins}} = \frac{1.5 \text{ mg}}{\text{basin}}$

$$\frac{F}{m} = \frac{(250^{\text{mg/L}})(20 \text{ mgD})(8.34)}{(3 \text{ basins})(1.5 \text{ mg/basin})(3000^{\text{mg/L}})(8.34)}$$

$$\frac{F}{m} = \frac{41700 \text{ ppd}}{112590 \text{ ppd}}$$

$$\frac{F}{m} = 0.37$$

8. Basin dimensions are
16 deep
33 wide
? length

Each basin holds 1.5 mg. Convert to $ft^3$

$$1.5 \text{ mg} \left| \frac{1000000 \text{ gal}}{1 \text{ mg}} \right| \frac{1 \text{ ft}^3}{7.48 \text{ gal}} \Big| = 200535 \text{ ft}^3$$

Volume = length × width × depth

$200535 \text{ ft}^3 = (\text{length})(33 \text{ ft})(16 \text{ ft})$

$380 \text{ ft} = \text{length}$

9. The surface overflow rate is defined as the amount of flow moving through the area of the clarifier.

The first step is to find the total surface area of both clarifiers.

$$A = \pi r^2$$
$$A = (3.1415)(75/2)(75/2)$$
$$A = (3.1415)(37.5)(37.5)$$
$$A = 4417.7 \text{ ft}^2$$

There are 2 clarifiers, so the total available surface area is 8835.5 ft²

Next, convert influent flow from MGD to gpm.

$$\frac{20 \text{ mg}}{\text{day}} \Big| \frac{1000000 \text{ gal}}{1 \text{ MG}} \Big| \frac{1 \text{ day}}{24 \text{ hrs}} \Big| \frac{1 \text{ hr}}{60 \text{ min}} \Big| = 13889 \text{ gpm}$$

$$\text{SOR} = \frac{13889 \text{ gpm}}{4417.7 \text{ ft}^2}$$
$$\text{SOR} = 3.14 \text{ gpm}/\text{ft}^2$$

## ACTIVATED SLUDGE – F:M, SRT, and MCRT

1. A plant ran blowers for 24 hrs/day at 5000 cu.ft/min. How many cu.ft/min of air were required to remove a pound of BOD per day if the activated sludge system removed 6000 lbs/day?

a) 595
b) 660
c) 1100
d) 1200

2. Calculate the F:M ratio. Influent flow volume is 1 MG, Average BOD to aeration tank = 140mg/L, Aeration tank capacity = 250,000 gal, MLSS concentration = 2000 mg/L

a) 0.25
b) 0.28
c) 0.30
d) 0.32

3. 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? Round to nearest unit.

a) 6000 lbs
b) 7005 lbs
c) 4008 lbs
d) 3503 lbs

4. How many lbs. of solids are in a 400,000 gallon aeration tank if the suspended solids concentration is 1200 mg/l?

a) 3000
b) 4000
c) 4400
d) 4800
e) 5200

5. What is the MLSS concentration in an activated sludge plant that has a 1 MG aeration basin and carries 16000 lbs of solids in the aeration basin?

a) 1800
b) 1760
c) 1860
d) 1920

6. Given the following, what is the F/M ratio of this activated sludge process? Tank dimensions are 80 ft long x 20 ft wide x 12 ft deep. Average flow rate is 300 gpm. Plant influent BOD is 180 mg/l. Primary effluent BOD is 150 mg/l. MLSS is 1350 mg/l.
a) 0.15
b) 0.33
c) 0.21
d) 0.40

7. If the influent flow to the aeration basin is 5 MGD with a BOD concentration of 200 mg/L, how much sludge will need to be wasted if the yield is 0.7 lb/lb?
a) 5840 lbs
b) 5480 lbs
c) 5237 lbs
d) 4088 lbs

8. Consider a conventional activated sludge treatment process with a desired F:M ratio of 0.8. If the plant flow is 5 mgd and BOD of the primary effluent is 150 mg/l, how many pounds of mixed liquor volatile suspended solids should be maintained in the aerator?
a) 7819 lb
b) 5402 lb
c) 10,465 lb
d) 89587 lb
?Operations Forum October 1998

9. In an aeration tank, the MLSS is 2500 mg/l, and the recorded 30-minute settling test indicates 230 ml. What is the sludge volume index (SVI)?
a) 65
b) 83
c) 92
d) 101
?Operations Forum October 1998

JOB ______ JOB NO. 67
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1. FIRST, FIND THE lbs OF BOD REMOVED PER MINUTE

$$\frac{6000\ \text{lbs BOD}}{\text{DAY}}\bigg|\frac{1\ \text{DAY}}{1440\ \text{min}}\bigg| = 4.17\ \text{lbs/min BOD}$$

$$\frac{5{,}000\ \text{cuft}}{\text{min}}\bigg|\frac{1\ \text{min}}{4.17\ \text{lbs BOD}}\bigg| = 1199\ \text{Cfm/lb BOD}$$

2. $$\frac{F}{m} = \frac{\text{lbs BOD}}{\text{lbs MLVSS}}$$

BOD
$\text{lbs} = (\text{mg/L})(Q, \text{mgd})(8.34)$
$\text{lbs} = (140\ \text{mg/L})(1\ \text{mgd})(8.34)$
$\text{lbs} = 1167.6$

MLVSS
$\text{lbs} = (\text{mg/L})(Q, \text{mgd})(8.34)$
$\text{lbs} = (2000\ \text{mg/L})(0.25\ \text{mgd})(8.34)$
$\text{lbs} = 4170$

$$\frac{F}{m} = \frac{1167.6\ \text{lbs BOD}}{4170\ \text{lbs MLSS}}$$

$$\frac{F}{M} = 0.28$$

NOTE: Since VSS was not available, the total MLSS was used

Typical Ranges of F:M

| | |
|---|---|
| Extended aeration | 0.05 - 0.10 |
| Conventional | 0.2 - 0.4 |
| High Rate | >1.0 |

