

Carbon Dioxide, Indoor Air Quality, and Plants

A Technical Note by Dr. Alan Darlington



Plant are living, growing organisms. In several ways, many of their basic physiological processes are very similar to other live forms such as humans.

System Description

The biofilters appear as vertical hydroponic green walls containing a wide range plants specifically selected for each site. However, the plant wall is actually an integrated part of the handling system for the building.

Air is actively forced through the wall of plants and highly specialized biological components actively degrade pollutants such formaldehyde and benzene in the air into their benign constituents of water and carbon dioxide. The clean air is then distributed throughout the building.

Issue

Plants give off CO₂ through respiration and are able to fix the same chemical through photosynthesis but CO₂ is a factor in indoor air quality (IAQ). So can plants influence IAQ by their impact on IAQ?

The Background

CO₂ and IAQ

The most common indoor gaseous contaminant is carbon dioxide (CO₂), with the occupants as its principle source. While atmospheric CO₂ levels are about 400 ppm, concentration in exhaled air is roughly 100 times higher (i.e. 40,000 ppm). Hence, CO₂ levels can quickly rise in sealed, occupied environments. Since elevated CO₂ concentrations have been linked with drowsiness and reduced productivity, most government regulations stipulate maximum allowable CO₂ concentrations of less than 1000 ppm higher than background levels (ASHRAE 1999). Furthermore, since it is easily measured, the indoor CO₂ concentration is commonly used to indicate the potential for other gaseous pollutants to accumulate within the indoor environment. Therefore, CO₂ is commonly used in determining ventilation rates in occupied spaces.

Plants and CO₂

Plant are living, growing organisms. In several ways, many of their basic physiological processes are very similar to other live forms such as humans. For example, plants 'respire' the same as people, in that they breakdown materials such as simple sugars into CO₂ and water to generate the energy they need to live. Oxygen is consumed as part of the reaction to release the energy from sugars. So, plants like people, consume O₂ and give off CO₂.



Plants do give off CO₂ as part of their normal physiological activity but it is frequently concurrent with photosynthesis.

What makes plant special is that they also possess the ability to carry out photosynthesis. With this chemical 'trick', the plants use light energy to combine CO₂ and water (H₂O) to form carbohydrates (CH₂O). A byproduct of the reaction is the release of oxygen (O₂). While respiration occurs fairly constantly in the plant, photosynthesis rates are heavily influenced by light levels. The more light; the more photosynthesis and the corollary of this is, the lower the light; the lower the photosynthetic rate.

What does it mean for plants and IAQ?

Plants as a source of CO₂ in indoor spaces.

Plants do give off CO₂ as part of their normal physiological activity but it is frequently concurrent with photosynthesis. Under good light conditions, the amount of CO₂ released by respiration is inconsequential compared the amount that is being fixed through photosynthesis. The system has a net fixation of carbon; the plants 'grow' in size with the increase in carbon resources. The fact that the plant wall needs to be pruned routinely is an indication this net accumulator of CO₂. Much of the material that pruned off the wall is carbon fixed through photosynthesis.

However, the light level can be reduced to the point where the resulting fixation of CO₂ by photosynthesis is just enough to compensate for the CO₂ released by photosynthesis (hence this light level is called the light compensation point). The light compensation point varies with plant species and a number of other conditions but typically would below 70 footcandles. Since light conditions in many situations is cyclic, plants may spend part of their day below the light compensation point. During this time, they would release more CO₂ than they are fixing. They would become a source of CO₂.

This reversal in the carbon flux through the plants is typically inconsequential indoors for a couple of reasons. First, the rate of CO₂ release by the plants is very low. Only a very small portion of what we call a 'plant' is actively engaged in respiration. Most of the plant is nothing more than wood (fibre) and water, which not really 'alive'. For a 100m² plant wall, the actual amount of material truly engaged in respiration would be considerably less than the respiration of one person. So, plants may increase CO₂ levels at night but it is not a substantial amount.



It is unrealistic that indoor plants are capable of significantly reducing CO₂, despite being a common marketing tool used to sell interior plants

Second, the amount of carbon released at night has to be substantially less than the amount fixed during the day or else the plant could not survive. The fact the plants are thriving in the environment despite diurnal fluctuations in light levels is an indication that the release is minor compared to the amount fixed

Plants as a sink of CO₂ in indoor spaces.

Green plants remove atmospheric CO₂ through the process of photosynthesis. This potential for plants to remove CO₂ is a common marketing tool used to sell interior plants. However, it is unrealistic that indoor plants are capable of significantly reducing CO₂. This is mainly due to low light levels in the indoor environment; which are often at or very near the photosynthetic compensation point of most common indoor plants. The light levels seen indoors even under artificially light conditions is not enough for optimum photosynthesis.

A corollary argument has been made that indoor plants can increase O₂ concentration and thus contribute to the enhancement of IAQ. However, the process of photosynthesis exchanges CO₂ for O₂ in roughly molar equivalent rates. Even if plants could exchange 100% of the ambient CO₂ (400ppm) for O₂ this would have an insignificant effect on the much higher ambient O₂ concentration; which is roughly 210,000 ppm.

Plants have been used in sealed life support system as a source of O₂ and sink for CO₂. It is generally accepted to be used as a sealed system, over 10 m² of plant surface area under full sunlight would be required per person. This is over 50 times larger and under lights 75 times brighter than what is used in the biofilters. It's very interesting to note that, the biofilters are far more effective at removing known carcinogens such as benzene or formaldehyde than the fairly benign contaminant CO₂.