UNITS FOR CO_2 CONCENTRATIONS

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Expressing CO_2 concentrations in parts per million does not take into account Colorado's high altitude. The result is a failure to take maximum advantage of Colorado's unique climate and less money in the till.

The usual expression for CO_2 concentration is parts per million (ppm), percent volume (%) or micrograms per liter ($\mu g\ 1^{-1}$). These units are relative, not absolute, and do not take into account the fact that atmospheric pressure at this elevation (one mile above sea level) is much less than at sea level. As most well know, the lowered pressure reduces exhaust fan capacity, combustion efficiency in heaters and boilers, and causes health problems for people sensitive to low oxygen — especially above the timberline (about 9000 feet). Now 325 ppm (the usual CO_2 concentration) at one mile high is the same as 325 ppm at sea level, but, as pointed out above, higher altitude means less air, and the absolute concentration of each gas in the air is reduced proportionately. The number of gas molecules per unit volume is less as elevation increases until the point is reached where life cannot be supported and you go to a space suit.

There are several ways to express absolute gas concentrations:

1. millimoles per cubic meter (mmol m^{-3}),
2. milligrams per cubic meter (mg m^{-3}),
3. millibars (mb),
4. Pascals (Pa), or
5. dynes per square centimeter (dynes cm^{-2}).

The last three are pressure units (e.g. pounds per square inch or psi) — what the physical chemist calls "partial" pressure — since, if the gas behaves ideally, the pressure of one gas in air is independent of the pressures of all other gases in air (e.g. oxygen, nitrogen, pollutants, etc.).

The total atmospheric pressure at sea level can be expressed as:

1. 14.7 pounds per square inch (psi),
2. 29.9 inches of mercury,
3. 760 mm mercury,
4. 1013.3 millibars, or
5. 101337.1 Pascals.

This pressure, measured by a barometer, varies with location and weather. However, when a scientist speaks of "standard conditions" (STP or NTP), he uses the units given above. At Fort Collins, we generally assume the total barometric pressure, or station pressure, as 635 mm mercury or 846.6 millibars, 846600 Pascals, or 24.8 inches mercury. This is about 16% less than at sea level. It means that, in a natural convection gas burner, one will get about 840 BTU from a cubic foot of gas compared to 1000 BTU at sea level, and the rating capacity of an exhaust fan must be reduced 1.2 times in order to obtain the actual air flow with fan-and-pad cooling.

What does this pressure difference due to elevation mean in terms of the actual CO_2 a grower may have available inside his greenhouse when he is ventilating? By using some high school physics, the absolute concentration of 335 ppm CO_2 at sea level and 32°F (STP) is 33.9 Pascals. At Fort Collins' or Denver's altitude and 32°F, however, the actual CO_2 concentration is 26.6 Pascals. We have been using this reporting method in our computer system at CSU. Employing the factory calibration for percent CO_2 on our gas analyzer, we have been getting lower concentration readings when the greenhouses are ventilating. We plan to do further calibration and checking on the ranges we are observing. We know, under Colorado conditions in the winter, CO_2 levels can go below 100 ppm (7.9 Pascals at Denver versus 10.1 at San Diego). A grower in Colorado who fails to employ CO_2 injection under non ventilating conditions in Colorado will significantly reduce his climatic advantage, reduce yield and quality, and make less money.