JOB

JOB NO. 68

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3. If the primary clarifiers are removing 30% of the influent BOD, then the food going to the aeration basin is

$$(240\ \text{mg/L})(0,70) = 168\ \text{mg/L}$$

$$\begin{aligned}\text{lbs BOD} &= (\text{mg/L})(Q,\text{mgd})(8.34)\\ &= (168\ \text{mg/L})(2\ \text{mgd})(8.34)\\ &= 2802.24\end{aligned}$$

$$\frac{F}{m} = \frac{\text{lbs BOD}}{\text{lbs MLVSS}}$$

$$0.4 = \frac{2802.24\ \text{lbs BOD}}{\text{lbs MLVSS}}$$

$$(0.4)(\text{lbs MLVSS}) = 2802.24\ \text{lbs BOD}$$

$$\text{lbs MLVSS} = 7005.6$$

4.

$$\begin{aligned}\text{lbs} &= (\text{mg/L})(Q,\text{mgd})(8.34)\\ \text{lbs} &= (1200\ \text{mg/L})(0.4\ \text{mg})(8.34)\\ \text{lbs} &= 4003.2\end{aligned}$$

5.

$$\begin{aligned}\text{lbs} &= (\text{mg/L})(Q,\text{mgd})(8.34)\\ 16{,}000\ \text{lbs} &= (\text{mg/L})(1\ \text{mg})(8.34)\\ 1918 &= \text{mg/L}\end{aligned}$$

JOB ____ JOB NO. 69
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6. First, find lbs of BOD

$$\frac{300\text{ gal}}{\text{min}}\Big|\frac{1440\text{ min}}{1\text{ day}}\Big|\frac{1\text{ mG}}{10^6\text{ gal}}\Big| = 0.432\ \frac{\text{mG}}{\text{day}}$$

$$\text{lbs BOD} = (\text{mg/L})(Q,\text{mgd})(8.34)$$
$$= (150\text{ mg/L})(0.432\text{ mgd})(8.34)$$
$$= 540.4$$

Then, find lbs of MLSS

Volume = length * width * height
= (80 ft)(20 ft)(12 ft)
= 19200 ft$^3$

$$19200\text{ ft}^3\Big|\frac{7.48\text{ gallons}}{1\text{ ft}^3}\Big|\frac{1\text{ MG}}{10^6\text{ gallons}}\Big| = 0.144\text{ mG}$$

$$\text{lbs MLSS} = (\text{mg/L})(Q,\text{mgd})(8.34)$$
$$= (1350\text{ mg/L})(0.144\text{ mgd})(8.34)$$
$$= 1621.3$$

$$\frac{F}{m} = \frac{\text{lbs BOD}}{\text{lbs MLSS}}$$
$$\frac{F}{m} = \frac{540.4\text{ lbs BOD}}{1621.3\text{ lbs MLSS}}$$
$$\frac{F}{m} = 0.33$$

7. $$\text{lbs BOD} = (\text{mg/L})(Q,\text{mgd})(8.34)$$
$$= (200\text{ mg/L})(5\text{ mgd})(8.34)$$
$$= 8340$$

if the yeild is 0.7 lbs MLSS for every lb BOD,
then (8340 lbs BOD)(0.7) = 5838 lbs MLSS to waste

JOB ______ JOB NO. 70

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8. $\text{lbs BOD} = (\text{mg/L})(Q,\ \text{mgd})(8.34)$

$= (150\ \text{mg/L})(5\ \text{mgd})(8.34)$

$= 6255$

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

$$0.8 = \frac{6255\ \text{lbs BOD}}{\text{lbs MLSS}}$$

$(0.8)(\text{lbs MLSS}) = 6255\ \text{lbs BOD}$

$\text{lbs MLSS} = 7818.75$

9. $$\text{SVI} = \frac{(\text{SSV at 30 min, mL})(1000)}{(\text{MLSS, mg/L})}$$

$$\text{SVI} = \frac{(230\ \text{mL})(1000)}{2500\ \text{mg/L}}$$

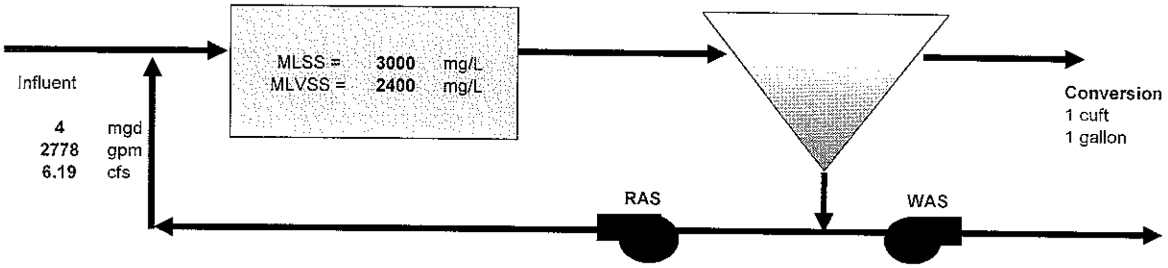
$\text{SVI} = 92\ \text{mL/g}$

*SSV = Settled sludge volume

SVI of 70-150 mL/g NORMAL

SVI > 200 is BULKING SLUDGE

Numbers in **RED** can be changed. Numbers in **BLUE** are calculated by the spreadsheet.



**Conversion Factors**

| | | |
|---|---|---|
| 1 cuft | = | 7.48 g |
| 1 gallon | = | 8.34 lt |

| **Aeration Basin Characteristics** | | |
|---|---|---|
| Length | 150 | ft |
| Width | 50 | ft |
| Depth | 12 | ft |
| # Basins | 2 | each |
| MLSS | 3000 | mg/L |
| MLVSS | 2400 | mg/L |
| Volume | 180000 | ft3 |
| | 1346400 | gallons |
| | 1.35 | mg |
| HRT | 8.1 | hours |

| **Secondary Clarifier Characteristics** | | |
|---|---|---|
| Diameter | 65 | ft |
| Depth | 12 | ft |
| # Clarifiers | 2 | |
| CCC* | 1200 | mg/L |
| *Clarifier core concentration of TSS | | |
| Volume | 79639 | ft3 |
| | 595703 | gallons |
| | 0.60 | mg |
| HRT | 3.57 | hours |

| **WAS Characteristics** | | |
|---|---|---|
| TSS | 6500 | mg/L |
| Flow | 0.05 | mgd |
| | 34.72 | gpm |

| **Effluent Characteristics** | | |
|---|---|---|
| TSS | 12 | mg/L |

| | | |
|---|---|---|
| Aeration Basin | 33687 | lbs |
| Clarifier | 5962 | lbs |
| WAS | 2711 | lbs |
| Effluent | 400 | lbs |
| SRT | 10.8 | days |
| MCRT | 12.7 | days |

$$pounds = (mg/L)(million\_gallons)(8.34)$$

$$MCRT = \frac{(Lbs\_MLSS\_AerationBa\sin) + (Lbs\_MLSS\_Clarifier)}{(Lbs\_WAS) + (Lbs\_TSS\_Effluent)}$$

***NOTE: SRT does not take the solids in the clarifier into account.**

Problem ~~One~~: #10

A WWTP has 2 aeration basins on-line. The combined volume of all basins is 180000 cuft. If the MLSS concentration is 3000 mg/L, how many pounds of MLSS are in the aeration basin?

