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Brownfields Resources

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Understanding Units of Measurement

Technical environmental reports involving soil, water, or air contamination often report numerical values in units unfamiliar to people who don't routinely read these types of reports. The different units of Measurement can be confusing. This brief is intended to help people understand measurement units they may see in technical environmental reports. Examples of typical units of measurement are given below.

Numbers
Million = 1,000,000
Billion = 1,000,000,000
Trillion = 1,000,000,000,000
One millionth = 0.000001
One billionth = 0.000000001
One trillionth = 0.000000000001

Mass
28 grams = about 1 ounce
1 kilogram (kg) = 1,000 grams
1 milligram (mg) = 1/1,000 gram = 0.001 gram
1 microgram (ug) = 1/1,000,000 gram = 0.000001 gram
1 nanogram (ng) = 1/1,000,000,000 gram = 0.000000001 gram
1 picogram (pg) = 1/1,000,000,000,000 gram = 0.000000000001 gram

Volume
One liter (L) = 1.06 quarts
One cubic meter (m^3) = 35.31 cubic feet (ft^3)
One cubic meter (m^3) = 1,000 liters (L)
One liter (L) = 1,000 milliliter (ml) = 1,000 cubic centimeters

Concentrations in Soil

Concentrations of chemicals in soil are typically measured in units of the mass of chemical (milligrams, mg or micrograms, ug) per mass of soil (kilogram, kg). This is written as mg/kg or ug/kg. Sometimes concentrations in soil are reported as parts per million (ppm) or parts per billion (ppb). Parts per million and parts per billion may be converted from one to the other using this relationship: 1 part per million = 1,000 parts per billion.

For soil, 1 ppm = 1 mg/kg of contaminant in soil, and 1 ppb = 1 ug/kg. A measurement of 6 mg/kg is the same as 6 ppm or 6,000 ppb, which is equal to 6,000 ug/kg.

Concentrations in Water

Concentrations of chemicals in water are typically Measured in units of mass of chemical (milligrams, mg or micrograms, ug) per volume of water (liter, L, l).

Concentrations in water can also be expressed as parts per million (ppm) or parts per billion (ppb). Parts per million and parts per billion may be converted from one to the other using this relationship: 1 part per million = 1,000 parts per billion.

For water, 1 ppm = approximately 1 mg/L (also written as mg/l) of contaminant in water, and 1 ppb = 1 ug/L (also written as ug/l). A measurement of 6 mg/L is the same as 6 ppm or 6,000 ppb, which is equal to 6,000 ug/L.

A way to visualize one part per billion (ppb) in water is to think of it as one drop in one billion drops of water or about one drop of water in a swimming pool. One part per million is about 1 cup of water in a swimming pool.

The metric system is commonly used to express most test results. This is convenient since metric units go by multiples of ten. 1 ppm = 1 μg/g.

- a gram is a thousandth of a kilogram (1g = 1,000kg)
- a milligram is a thousandth of a gram (1mg = 0.001g)
- a milligram is also a millionth of a kilogram (1mg = 1,000,000kg)
- a milligram is one part per million of a kilogram, which is the same as one milligram per kilogram: 1 ppm = 1 mg/kg

With the ability and need to detect even smaller amounts of contaminants, the terms part per billion and part per trillion are becoming more commonly seen. Extremely toxic chemicals such as dioxin are often analyzed at the parts per trillion level.

Occasionally, concentrations of chemicals in water may be written as grams per cubic meter (g/m^3). This is the same as grams per 1,000 liters, which may be converted to milligrams per liter (mg/L). Therefore, 1 g/m^3 = 1 mg/L = 1 ppm. Likewise, one milligram per cubic meter (mg/m^3) is the same concentration in water as one microgram per liter (ug/L), which is about 1 ppb.

Concentrations in Air

Concentrations of chemicals in air are typically measured in units of the mass of chemical (milligrams, micrograms, nanograms, or picograms) per volume of air (cubic meter or cubic feet). However, concentrations may also be expressed as parts per million (ppm) or parts per billion (ppb) by using a conversion factor. The conversion factor is based on the molecular weight of the chemical and is different for each chemical. Also, atmospheric temperature and pressure affect the calculation.

Typically, conversions for chemicals in air are made assuming a pressure of 1 atmosphere and a temperature of 25 degrees Celsius. For these conditions, the equation to convert from concentration in parts per million to concentration in milligrams per cubic meter (mg/m^3) is as follows:

Concentration (mg/m^3) = 0.0409 x concentration (ppm) x molecular weight

To convert from mg/m^3 to ppm, the equation is as follows:

Concentration (ppm) = 24.45 x concentration (mg/m^3) ÷ molecular weight

The same equations may be used to convert micrograms per cubic meter (ug/m^3) to parts per billion (ppb) and vice versa:

Concentration (ug/m^3) = 0.0409 x concentration (ppb) x molecular weight

Or, concentration (ppb) = 24.45 x concentration (ug/m^3) ÷ molecular weight

Here is an example. The molecular weight of benzene is 78. If the concentration of benzene in air is 10 mg/m^3, convert to the units of ppm by multiplying 24.45 x 10 mg/m^3 ÷ 78 = 3.13 ppm.

Note: Sometimes you will see chemical concentrations in air given in concentration per cubic feet (ft^3) instead of concentration per cubic meter (m^3). The conversion from cubic feet to cubic meter and vice versa is as follows: 1 ft^3 = 0.02832 m^3 and 1 m^3 = 35.31 ft^3.

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