

Conversions, Calculations and Concentrations

Volume (metric and U.S. liquid measures)

Units	cm ³	liter	m ³	in. ³	ft. ³	yd. ³	fl oz.	fl pt.	fl qt.	gal.	bbl. (oil)	bbl. (liq.)
cm ³	1	0.001	1 x 10 ⁻⁶	0.06102	3.53 x 10 ⁻⁵	1.31 x 10 ⁻⁶	0.03381	0.00211	0.00106	2.64 x 10 ⁻⁴	6.29 x 10 ⁻⁶	8.39 x 10 ⁻⁶
liter	1000	1	0.001	61.02	0.03532	0.00131	33.81	2.113	1.057	0.2642	0.00629	0.00839
m ³	1 x 10 ⁶	1000	1	6.10 x 10 ⁴	35.31	1.308	3.38 x 10 ⁴	2113	1057	264.2	6.290	8.386
in. ³	16.39	0.01639	1.64 x 10 ⁻⁵	1	5.79 x 10 ⁻⁴	2.14 x 10 ⁻⁵	0.5541	0.03463	0.01732	0.00433	1.03 x 10 ⁻⁴	1.37 x 10 ⁻⁴
ft. ³	2.83 x 10 ⁴	28.32	0.02832	1728	1	0.03704	957.5	59.84	29.92	7.481	0.1781	0.2375
yd. ³	7.65 x 10 ⁵	764.5	0.7646	4.67 x 10 ⁴	27	1	2.59 x 10 ⁴	1616	807.9	202.0	4.809	6.412
fl oz.	29.57	0.02957	2.96 x 10 ⁻⁵	1.805	0.00104	3.87 x 10 ⁻⁵	1	0.06250	0.03125	0.00781	1.86 x 10 ⁻⁴	2.48 x 10 ⁻⁴
fl pt.	473.2	0.4732	4.73 x 10 ⁻⁴	28.88	0.01671	6.19 x 10 ⁻⁴	16	1	0.5000	0.1250	0.00298	0.00397
fl qt.	946.4	0.9463	9.46 x 10 ⁻⁴	57.75	0.03342	0.00124	32	2	1	0.2500	0.00595	0.00794
gal.	3785	3.785	0.00379	231.0	0.1337	0.00495	128	8	4	1	0.02381	0.03175
bbl. (oil)	1.59 x 10 ⁵	159.0	0.1590	9702	5.615	0.2079	5376	336	168	42	1	1.333
bbl. (liq)	1.19 x 10 ⁵	119.2	0.1192	7276	4.211	0.1560	4032	252	126	31.5	0.7500	1

Mass

Units	g	kg	oz.	lb.	metric ton	ton
g	1	10 ⁻³	0.03527396	2.204623 x 10 ⁻³	10 ⁻⁶	1.102311 x 10 ⁻⁶
kg	1000	1	35.27396	2.204623	10 ⁻³	1.102311 x 10 ⁻³
oz. (avdp)	28.34952	0.02834952	1	0.0625	2.834952 x 10 ⁻⁵	3.125 x 10 ⁻⁵
lb. (avdp)	453.5924	0.4535924	16	1	4.535924 x 10 ⁻⁴	0.0005
metric ton	10 ⁶	1000	35273.96	2204.623	1	1.102311
ton	907184.7	907.1847	32000	2000	0.9071847	1

Length

Units	cm	m	km	in.	ft.	mile
cm	1	0.01	1 x 10 ⁻⁵	0.3937	0.03281	6.214 x 10 ⁻⁶
m	100	1	0.001	39.37	3.281	6.214 x 10 ⁻⁴
km	1 x 10 ⁵	1000	1	3.94 x 10 ⁴	3281	0.6214
in.	2.540	0.02540	2.540 x 10 ⁻⁵	1	0.08333	1.578 x 10 ⁻⁵
ft.	30.48	0.3048	3.048 x 10 ⁻⁴	12	1	1.894 x 10 ⁻⁴
mile	1.609 x 10 ⁵	1609	1.609	6.336 x 10 ⁴	5280	1

Area

Units	cm ²	m ²	km ²	in. ²	ft. ²	mile ²
cm ²	1	1 x 10 ⁻⁴	1 x 10 ⁻¹⁰	0.1550	1.076 x 10 ⁻³	3.861 x 10 ⁻¹¹
m ²	1 x 10 ⁴	1	1 x 10 ⁻⁶	1550	10.76	3.861 x 10 ⁻⁷
km ²	1 x 10 ¹⁰	1 x 10 ⁶	1	1.55 x 10 ⁹	1.076 x 10 ⁷	0.3861
in. ²	6.452	6.452 x 10 ⁻⁴	6.405 x 10 ⁻¹⁰	1	6.944 x 10 ⁻³	2.491 x 10 ⁻¹⁰
ft. ²	929.0	9.290 x 10 ⁻⁸	144	1		
mile ²						