Answer: lbs Convert cuft to million gallons. Then calculate pounds.

Problem ~~Two~~: #11

A WWTP has 33686.928 pounds of MLSS under aeration. There are 2 clarifiers on-line. Each one is 65 feet in diameter and 12 feet deep. A core sample taken with a sludge judge contains 1200 mg/L of TSS. Assuming a WAS concentration of 6500 mg/L at a flow rate of 34.7222222222222 gpm, what is the SRT or solids retention time?

Answer: ____ days Note: even though clarifier data is given, the problem is asking for SRT, not MCRT.

Problem ~~Three~~: #12

For the wastewater treatment plant described in problem two, where should the wasting rate be set if the target MCRT is 15 days? Express your answer as gpm. MLSS = 3000 mg/L.

Answer: lbs per day to waste
gpm

$$MCRT = \frac{(\text{Lbs Aeration + Lbs Clarifier})}{(\text{Lbs WAS + Lbs Effluent})}$$

Problem ~~Four~~: #13

A WWTP has 2 aeration basins on-line. Each basin is 150 feet long by 50 feet wide by 12 feet deep. The MLSS concentration is 3000 mg/L. The waste pump operates at 34.7222222222222 gpm for 15 minutes out of every hour. If the WAS concentration is 6500 mg/L, what is the SRT?

Answer: ____ days Note: The pump runs for 15 minutes or 1/4 of the total time per hour.

Problem ~~Five~~: #14

For the WWTP described in problem ~~two~~ 12, what percentage of the solids inventory is in the secondary clarifiers?

Answer:

JOB ______ JOB NO. 92
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10. $$180{,}000\ \text{cuft}\ \Big|\ \frac{7.48\ \text{gal}}{1\ \text{cuft}}\ \Big|\ \frac{1\ \text{mg}}{10^6\ \text{gal}}\ \Big| = 1.3464\ \text{mg}$$

$\text{lbs} = (\text{mg/L})(Q, \text{mgd})(8.34)$
$\text{lbs} = (3000\ \text{mg/L})(1.3464\ \text{mgd})(8.34)$
$\text{lbs} = 33687$

11. $$\text{SRT} = \frac{\text{lbs in A-basin}}{\text{lbs WAS} + \text{lbs EFF}}$$

SRT = Solids Retention Time

$$\frac{34.72\ \text{gal WAS}}{\text{min}}\ \Big|\ \frac{1440\ \text{min}}{1\ \text{day}}\ \Big|\ \frac{1\ \text{mg}}{10^6\ \text{gal}}\ \Big| = 0.05\ \text{mg}$$

$\text{lbs WAS} = (\text{mg/L})(Q, \text{mgd})(8.34)$
$= (6500\ \text{mg/L})(0.05\ \text{mgd})(8.34)$
$= 2710.5$

$$\text{SRT} = \frac{\text{lbs in A-basin}}{\text{lbs WAS} + \text{lbs EFF}}$$

assumed to be zero since no info. given

$$\text{SRT} = \frac{33686.9\ \text{lbs MLSS}}{2710.5\ \text{lbs WAS}}$$

$\text{SRT} = 12.4$ days

12. $$\text{MCRT} = \frac{\text{lbs A-basin} + \text{lbs clarifier}}{\text{lbs WAS} + \text{lbs effluent}}$$

know these

this is zero

Set at 15 days

The only thing I don't know is lbs of MLSS in the clarifier.

JOB ______ JOB NO. 93

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12. cont.

2 clarifiers

$V = \pi r^2 h$

$V = (3.14)(32.5\ ft)(32.5\ ft)(12\ ft)$

$V = 39799.5\ ft^3$

↑ multiply by 2 for total volume

$V = 79599\ ft^3$

$$79599\ ft^3 \Big| \frac{7.48\ gal}{1\ ft^3} \Big| \frac{1\ MG}{10^6\ gal} \Big| = 0.5954\ MG$$

$$lbs\ in\ Clarifier = (mg/L)(Q, mgd)(8.34)$$

$$= (1200\ mg/L)(0.5954\ mg)(8.34)$$

$$= 4958$$

$$MCRT = \frac{lbs\ A\cdot basin + lbs\ Clarifier}{lbs\ WAS + lbs\ EFF}$$

$$15\ days = \frac{33686.9\ lbs + 4958\ lbs}{lbs\ WAS + 0}$$

$$15 = \frac{38644.9}{lbs\ WAS}$$

$$(15)(lbs\ WAS) = 38644.9$$

$$lbs\ WAS = 2576.3$$

← last step is to calculate gpm from lbs

$$lbs\ WAS = (mg/L)(Q, mgd)(8.34)$$

$$2576.3 = (3000\ mg/L)(Q, mgd)(8.34)$$

$$0.1029 = Q, mgd$$

$$\frac{0.1029\ MG}{day} \Big| \frac{10^6\ gallons}{1\ MG} \Big| \frac{1\ day}{1440\ min} \Big| = 71.5\ gpm$$

JOB ______ JOB NO. 94

SHEET NO. ______ OF ______

CALCULATED BY ______ DATE ______

CHECKED BY ______ DATE ______

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13. Volume = length × width × depth

