

Tech Brief

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Basic Water and Wastewater Formulas

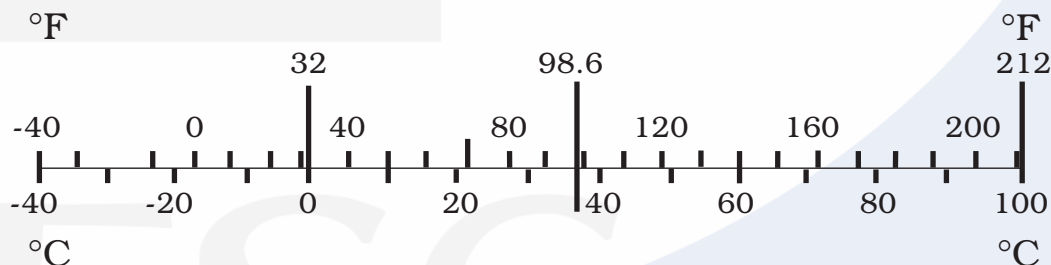
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Summary

Operators obtaining or maintaining their certification must be able to calculate complex formulas and conversion factors. This *Tech Brief* provides basic examples of these formulas and conversion factors.

Metric Conversion Factors (Approximate) Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
Length	mm millimeters	0.04	inches	in
	cm centimeters	0.4	inches	in
	m meters	3.3	feet	ft
	m meters	1.1	yards	yds
	km kilometers	0.6	miles	mi
Area	cm ² square centimeters	0.16	square inches	in ²
	m ² square meters	1.2	square yards	yd ²
	km ² square kilometers	0.4	square miles	mi ²
	ha hectares (10,000m ²)	2.5	acres	acrs
Mass (Weight)	g grams	0.035	ounces	oz
	kg kilograms	2.2	pounds	lbs
	t tones (1,000kg)	1.1	short tons	
Volume	ml milliliters	0.03	fluid ounces	fl oz
	l liters	2.1	pints	pt
	l liters	1.06	quarts	qt
	l liters	0.26	gallons	gal
	m ³ cubic meters	35.0	cubic feet	ft ³
	m ³ cubic meters	1.3	cubic yards	yd ³
Temp. F = (9/5)C + 32	°C Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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Basic Water and Wastewater Formulas

Area, ft² Rectangle, Width, *ft* x Length, *ft*
 Circle, $\frac{(\text{Diameter, ft})^2 \pi}{4}$

Backwash Rate, gpm/ft² $\frac{\text{Flow, gpm}}{\text{Area, ft}^2}$

Filtration Rate, gpm/ft² $\frac{\text{Flow, gpm}}{\text{Area, ft}^2}$

Chlorine Dose, mg/L
 Cl₂ Demand, mg/L+Free Cl₂ Residual, mg/L

Circumference of a circle, ft $(\pi)(\text{Diameter, ft})$
 or
 $2(\pi)(\text{Radius, ft})$

Detention time, hrs $\frac{(\text{Volume, gal})(24 \text{ hrs/day})}{\text{Flow, gpd}}$

Flow, cfs $(\text{Velocity, ft/sec})(\text{Area, ft}^2)$

Velocity, ft/sec $\frac{\text{Flow, cfs}}{\text{Area, ft}^2}$

Velocity, ft/sec $\frac{\text{Distance, ft.}}{\text{Time, sec.}}$

Water Horsepower, HP $\frac{(\text{Flow, gpm})(\text{Head, ft})}{3960}$

Pounds, lbs $(\text{Flow, MGD})(\text{Conc. mg/L})(8.34 \text{ lbs/gal})$

Power, watts $(\text{Voltage, volts})(\text{Current, amp})$

Power Factor $\frac{\text{Actual Power, watts}}{\text{Apparent Power, V-A}}$

Removal, % $\frac{\text{In} - \text{Out}}{\text{In}}$

Solution Strength, % $\frac{\text{Weight of Chemical}}{\text{Weight of Solution}} \times 100$