CONVERSIONS

1000 ng (nanograms)	=	1.0 ug (microgram)
1000 ug (micrograms)	=	1.0 mg (milligram)
1000 mg (milligrams)	=	1.0 g (gram)
1000 g (grams)	=	1.0 Kg (kilogram)
1000 uL (microliters)	=	1.0 mL (milliliter)
1000 mL (milliliters)	=	1.0 L (liter)
1000 L (liters)	=	1.0 M ³ (cubic meter)
1.0 mL (milliliter)	=	1.0 cc (cubic centimeter)

Some samples of these conversions are:

7465 ng = 7.465 ug	7.465 ug = 0.007465 mg
0.339 mg = 339 ug	0.7891 Kg = 789.1 g
244.7 mL = 0.2447 L	1.349 M ³ = 1349 L
1428.7 L = 1.4287 M ³	546 cc = 546 mL

CALCULATING AIR VOLUMES

Calculating accurate air volumes (exact amounts of air drawn through air sampling media) is imperative in reaching meaningful results. The air volume is simply the product of two terms, flowrate and sampling time:

$$\text{Air Volume} = \text{Flowrate} \times \text{Sampling Time}$$

The flowrate is usually expressed in liters/minute or in milliliters/minute (mL/minute is the same as cc/minute). The sampling time needs to be expressed in minutes, and therefore the product of these two terms, the air volume, will be either liters or milliliters.

Some samples of calculating air volumes are:

11.7 L/ min.	x	240 minutes	=	2808 L
20 mL/min.	x	462 minutes	=	9240 mL (= 9.240 L)
540 cc/min.	x	366 minutes	=	197640 cc (= 197.640 L)
3.4 L/min.	x	480 minutes	=	1632 L (= 1.632 M ³)

CONCENTRATIONS: AN IMPORTANT CONCEPT

Concentration is an important concept in expressing analytical results in environmental and industrial hygiene testing. A concentration is so much of something per something else. When dealing with concentrations, the word per is used to separate two quantities, such as in "parts per million" and mg/M³. The most commonly used concentrations are:

mg/Kg	(milligrams per kilogram)
mg/M ³	(milligrams per cubic meter)
PPM	(parts per million)
fibers/cc	(fibers per cubic centimeter of air)
mg/L	(milligrams per liter)

Note that there are basically two types of concentrations, weight per weight and weight per volume. Weight per weight concentrations (mg/Kg) are used to express contaminant levels of solids, such as the level of lead in paint chips. Weight per volume concentrations (mg/M³ and mg/L) are used to express contaminant levels of both air and liquids. The amount of benzene vapor in air and the amount of iron in water (most likely expressed as mg/M³ and mg/L, respectively) would both be weight per volume concentrations.

Obviously, concentrations are necessary to make sense out of analytical results. Knowing only the total weight of metal found on a filter is useless without knowing the exact amount of air in which that amount of metal was contained.

WHEN SENDING SAMPLES TO SCHNEIDER LABORATORIES GLOBAL, INC. PLEASE INCLUDE THE AIR VOLUMES IF THEY ARE AIR SAMPLES. THE CONCENTRATION CANNOT BE CALCULATED WITHOUT THE AIR VOLUME.

The concentration can always be determined if the amount of contaminant and the volume of air drawn through the sampler are known. Start with the weight amount of contaminant found on the entire sample, then divide by the air volume to arrive at the concentration, for example:

A charcoal tube is sent to the lab for benzene analysis, but the volume of air, 24.17 L, was not included. The lab produces a result of 0.03 mg benzene. To compare these results to a PEL or TLV, the concentration is needed.

$$\frac{0.03 \text{ mg benzene}}{0.02417 \text{ M}^3 \text{ air}} = 1.24 \text{ mg/M}^3 \text{ benzene}$$

Notice that liters were converted to cubic meters so that the result may be expressed as mg/M³, not mg/L.

For fiber counting, as in asbestos analysis, the application is similar. The concentration is now number of fibers per volume of air.

A 1243.7 L air sample is sent to the lab, but the air volume is not included. A result of 7847 fibers/filter was reported. Knowing the total number of fibers on the entire filter and the air volume, the concentration of fibers in air can easily be calculated:

$$\frac{7847 \text{ fibers}}{1,243,000 \text{ cc air}} = 0.0063 \text{ fibers/cc}$$

Notice the conversion from liters to cubic centimeters, so that the results are in fibers/cc not in fibers/L.

Remember, when working with concentrations, both the weight value and the volume value can be changed into the preferred units before the division is done. For example, a result of

517.3 mg/L chlordane in water

can be correctly expressed as any of the following, without changing the result:

517300 ug/L

517.3 ug/mL

One last word about concentrations: Parts per million, or PPM, is frequently used to express concentrations such as volume per volume of air, volume per volume of liquid (usually water - aqueous solutions), and weight per weight. For example, in testing a solid for lead we found that it contained 34 ug of lead per gram of solid, we could say that the solid contained 34 PPM lead, since there are a million micrograms in one gram.