$V = (150\text{ ft})(50\text{ ft})(12\text{ ft})$

$V = 90{,}000\text{ ft}^3$ for one basin, so $180{,}000\text{ ft}^3$ for 2 basins

$$180{,}000\text{ ft}^3 \left|\frac{7.48\text{ gal}}{1\text{ ft}^3}\right|\frac{1\text{ MG}}{1{,}000{,}000\text{ gal}}\right| = 1.35\text{ mg}$$

lbs MLSS = (mg/L)(Q, mgd)(8.34)

lbs MLSS = (3000 mg/L)(1.35 mg)(8.34)

lbs MLSS = 33777

$$\frac{34.72\text{ gal}}{\text{min}}\left|\frac{15\text{ min}}{\text{hour}}\right|\frac{24\text{ hours}}{1\text{ day}}\left|\frac{1\text{ day}}{10^6\text{ gal}}\right| = 0.0125\ \frac{\text{Mgal}}{\text{day}}$$

lbs WAS = (mg/L)(Q, mgd)(8.34)

lbs WAS = (6500 mg/L)(0.0125 mgd)(8.34)

lbs WAS = 667.6

$$SRT = \frac{\text{lbs A. basin}}{\text{lbs WAS} + \text{lbs EFF}}$$

$$SRT = \frac{33777\text{ lbs MLSS}}{667.6\text{ lbs WAS} + 0}$$

SRT = 50.6 days

14. $$\%\ \text{CLARIFIER} = \frac{\text{CLARIFIER}}{\text{TOTAL}}$$

$$\%\ \text{CLARIFIER} = \frac{4958\text{ lbs}}{33686.9 + 4958}$$

% CLARIFIER = 0.128

OR

12.8%

# Sidney's Big Book of Water and Wastewater Math

INDIGO WATER GROUP

## Unit Conversions to Know by Heart

1 inch = 2.54 centimeters
1 meter = 3.28 feet
1 mile = 5280 feet

1 acre = 43,560 $ft^2$
1 $m^2$ = 10.76 $ft^2$

1 gallon = 3.785 liters
1 $ft^3$ = 7.48 gallons
1 $m^3$ = 35.31 $ft^3$

1 ft water = 0.433 psi

1 gallon = 8.34 lbs when specific gravity is 1.0
1 kg = 2.2 lbs

1% = 10,000 mg/L
1 mg/L = 1 ppm
1 $\mu$g/L = 1 ppb

1 day = 1440 minutes
1 hp = 0.746 kW

1 gram = 15.43 grains
1 grain per gallon = 17.1 mg/L

## Water Formulas

pounds per day = (concentration in mg/L)*(flow rate in mgd)*(8.34)

chlorine dose = demand + residual

velocity = $\frac{\text{flow}}{\text{area}}$ $\qquad$ $V = \frac{Q}{A}$

flow rate = $\frac{\text{volume}}{\text{time}}$ $\qquad$ $Q = \frac{V}{t}$

overflow rate = $\frac{\text{flow rate}}{\text{area}}$

weir loading rate = $\frac{\text{flow rate}}{\text{feet of weir}}$

(concentration 1)*(volume 1) = (concentration 2)*(volume 2) $\qquad$ $C_1V_1 = C_2V_2$

(conc. 1)*(volume 1) + (conc. 2)*(volume 2) = (conc. 3)*(volume 3)

$$C_1V_1 + C_2V_2 = C_3V_3$$

horsepower = $\frac{\text{(flow in gpm)*(lift in feet)}}{3960}$

# Solids Handling and Digestion

# PERCENT VSS REDUCTION

DIGESTION IS A RESIDUAL SOLIDS TREATMENT PROCESS THAT IS BASED ON THE PRINCIPAL THAT, WHEN THERE IS AN INADEQUATE SUPPLY OF FOOD (BOD) AVAILABLE, MICROORGANISMS WILL METABOLIZE OR EAT THEIR OWN CELLULAR MASS.

DIGESTION OF SOLIDS:

1) MAKES SLUDGE RELATIVELY INERT.
2) REDUCES ODORS.
3) REDUCES BACTERIA AND PATHOGENIC ORGANISMS.
4) REDUCES THE VOLUME AND WEIGHT OF SLUDGE.

BIOSOLIDS 503 REGULATION REQUIRES A 38% REDUCTION IN THE PERCENTAGE OF VOLATILE SUSPENDED SOLIDS.

CALCULATE AS:

$$\%VSS\ \text{REDUCTION} = \frac{(\%VSS_{IN} - \%VSS_{OUT})}{(\%VSS_{IN} - (\%VSS_{IN} * \%VSS_{OUT})} * 100$$

EXAMPLE:

WAS Conc = 8000 mg/L TSS
6400 mg/L TVSS

Digested solids = 12,000 mg/L TSS
8,040 mg/L TVSS

WHAT IS THE % VSS REDUCTION?

$$\% \text{ VSS} = \left[\frac{\text{TVSS}}{\text{TSS}}\right] * 100$$

$$\% \text{VSS}_{\text{WAS}} = \frac{6400 \ \text{mg/L}}{8000 \ \text{mg/L}} * 100$$

$$= 80\%$$

$$\% \text{ VSS}_{\text{OUT}} = \frac{8,040 \ \text{mg/L}}{12000 \ \text{mg/L}} * 100$$

$$= 67\%$$

$$\% \text{VSS REDUCTION} = \frac{(\% \text{VSS}_{\text{IN}} - \% \text{VSS}_{\text{OUT}})}{(\% \text{VSS}_{\text{IN}} - (\% \text{VSS}_{\text{IN}} * \% \text{VSS}_{\text{OUT}})} * 100$$

$$\% \text{VSS REDUCTION} = \frac{(0.80 - 0.67)}{(0.80 - (0.80 * 0.67))} * 100$$

$$= 49.2\%$$

## SOLIDS HANDLING

1. Feed solids to an anaerobic digester contain 80% volatile solids (VS) and the digested solids contain 50% VS. Compute the VS reduction.
   a) 23.1%
   b) 37.5%
   c) 40.0%
   d) 75.0%

?Operations Forum September 1997

2. How many lbs/day of suspended solids are removed by a primary clarifier given the following: Flow rate = 2.7 MGD, Influent TSS = 230 mg/l, Primary effluent TSS = 110 mg/l
   a) 3204 lbs/day
   b) 2702 lbs/day
   c) 2683 lbs/day

3. Determine the organic loading to an anaerobic digester given the following: Digester volume = 50,000 cubic feet, Feed sludge volume = 8000 lbs/day, %TS = 4.5%, %VS = 74%
   a) 0.05 lbs VS/cubic ft/day
   b) 0.11 lbs VS/cubic ft/day
   c) 0.08 lbs VS/cubic ft/day

4. If a sludge draw off of 8000 gallons contains 6% solids, how many lbs. were pumped?
   a) 2842 lbs.
   b) 2916 lbs.
   c) 4003 lbs.
   d) 16091 lbs.