Surface Overflow Rate, gpd/ft² $\frac{\text{Flow, gpd}}{\text{Area, ft}^2}$

Temperature °F $(1.8 \times \text{°C}) + 32$
 °C $(\text{°F}-32) (5/9)$

Velocity, ft/sec $\frac{\text{Flow, ft}^3/\text{sec}}{\text{Area, ft}^2}$

Volume, ft³
 Rectangle; Width, *ft* x Length, *ft* x Height, *ft*

Cylinder; $\frac{\pi (\text{Diameter, ft})^2 (\text{Height, ft})}{4}$

Cone; $\frac{\pi (\text{Diameter, ft})^2 (\text{Height, ft})}{12}$

Sphere; $\frac{\pi (\text{Diameter, ft})^3}{6}$

Reservoir Volume, gal. =
 $\frac{\text{Volume, ac-ft} \times 43,560 \text{ ft}^2}{\text{ac.} \times 7.48 \text{ gal/ft}^3}$

Reservoir Surface Area, ac. =
 $\frac{\text{Surface Area, ft}^2}{43,560 \text{ ft}^2/\text{ac}}$

Slope = $\frac{\text{Fall, ft}}{\text{Length, ft}}$

Grade = $\frac{\text{Rise, ft}}{\text{Run, ft}}$

Conversion Factors

1 ft³ water = 7.48 gal

1 yd³ = 27ft³

1 gal water = 8.34 lbs

1 ft³ water = 62.4 lbs

1 MGD* = 694 gpm

1 MGD = 1.547 cfs

1 liter = 0.264 gal

1 liter/sec = 15.85 gpm

1 acre = 43,560 ft²

1 psi = 2.31 feet of water

1 mg/L = 1 ppm

1% = 10,000 mg/L

1 kilogram = 2.20 lbs

1 centimeter = 0.394 inches

*MGD = million gallons per day

1 kilowatt = 1.34 HP

1 HP = 550 ft-lbs/sec

1 HP = 0.746 kilowatts

1 meter = 3.28 feet

1 mile = 5280 feet

1 kilopascal = 0.145 psi

π (Pi) = 3.1416

Powers of Ten

Prefixes and symbols to form decimal multiples and/or submultiples.

Power of Ten	E Notation	Decimal Equivalent	Prefix	Phonic	Symbol
10^{12}	E+12	1,000,000,000,000	tera	ter'a	T
10^9	E+09	1,000,000,000	giga	ji'ga	G
10^6	E+06	1,000,000	mega	meg'a	M
10^3	E+03	1,000	kilo	kil'o	k
10^2	E+02	100	hecto	hek'to	h
10	E+01	10	deka	dek'a	da
10^{-1}	E-01	0.1	deci	des'I	d
10^{-2}	E-02	0.01	centi	sen'ti	c
10^{-3}	E-03	0.001	milli	mil'I	m
10^{-6}	E-06	0.000,001	micro	mi'kro	u
10^{-9}	E-09	0.000,000,001	nano	nan'o	n
10^{-12}	E-12	0.000,000,000,001	pico	pe'ko	p
10^{-15}	E-15	0.000,000,000,000,001	femto	fem'to	f
10^{-18}	E-18	0.000,000,000,000,000,001	atto	at'to	a

Sample Questions

1. An empty storage tank at standard atmospheric pressure (not under pressurized condition) is 8 feet in diameter and 32 feet high. How long will it take to fill 90 percent of the tank volume if a pump is discharging a constant 24 gallons per minute into the tank?

- 7 hours and 31 minutes
- 8 hours and 21 minutes
- 8 hours and 23 minutes
- 9 hours and 17 minutes

Solution: Don't look at the problem as a whole. Instead, break it into steps:

First, calculate the area of a circle 8 feet in diameter;

$$\frac{(\text{Diameter, ft})^2}{4} \pi, \frac{8^2}{4} \pi, \frac{64}{4} \pi, 16(3.1416) = 50.26 \text{ ft}^2$$

Second, calculate the volume of a cylinder;

$$\frac{(\text{Diameter, ft})^2}{4} \pi (\text{Height, ft}),$$

since the area is already calculated, just multiply by the height.

$$50.26 \text{ ft}^2 \times 32 \text{ ft high} = 1,608.5 \text{ ft}^3 \text{ (cubic feet)}$$

Third, convert from ft^3 (cubic feet) to gallons;
 $1 \text{ ft}^3 \text{ water} = 7.48 \text{ gallons}$

$$1,608.5 \text{ ft}^3 \times \frac{7.48 \text{ gallons}}{\text{ft}^3} = 12,031.5 \text{ gallons,}$$

this is total volume tank can hold

Fourth, calculate what 90% of the total volume would be

$$12,031.5 \text{ gallons} \times \frac{90\%}{100}$$

$$12,031.50 \text{ gallons} \times .90 = 10,828.39 \text{ gallons}$$

Fifth, calculate time to pump at 24 gallons per minute

$$\frac{10,828.39 \text{ gallons}}{24 \text{ gallons}} = 451.18 \text{ minutes}$$