Applying PPM values to lead contamination in water is not difficult if we remember one very important premise in chemistry. One milliliter (1.0 mL) of water weighs exactly one gram (1.0g). Knowing this, it is easy to understand that if water contains 69 ug of lead per mL, then that water is 69 PPM lead. This is because 69 ug/mL is the equivalent of saying 69 ug/g (remember, 1.0 mL of water weighs 1.0 g). So, 69 ug of lead per gram of water means, by definition, 69 PPM.

Lastly, PPM can refer to volume of contaminant per volume of air. In this case the contaminant is usually an organic vapor. This type of PPM application is the most difficult to understand. It is based on the following two chemical principles:

- 1) A chemical's molecular weight is the number of grams of that chemical found in one mole of that chemical.
- 2) At 25° C temperature and 1 atmosphere pressure, one mole of any chemical (in a vapor state if it is normally a liquid) or gas occupies exactly the same amount of air space, 24.45 liters. Volume per air volume results of solvent vapors and gases in PPM, can be expressed by using the following:

$$\frac{\text{mg contaminant}}{\text{M}^3 \text{ air}} \times \frac{24.45 \text{ L/mole}}{\text{m.w. as g/mole}} = \text{PPM contaminant in air}$$

Always remember, when using PPM, volume or weight per volume must always be expressed - never use "mixed" values such as weight per volume.

Sometimes it is useful to convert results expressed in PPM to results expressed as a percentage (or vice versa), as shown below:

$$\text{parts per million} = (\text{percent}) \times (0.0001)$$

$$\text{Percent} = \frac{\text{parts per million}}{0.0001}$$

TIME-WEIGHTED AVERAGES

Time weighted averages are expressions on concentrations that have been “time weighted” for the purpose of comparison with 8-hour contaminant concentrations. In other words, if a sample result (always as a concentration) is multiplied by a factor that would make the resultant concentration represented the contaminant level if the sampling time had been exactly eight hours, instead of more or less than eight hours. If sampled for exactly 8 hours, the sample result (concentration) is already, by definition, an 8-hour TWA.

If the sampling is less than eight hours, then the sample concentration is multiplied by a factor that is less than 1. This would take the concentration of contaminant to which the employee was exposed and “spread it out” to represent what the concentration would have been if the exposure was 8 hours. The weight of the contaminant would be unchanged. If sampling is more than 8 hours (for instance a worker who works 4 10-hour days), the sample concentration would be multiplied by a factor that is greater than 1; this would take the concentration of contaminant to which the employee was exposed and “squeeze it into an 8-hour time frame” to represent what the concentration would have been if the exposure was 8 hours, but the weight of the contaminant would be unchanged.

TWA's are expressed as either PPM or mg/M³ values. Hygienists need to calculate TWA's for all their sample results because the OSHA PEL's and the ACGIH TLV's are all expressed as either PPM TWA's or as mg/M³ TWA's. In order to compare results to the standards, both values need to be time weighted averages. The following calculations are used to arrive at 8-hour TWA's.

$$\frac{\text{mg}}{\text{M}^3} \times \frac{\text{minutes sampled}}{480 \text{ minutes}} = \frac{\text{mg}}{\text{M}^3} \text{ TWA}$$

$$\text{PPM} \times \frac{\text{minutes sampled}}{480 \text{ minutes}} = \text{PPM TWA}$$

While sampling a painter for mineral spirits, the pump ran for 6 hours and 15 minutes while he was painting, and he spent the remainder of his shift unexposed to solvent vapors. The lab reports a result of 0.344 mg/M³ mineral spirits for the charcoal tube. The following converts this concentration to an 8-hour TWA.

$$0.344 \text{ mg/M}^3 \times \frac{375 \text{ minutes}}{480 \text{ minutes}} = 0.269 \text{ mg/M}^3 \text{ TWA}$$

Remember, the painter was sampled for less than 8 hours, so the factor multiplied by the concentration is less than 1.

A lab report for formaldehyde states that the exposure was 0.85 PPM. This sample was taken on an employee working a 12-hour shift, but was sampled for 11 hours and 15 minutes because he took a break. An 8-hour TWA is calculated in order to compare his exposure to the standard.

$$0.85 \text{ PPM} \quad \times \quad \frac{675 \text{ minutes}}{480 \text{ minutes}} \quad = \quad 1.20 \text{ PPM TWA}$$

Since sampling was more than 8 hours, a factor greater than 1 is multiplied raising the concentration to represent what the concentration would have been during an 8-hour period had the weight of formaldehyde found remained the same.