5. Given the following, what is the digester detention time? Diameter = 80 ft Depth = 25 ft Sludge feed rate = 25000 gpd
   a) 37.6 days
   b) 47.8 days
   c) 25.2 days

6. The volume of a primary anaerobic digester is 40,000 cubic feet. The raw sludge feed rate is 6000 lbs dry sludge per day and the volatile solids content is 78%. What is the organic loading rate in lbs VS/cubic foot/day?
   a) 8.5
   b) 0.117
   c) 0.305
   d) 6.2

7. Given the following information, calculate the %VSS reduction in the digester.
Influent %VSS = 80% Effluent %VSS = 67%

a) 49%
b) 67%
c) 13%
d) 81%

8. Primary sludge containing 5% solids is pumped to a digester continuously at a rate of 25 gal/min. How many pounds of volatile solids are added to the digester each day if total solids are 73% volatile solids?

a) 1310 lb/d
b) 1800 lb/d
c) 9830 lb/d
d) 10,960 lb/d
e) 15,010 lb/d

?Operations Forum February 1999

9. If a gravity sludge thickener receives 20 gpm of primary sludge at a concentration of 3.0% total solids, and the thickener overflow solids concentration is 0.15% total solids, what is the solids removal efficiency?

a) 92
b) 93
c) 95
d) 97

?Operations Forum February 1997

10. How many pounds of solids are pumped to a digester each day if the digester receives a 10,000 gal/d load containing 5% total solids?

a) 1,668,000 lb/d
b) 5250 lb/d
c) 4170 lb/d
d) 864,000 lb/d

?Operations Forum November 1998

11. A jar test conducted on 1 liter of secondary sludge with 1.5% total solids requires 50 ml of a 0.10% solution of dry polymer for flocculation. Determine the polymer dosage in lb/ton of solids.

a) 5.5
b) 6.7
c) 7.6

?Operations Forum May 1998

12. What is the solids recovery rate of a belt filter press with the following operational data? Hours of operation = 10; solids filtered = 80,000 gal; solids content = 5%; cake solids = 22%; cake produced = 68 wet tons.
a) 20%
b) 63%
c) 82%
d) 90%
?Operations Forum May 1998

13. If solids have a cadmium concentration of 20 mg/kg dry weight, and the allowable biosolids land-spreading limit is 10 lb/ac of cadmium, what is the maximum application rate of biosolids in tons per acre?
a) 114 ton/ac
b) 187 ton/ac
c) 223 ton/ac
d) 250 ton/ac
?Operations Forum April 1997

14. Primary sludge is produced at a rate of 40,000 pounds per day. If the sludge contains 6% solids, how many gallons of sludge will need to be pumped out of the primary clarifiers?
a) 79936 gallons per day
b) 7993605 gallons per day
c) 89126 gallons per day
d) 60012 gallons per day

15. Primary sludge is produced at a rate of 25,000 gallons per day and contains 6% solids. After dewatering, the primary sludge contains 17% solids. How many gallons of sludge remain after dewatering?
a) 8823 gallons per day
b) 7500 gallons per day
c) 70833 gallons per day
d) 10510 gallons per day

16. Calculate the solids loading rate in ppd/sft for a gravity thickener given the following information: The thickener is 50 feet in diameter and 15 feet deep. Feed sludge contains 5% solids and enters at a flow rate of 130 gpm.
a) 39.8 ppd/sft
b) 35.7 ppd/sft
c) 9.94 ppd/sft
d) 45.3 ppd/sft

JOB SOLIDS HANDLING, JOB NO. 108

SHEET NO. ______ OF ______

CALCULATED BY ______ DATE ______

CHECKED BY ______ DATE ______

SUBJECT ______

1. FIRST, CONVERT PERCENTAGES TO DECIMAL FORM

80% → 0.8

50% → 0.5

$$\% \text{ VS Reduction} = \frac{(In - Out)}{In - (In * Out)}$$

$$\% \text{ VS Reduction} = \frac{(0.8 - 0.5)}{0.8 - (0.8)(0.5)}$$

$$= \frac{0.3}{0.8 - 0.4}$$

$$= \frac{0.3}{0.4}$$

$$= 0.75 \quad \text{OR} \quad 75\%$$

2. ppd = (mg/L)(Q, mgd)(8.34)

ppd = (230 − 110 mg/L)(2.7 mgd)(8.34)

ppd = (120 mg/L)(2.7 mgd)(8.34)

ppd = 2702

3. total lbs of loading = 8000 ppd

74% of the total is volatile sollids, so

(8000 ppd)(0.74) = 5902 ppd VS

$$\frac{\text{lbs VS}}{\text{cuft}} = \frac{5902 \text{ ppd VS}}{50{,}000 \text{ cuft}}$$

$$= 0.1184 \frac{\text{pound VS}}{\text{day} \cdot \text{cuft}}$$

JOB SOLIDS HANDLING JOB NO. 109

SHEET NO. OF

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4. $1\% = 10{,}000 \text{ mg/L}$

$$6\% \left| \frac{10{,}000 \text{ mg/L}}{1\%} \right| = 60{,}000 \text{ mg/L}$$

$$8000 \text{ gallons} \left| \frac{1 \text{ MG}}{1{,}000{,}000 \text{ gal}} \right| = 0.008 \text{ mgd}$$

$$\text{ppd} = (\text{mg/L})(Q, \text{mgd})(8.34)$$
$$\text{ppd} = (60{,}000 \text{ mg/L})(0.008 \text{ mgd})(8.34)$$
$$\text{ppd} = 4003$$

5. $\text{FLOW} = \dfrac{\text{VOLUME}}{\text{TIME}}$

$$\text{Volume} = \pi r^2 h$$
$$V = (3.14)(40 \text{ ft})(40 \text{ ft})(25 \text{ ft})$$
$$V = 125600 \text{ ft}^3$$

$$125600 \text{ ft}^3 \left| \frac{7.48 \text{ gal}}{1 \text{ ft}^3} \right| = 939{,}488 \text{ gallons}$$

$$25{,}000 \frac{\text{gal}}{\text{day}} = \frac{939{,}488 \text{ gallons}}{t}$$
$$(25{,}000)(t) = 939{,}488$$
$$t = 37.6 \text{ days}$$