Sixth, convert minutes to hours and minutes;
 60 minutes = 1 hour

$$\frac{451.18 \text{ minutes}}{60 \text{ minutes}} = 7.52 \text{ hours}$$

Now take the .52 hours and multiply by 60 minutes/hour

$$7 \text{ hours and } (0.52 \times 60) = 31.2 \text{ minutes}$$

7 hours and 31 minutes

The answer is a. 7 hours and 31 minutes

27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0 cm

2. How many cubic feet of water will a rectangular tank that is 20-feet long by 15-feet wide and 10-feet high hold?

- a. 2,000 cubic feet
- b. 3,000 cubic feet
- c. 850 cubic feet
- d. 1,200 cubic feet

Solution:

Calculate the volume for a rectangular box (L x W x D or H) Length x Width x Depth or Height.

$$20 \text{ ft} \times 15 \text{ ft} \times 10 \text{ ft} = 3,000 \text{ ft}^3 \text{ (cubic feet)}$$

The answer is b. 3,000 cubic feet

3. Calculate the chlorine demand using the following data:

Raw water flow is 0.75 MGD

Chlorinator feed rate is 4.0 mg/L

Chlorine residual (free) is 1.8 mg/L

- a. 0.8 mg/L
- b. 2.2 mg/L
- c. 4.0 mg/L
- d. 5.8 mg/L

Solution:

If solution strength is not given, then use 100%

Often more information is given than needed to solve specific problems. In this problem, the raw water flow rate (0.75 MGD) is not needed.

The equation to be used is the Chlorine Dose Equation

$$\text{Chlorine Dose, mg/L} = (\text{Cl}_2 \text{ Demand, mg/L}) + \text{Free Cl}_2 \text{ Residual, mg/L}$$

Solve this Equation for the Chlorine Demand Cl_2 , mg/L;

$$\text{Cl}_2 \text{ Demand, mg/L} = \text{Chlorine Dose, mg/L} - \text{Free Cl}_2 \text{ Residual, mg/L}$$

$$\text{Cl}_2 \text{ Chlorine Demand, mg/L} = 4.0 \text{ mg/L} - 1.8 \text{ mg/L}$$

$$\text{Cl}_2 \text{ Chlorine Demand, mg/L} = 2.2 \text{ mg/L}$$

The answer is b. 2.2 mg/L

4. Calculate the volume, in gallons, of a tank that is 75 feet long, 20 feet high, and 10 feet deep.

- a. 15,000 gallons
- b. 112,200 gallons
- c. 150,000 gallons
- d. 224,400 gallons

Solution:

First, calculate the volume for a rectangular box (L x W x D or H) Length x Width x Depth or Height.

$$75 \text{ ft} \times 20 \text{ ft} \times 10 \text{ ft} = 15,000 \text{ ft}^3 \text{ (cubic feet)}$$

Second, convert ft^3 (cubic feet) to gallons, 1 ft^3 (cubic feet) water = 7.48 gallons

$$15,000 \text{ ft}^3 \times \frac{7.48 \text{ gallons}}{\text{ft}^3} = 112,200 \text{ gallons, this is the tank volume in gallons}$$

The answer is b. 112,200 gallons

5. How many pounds of a chemical applied at the rate of 3 mg/L are required to dose 200,000 gallons?

- a. 1 lb
- b. 3 lbs
- c. 5 lbs
- d. 16 lbs

Solution:

If a solution strength is not given, use 100%

The equation to be used is the pounds, lbs equation – (Flow, MGD)(Conc.mg/L)(8.34 lbs/gal)

Convert the flow or gallons to MGD;

$$\frac{200,000 \text{ gallons per day}}{1,000,000 \text{ million gallons}} = 0.2 \text{ MGD}$$

The concentration is the rate in this case = 3 mg/L

Now plug the givens (known) into the pounds equation

$$(0.2, \text{ MGD})(3 \text{ mg/L})(8.34 \text{ lbs/gal, day}) = 5.004 \text{ lbs}$$

The answer is c. 5 lbs

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