Pest Education Services & Training

UNITS USED IN FUMIGATION

There are three principal measurements of concentration of interest in fumigation. Confusingly these are all measured in different units.

- Concentrations of fumigants around the levels used to kill pests – typically measured in grams of fumigant per cubic meter of air (g/m^3 or $g\ m^{-3}$)
- Concentrations at levels that may affect human health – typically measured in parts per million by volume of fumigant per total volume of gas (air + fumigant) (ppm v/v)
- Concentrations of residues on the treated product – typically measured either as parts per million by mass of residual fumigant or reaction product per weight of treated material (ppm w/w) or milligrams of residual fumigant or reaction product per milligram of treated material (mg/kg).

Toxicity to humans or test animals may also be given in mg/kg.

Examples of use of these measures:

- A methyl bromide dosage rate – 48 g/m^3
- A maximum workspace concentration (TLV) for phosphine – 0.3 ppm v/v
- A residue limit for bromide ion arising from a methyl bromide fumigation – 50 ppm w/w.

Some other units of concentration for fumigants in air will sometimes be encountered. Conversions are given below:

- 1000 micrograms per cubic metre ($\mu g/m^3$) = 1 g/m^3
- 1 milligram per litre (mg/L) = 1 g/m^3
- 1 pound (avdp.) per cubic foot = 16 g/m^3
- 1 ounce (avdp.) per cubic foot = 1 g/m^3.

Pounds per cubic foot (lb/cu. ft) are used as a measure of fumigant dosage in older Australian schedules (and some modern US ones) and traces are still present in modern dosage rates. Thus, dosage rates are often given in multiples of 16g/m^3, corresponding to 1 lb/cu. ft (e.g. 48g/m^3, formerly 3 lb/cu. ft).

This all looks quite simple, but this is deceptive. For residues, mg/kg is numerically the same as ppm w/w, but for gases g/m^3 is **not** the same as ppm v/v, or even directly convertible, except at a fixed temperature and pressure, and the conversion factor varies with the different fumigants.

'parts per million, v/v' is the volume occupied by the gas (fumigant) per million parts of total gas (essentially, air). Because both components, fumigant and air, are gases the proportion, and thus 'ppm v/v', remain unchanged when the temperature and/or the pressure of the mixture changes (all gases behave approximately the same when heated, cooled, compressed or expanded around normal ambient temperatures).

This contrasts with g/m^3, where if the temperature increases or the pressure drops, both causing expansion of the gas, the concentration falls (?where does it go?). This is because the same mass of gas is now dispersed over a larger volume. An example of this change is given below. If the temperature falls or the pressure rises, the concentration rises, as the volume containing the fixed quantity of fumigant is now smaller.

Example:

If a cubic metre of air containing fumigant (e.g. methyl bromide), originally at 48 g/m^3 and 20C, 760 mm Hg , is heated to 30C and the atmospheric pressure falls to 750 mm Hg, what is the new concentration per cubic metre?

The combined gas laws say:

$$p_1.V_1/T_1 = p_2.V_2/T_2,$$

where *p, V* and *T* are the pressure, volume and absolute temperatures at the initial (subscript 1) and final (subscript 2) conditions.

Thus:

$$(760 \times 1)/(20 + 273) = (750 \times V_2)/(30 + 273),$$

giving

$$V_2 = 760(30+273)/750(20+273) = 1.0479 \text{ m}^3.$$

But originally there was 48 g of fumigant in 1.0 m^3, and the same quantity is now in V_2 (1.0479 m^3).

So the new concentration is:

$$48/V_2 = 48/1.0479 = 45.8 \text{ g/m}^3.$$

Historically, health concentrations for humans, and gas toxicity generally for warm blooded animals, has been expressed in ppm v/v, while fumigators apply fumigant by weight into a known volume (we hope). There are good practical and theoretical reasons for both of these.

Indicator tubes are often used for measuring health concentrations of fumigants. Typically, they have a scale marked in “ppm”, related to the health concentration set in ppm v/v. High range indicator tubes, for measuring concentrations in the fumigation range can also be calibrated in “ppm” (e.g. Dräger high range phosphine tubes). As a carryover from this, many electronic instruments for measuring phosphine concentrations indicate in “ppm” and some phosphine labels even are set in “ppm” (e.g. Siroflo label).
For conversion of fumigant concentrations to the more convenient and understandable g/m^3 units, it is usually sufficient to use the conversion factors given in Table 1, below. For accurate scientific work in fumigation, it is necessary to recalibrate instruments and indicator tubes that read in “ppm” to g/m^3, and take pressure and temperature of the gas samples into account.

Table 1. Conversion factors for g/m3 and ppm v/v for various fumigants at 25C, 760 mm Hg (from Bond 1984).

Fumigant	Concentration in g/m3	Equivalent conc. in ppm v/v
Hydrogen cyanide	1.0	905
Methyl bromide	1.0	257
Phosphine	1.0	718
Sulphuryl fluoride	1.0	240