6. $(6000 \text{ lbs dry sludge})(0.78 \text{ Volatile}) = 4680 \text{ lbs VS}$

$$\frac{\text{lb VS}}{\text{cuft day}} = \frac{4680 \text{ lbs VS}}{40{,}000 \text{ cuft}}$$
$$= 0.117$$

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7. $\% \text{VS Reduction} = \dfrac{(\text{In} - \text{Out})}{\text{In} - (\text{In})(\text{Out})}$

$$= \frac{(0.8 - 0.67)}{0.8 - (0.8)(0.67)}$$

$$= \frac{0.13}{0.8 - 0.536}$$

$$= \frac{0.13}{0.264}$$

$$= 0.49 \longrightarrow 49\%$$

8. $5\% \left| \dfrac{10{,}000 \text{ mg/L}}{1\%} \right| = 50{,}000 \text{ mg/L}$

$$\frac{25 \text{ gal}}{\text{min}} \left| \frac{1440 \text{ min}}{1 \text{ day}} \right| \frac{1 \text{ mg}}{1{,}000{,}000 \text{ gal}} \Bigg| = 0.036 \text{ mgd}$$

$\text{ppd} = (\text{mg/L})(Q, \text{mgd})(8.34)$

$\text{ppd} = (50{,}000 \text{ mg/L})(0.036 \text{ mgd})(8.34)$

$\text{ppd} = 15{,}012 \leftarrow$ TOTAL SOLIDS

$(15{,}012 \text{ ppd total solids})(0.73) = 10959 \text{ ppd}$ Volatile Solids

9. $\text{Removal Efficiency} = \left[\dfrac{\text{In} - \text{Out}}{\text{In}}\right] * 100$

$$= \left[\frac{3.0 - 0.15}{3.0}\right] * 100$$

$$= 95.0\%$$

JOB Solids Handling JOB NO. 111

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10. 1% = 10,000 mg/L

$$\frac{10{,}000\ \text{gal}}{\text{day}}\left|\frac{1\ \text{mg}}{1{,}000{,}000\ \text{gal}}\right| = 0.01\ \frac{\text{mg}}{\text{day}}$$

$$\text{ppd} = (\text{mg/L})(Q,\ \text{mgd})(8.34)$$
$$\text{ppd} = (50{,}000\ \text{mg/L})(0.01\ \text{mgd})(8.34)$$
$$\text{ppd} = 4170$$

11. $$0.10\%\ \text{polymer}\left|\frac{10{,}000\ \text{mg/L}}{1\%}\right| = 1{,}000\ \text{mg/L polymer conc.}$$

$$\text{USED}\quad 50\ \text{mL}\left|\frac{1\ \text{L}}{1000\ \text{mL}}\right|\frac{1000\ \text{mg}}{1\ \text{L}}\right| = 50$$ mg added to 1L JAR TEST

$$\frac{1.5\%\ \text{TS}}{\text{LITER}}\left|\frac{10{,}000\ \text{mg}}{1\%}\right| = 15{,}000\ \text{mg TS/LITER}$$

IT'S A COMPLICATED UNIT CONVERSION

$$\frac{50\ \text{mg Polymer}}{15{,}000\ \text{mg TS}}\left|\frac{1\ \text{g}}{1000\ \text{mg P}}\right|\frac{1\ \text{kg}}{1000\ \text{g P}}\left|\frac{1\ \text{lb Poly}}{2.2\ \text{lbs P}}\right|\frac{1000\ \text{mg TS}}{1\ \text{g}}\left|\frac{1000\ \text{g TS}}{1\ \text{kg}}\right|\frac{2.2\ \text{kg TS}}{1\ \text{lb}}\right| = \frac{\text{lbs Poly}}{\text{lb TS}}$$

$$\frac{50\ \text{lbs Poly}}{15{,}000\ \text{lbs TS}}\left|\frac{2000\ \text{lbs TS}}{1\ \text{ton TS}}\right| = 6.7\ \frac{\text{lbs Poly}}{\text{ton TS}}$$

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12. IF 100% OF THE SOLIDS ARE CAPTURED, THEN THE VOLUMES WILL BE DIRECTLY PORPORTIONAL. USE THE DILUTION EQN.

$C_1 V_1 = C_2 V_2$ * PERFECT CONDITIONS

$$(5\%)(80{,}000\text{ gal}) = (22\%)(V_2)$$

$$18182\text{ gal} = V_2$$

If one gallon weighs 8.34 lbs ... (APPROXIMATELY)

$$18182\text{ gal}\left|\frac{8.34\text{ lbs}}{1\text{ gal}}\right|\frac{1\text{ ton}}{2000\text{ lbs}}\right| = 75.82\text{ tons fed}$$

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

$$= \left[\frac{(75.82 - 68)}{75.82}\right] * 100$$

= 10.3% NOT CAPTURED

∴ 89.6% CAPTURED

13. JUST ANOTHER UNIT CONVERSION

$$\frac{20\text{ mg Cd}}{\text{kg Bio}}\left|\frac{1\text{ g Cd}}{1000\text{ mg Cd}}\right|\frac{1\text{ kg Cd}}{1000\text{ g Cd}}\left|\frac{1\text{ lb Cd}}{2.2\text{ kg Cd}}\right|\frac{2.2\text{ kg Bio}}{1\text{ lb Bio}}\left|\frac{2000\text{ lbs Bio}}{1\text{ ton}}\right| = 0.088\ \frac{\text{lbs Cd}}{\text{ton Bio}}$$

$$\frac{10\text{ lbs Cd}}{\text{acre}}\left|\frac{1\text{ ton Biosolids}}{0.088\text{ lbs Cd}}\right| = 113.6\ \frac{\text{tons biosolids}}{\text{acre}}$$

JOB Solids Handling JOB NO. 113

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14. 1% = 10,000 mg/L

ppd = (mg/L)(Q, mgd)(8.34)

40,000 ppd = (60,000 mg/L)(Q, mgd)(8.34)

0.0799 mgd = $\boxed{Q}$

$\frac{0.0799 \text{ mg}}{\text{day}} \Big| \frac{1,000,000 \text{ gal}}{1 \text{ mg}} \Big| = 79,936$ gallons/day

15. USE THE DILUTION EQN.

$C_1V_1 = C_2V_2$

$(6\%)(25,000 \text{ gpd}) = (17\%)(V_2)$

$8823 \text{ gpd} = V_2$

16. $\frac{130 \text{ gal}}{\text{min}} \Big| \frac{1440 \text{ min}}{1 \text{ day}} \Big| \frac{1 \text{ mg}}{1,000,000 \text{ gal}} \Big| = 0.1872$ mgd

$5\% \Big| \frac{10,000 \text{ mg/L}}{1\%} \Big| = 50,000$ mg/L

ppd = (mg/L)(Q, mgd)(8.34)

ppd = (50,000 mg/L)(0.1872 mgd)(8.34)

ppd = 78062.4

Area = $\pi r^2$

Area = (3.14)(25ft)(25 ft)

Area = 1962.5 ft$^2$

load rate = $\frac{\text{ppd solids}}{\text{area}}$

load rate = $\frac{78062.4 \text{ ppd}}{1962.5 \text{ ft}^2}$

load rate ≈ 39.8 lbs/ft$^2$·day

# Sidney's Big Book of Water and Wastewater Math

INDIGO WATER GROUP

## Unit Conversions to Know by Heart

1 inch = 2.54 centimeters
1 meter = 3.28 feet
1 mile = 5280 feet

1 acre = 43,560 $ft^2$
1 $m^2$ = 10.76 $ft^2$

1 gallon = 3.785 liters
1 $ft^3$ = 7.48 gallons
1 $m^3$ = 35.31 $ft^3$

1 ft water = 0.433 psi

1 gallon = 8.34 lbs when specific gravity is 1.0
1 kg = 2.2 lbs

1% = 10,000 mg/L
1 mg/L = 1 ppm
1 µg/L = 1 ppb

1 day = 1440 minutes
1 hp = 0.746 kW

1 gram = 15.43 grains
1 grain per gallon = 17.1 mg/L

## Water Formulas

pounds per day = (concentration in mg/L)*(flow rate in mgd)*(8.34)

chlorine dose = demand + residual

$$\text{velocity} = \frac{\text{flow}}{\text{area}} \qquad V = \frac{Q}{A}$$

$$\text{flow rate} = \frac{\text{volume}}{\text{time}} \qquad Q = \frac{V}{t}$$

$$\text{overflow rate} = \frac{\text{flow rate}}{\text{area}}$$

$$\text{weir loading rate} = \frac{\text{flow rate}}{\text{feet of weir}}$$

(concentration 1)*(volume 1) = (concentration 2)*(volume 2)   $C_1V_1 = C_2V_2$

(conc. 1)*(volume 1) + (conc. 2)*(volume 2) = (conc. 3)*(volume 3)

$$C_1V_1 + C_2V_2 = C_3V_3$$

$$\text{horsepower} = \frac{(\text{flow in gpm})*(\text{lift in feet})}{3960}$$

# Miscellaneous

**MISC.**

1. How long must a grit chamber be to permit particle settling given the following: Flow velocity = 0.96 ft/sec, Water depth = 16", Particle settling rate = .075 ft/sec
   a) 17 ft.
   b) 22 ft.
   c) 18 ft.
   d) 19 ft.

2. Calculate the percent volatile solids. 100mL of sample, crucible weight = 19.985 g, crucible + dry solids = 20.050 g, crucible plus ash = 20.006 g
   a) 33%
   b) 50%
   c) 67%
   d) 74%

3. If the sewer rate is $5.50 for the first 500 cu ft and all wastewater generated over the minimum is billed at a rate of $0.25 per 100 cu ft, how much would a customer generating 1200 cu ft be billed?
   a) $5.25
   b) $6.25
   c) $6.75
   d) $7.25

4. Calculate the percent reduction in flows achieved by an industrial water conservation program if wastewater flows are reduced from 350 gpm to 220 gpm
   a) 31%
   b) 37%
   c) 44%
   d) 59%
   e) 63%

5. Determine the percent of dissolved oxygen saturation in the receiving waters of an effluent discharge when the actual dissolved oxygen concentration is 8.2 mg/l and the saturation concentration of dissolved oxygen is 9.4 mg/l.
   a) 82%
   b) 87%
   c) 94%
   d) 100%

?Operations Forum April 2001

6. A plant runs blowers for 24 hours at 100,000 ft3/min to aerate 100 mgd of flow containing 250 mg/l of BOD. Ninety percent of BOD was removed. How many cubic feet of air was required for each pound of BOD removed?

a) 770
b) 1200
c) 595
d) 1000

7. The secondary influent flow to a treatment plant consists of 100 mgd of primary effluent with 110 mg/l total suspended solids. What percentage of the suspended solids loading does a 1-mgd sidestream containing 1200 mg/l TSS represent?

a) 8.5%
b) 9.8%
c) 10.5%

?Operations Forum May 1998

8. One hundred mgd of secondary influent to a treatment plant contains 110 mg/l of suspended solids. A side-stream from a 1-mgd dewatering plant with 1200 mg/l suspended solids is returned. What is the total suspended solids load on the secondary treatment plant, in pounds?

a) 91,740 lb
b) 101,750 lb
c) 10,008 lb

?Operations Forum March 1998

9. A wet well level transmitter says 56% on a scale of 0% to 100%. The full depth of the wet well is 35 ft. How many feet of water are in the wet well?

a) 15.2 ft
b) 17.8 ft
c) 19.6 ft
d) 20.3 ft

?Operations Forum November 1997

10. Given the following, calculate the BOD5 of an unseeded sample: Initial DO = 9.0 mg/L, Final DO = 5.0 mg/L, Bottle volume = 300 mL, Sample volume = 6.0 mL

a) 150
b) 175
c) 200
d) 225

JOB Misc

JOB NO. 121

SHEET NO.

OF

CALCULATED BY

DATE

CHECKED BY

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SUBJECT

1. depth = 16 inches = 1.33 ft

$$1.33 \text{ feet depth} \left| \frac{1 \text{ second}}{0.075 \text{ ft depth}} \right| \frac{0.96 \text{ ft length}}{1 \text{ second}} \bigg| = 17 \text{ feet length}$$

2. 20.050 grams crucible + solids
− 19.985 grams crucible

0.065 grams solids

20.006 grams crucible + inert solids
− 19.985 grams crucible

0.021 grams inert solids

TS = TVS + Inert Solids
0.065 g = TVS + 0.021 g
0.044 g = TVS

$$\text{Percent} = \left[\frac{\text{PART}}{\text{WHOLE}}\right] * 100$$

$$\text{PERCENT} = \left[\frac{0.044 \text{ g}}{0.065 \text{ g}}\right] * 100$$

PERCENT = 67.7%

3. 1200 cuft
− 500 cuft

700 cuft

\$5.50 + (7)(\$0.25) = billed
\$5.50 + \$1.75 = billed
\$7.25 = billed

4. $$\text{PERCENT} = \left[\frac{\text{PART}}{\text{WHOLE}}\right] * 100$$

JOB MKC JOB NO. 122

SHEET NO. OF

CALCULATED BY DATE

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SUBJECT

4. (cont.)

$$\begin{array}{r} 350 \text{ gpm} \\ -220 \text{ gpm} \\ \hline 130 \text{ gpm SAVED} \end{array}$$

$$\text{PERCENT} = \left[\frac{130 \text{ gpm}}{350 \text{ gpm}}\right] * 100$$

$$\text{PERCENT} = 37\%$$

5. $$\text{PERCENT} = \left[\frac{8.2 \text{ mg/L}}{9.4 \text{ mg/L}}\right] * 100$$

$$\text{PERCENT} = 87.2\%$$

6. $$\text{ppd} = (\text{mg/L})(Q,\text{ mgd})(8.34)$$

$$\text{ppd} = (250 \text{ mg/L})(100 \text{ mgd})(8.34)$$

$$\text{ppd} = 208{,}500$$

IF 90% REMOVED, THEN (208,500)(0.90) = 187,650 ppd BOD REMOVED

$$\frac{100{,}000 \text{ ft}^3}{\text{min}} \bigg| \frac{1440 \text{ min}}{1 \text{ day}} \bigg| = 144{,}000{,}000 \ \frac{\text{cf}}{\text{d}}$$

$$\frac{\text{air}}{\text{lb BOD}} = \frac{144{,}000{,}000 \text{ cf/d}}{187{,}650 \text{ ppd}}$$

$$\frac{\text{air}}{\text{lb BOD}} = 767 \text{ cf/lb}$$

JOB MISC JOB NO. 123

SHEET NO. OF

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SUBJECT

7. $\text{ppd side} = (\text{mg/L})(Q, \text{mgd})(8.34)$

$\text{ppd side} = (1200\ \text{mg/L})(1\ \text{mgd})(8.34)$

$\text{ppd side} = 10008$

$\text{ppd main} = (\text{mg/L})(Q, \text{mgd})(8.34)$

$\text{ppd main} = (110\ \text{mg/L})(100\ \text{mgd})(8.34)$

$\text{ppd main} = 91740$

$$\text{PERCENT} = \left[\frac{\text{PART}}{\text{WHOLE}}\right] + 100$$

$$= \left[\frac{10008\ \text{ppd}}{10008\ \text{ppd} + 91740\ \text{ppd}}\right] + 100$$

$$= \left[\frac{10008}{101748}\right] + 100$$

$$= 9.8\%$$

8. TOTAL LOAD = 101,748 lbs *see #7

9. (35 ft)(0.56) = 19.6 ft full

10. $$\text{BOD} = \frac{DO_{START} - DO_{END}}{(\text{SAMPLE VOLUME}/300\ \text{mL})}$$

$$\text{BOD} = \frac{9.0 - 5.0}{(6\ \text{mL}/300\ \text{mL})}$$

$$\text{BOD} = \frac{4\ \text{mg/L}}{0.02}$$

$$\text{BOD} = 200\ \text{mg/L}$$

104. A wet well level transmitter says 56% on a scale of 0% to 100%. The full depth of the wet well is 35 ft. How many feet of water are in the wet well?

a) 15.2 ft
b) 17.8 ft
c) 19.6 ft
d) 20.3 ft

Operations Forum November 1997

105. Of the $900 allotted for maintenance in the monthly budget, 15 percent was spent on pump repair. How much money was spent?

a) $135
b) $765
c) $450
d) $13.5

106. A water treatment plant treats 36,520,000 gallons during the month of July. The total water measured in various storage tanks is 28,710,000 gallons. What percentage of treated water is unaccounted for?

a) 78.6%
b) 21.4%
c) 27.2%
d) 63.0%

107. Scientific notation is a method by which any number can be expressed as a term multiplied by a power of ten, such as 8.75 x 10^-2. Express this number in decimal form.

a) 0.0875
b) 0.875
c) 875.00
d) 87.5

108. Express 7,960 in scientific notation.

a) 7.96 * 10^3
b) 7.96 * 10^-3
c) 7.96*10^5

None of these is correct.

109. Last month your Water System pumped 7,106,300 gallons of water into the distribution system. Your system was able to account for 5,264,800 gallons. What was your unaccounted for % of water for this month?

a) 47.1 %
b) 88 %
c) 2.95 %
d) 25.9 %
e) 74.1 %

110. You have replaced 3/4 of the water meters in your system. You have a total of 540. How many will you need to complete the task of replacing all the meters?

a) 195
b) 405
c) 135
d) 275
e) 54

111. Your plant's maximum capacity is 1.3 MGD. If you produced 67% of this capacity in one day how many gallons would this be ?

a) 1,100,201 gallons
b) 19,402 gallons
c) 194,020 gallons
d) 87,100 gallons
e) 871,000 gallons

104. $(35\text{ ft})(0.56) = \text{level}$

$19.6\text{ ft} = \text{level}$

105. $(\$900)(0.15) = \text{spent}$

$\$135 = \text{spent}$

106.

$$\% \text{ MISSING} = \left[\frac{36{,}520{,}000 - 28{,}710{,}000}{36{,}520{,}000}\right] * 100$$

$$\% \text{ MISSING} = \left[\frac{7810000}{36520000}\right] * 100$$

$$\% \text{ MISSING} = 21.4$$

107. $8.75 \times 10^{-2} = 0.0875$

-2 means move the decimal point 2 places to the left

108. $7{,}960 = 7.96 \times 10^{3}$

109. $$\% \text{ MISSING} = \left[\frac{7{,}106{,}300 - 5{,}264{,}800}{7{,}106{,}300}\right] * 100$$

$$\% \text{ MISSING} = 25.9$$

110. (540 meters)(3/4) = 405 replaced already

540 meters total
−405 replaced
135 still need replacing

111. 1.3 MGD = 1300000 $\frac{\text{gallons}}{\text{day}}$

(1300000 gallons)(0.67) = production
871000 gallons = production