Soil Gas

by Dave Potts, Mike Schaefer, and Will Schnell

Turfgrass managers have long realized the benefits of root zone aeration. Considerable resources have been directed toward maximizing air/soil gas exchange levels to promote overall plant health and stamina. Recent technological advancements now permit these aeration levels to be accurately quantified.

What is air?

Air is: nitrogen (78.08%), oxygen (20.95%), argon (0.93%), carbon dioxide (0.03%), neon (0.0018%), helium (0.0005%), krypton (0.0001%), and xenon (0.00001%). Air also contains water vapor, hydrocarbons, hydrogen peroxide, sulfur compounds, and dust particles.

What is soil?

Like air, soil is comprised of components: minerals, organic matter (both living and dead), water, and gasses. The percentage of each varies with soil texture and structure. In a typical sand-based root zone, the ratio between space occupied by solids and pore space is close to 1:1. This pore space consists of both soil gasses and water as illustrated in Figure 1.

Why are soil gas concentrations different than those in air?

To a large degree, soil gasses are produced through plant and microbial metabolic processes. Aerobic metabolism is fueled by the presence of organic matter, oxygen, and moisture. Byproducts include water and carbon dioxide. This process accelerates as temperature increases.

In the soil, gasses exchange at a relatively slow rate, principally by diffusion or displacement of fluids (liquid and gaseous). Carbon dioxide builds up in the root zone and resides there until it is influenced by one of these mechanisms.

As oxygen is consumed through the metabolic processes, carbon dioxide is produced. The concentration of carbon dioxide increases and the concentration of oxygen decreases proportionately.

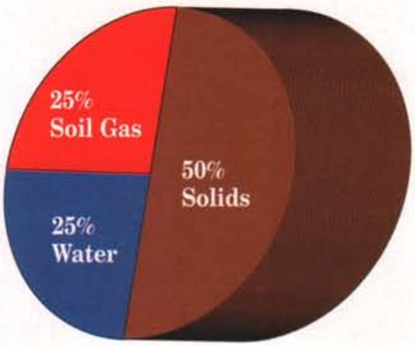
This ultimately limits the activity of aerobic organisms within the root zone. If oxygen continues to be depleted, anaerobic metabolic processes will begin to dominate. This results in the production of methane, hydrogen sulfide, and other toxic gasses.

What factors govern soil gas formation?

Many variables influence the composition of soil gas. These include, but are not limited to the following:

• *Temperature:* In general, oxygen demand increases with temperature. Most microorganisms living in soil are mesophilic; they grow best at 25°C. However, mesophiles will continue to grow at temperatures as low as 15°C, and as high as 35°C.

Figure 1. Typical solid:fluid ratio in a sand-based root zone.



Cool-season grasses have an optimum temperature range of 27-35°C. When soil temperatures approach the high and low extremes of the 15-35°C range of mesophile growth, a decrease or cessation of biological activity results. Additionally, temperature gradients that develop between soil and atmosphere create thermal diffusion.

• *Soil Moisture Content:* Moist soils have a lower gas diffusion rate than drier soils. When soils are saturated, oxygen diffusion is limited to the solubility at a given temperature.

For instance, at 15°C the solubility of oxygen in water is 0.001%. By comparison, the concentration of oxygen in air is 20.95%.

Soil moisture is also a good thermal conductor and can greatly affect soil temperature. Conversely, dry soils contain a higher percentage of gasses, which are more efficient insulators.

• *Organic Matter:* Organic matter provides an energy source for soil microbes and plants. Microbial action is instrumental in the decomposition and mineralization of organic matter into phosphorous and nitrogen, which makes it available for plant uptake. When this metabolic process occurs, oxygen is consumed and carbon dioxide is produced.

• *Soil Permeability:* Low-permeability soils have correspondingly low gas diffusion rates; high-permeability soils have high gas diffusion rates. When diffusion is limited, oxygen is consumed more rapidly than it is replaced. Consequently, carbon dioxide concentrations increase.

• *Wind:* When winds of relatively high velocities are directed into soil, a differential pressure gradient develops. This pressure gradient results in the exchange of soil gas with air.

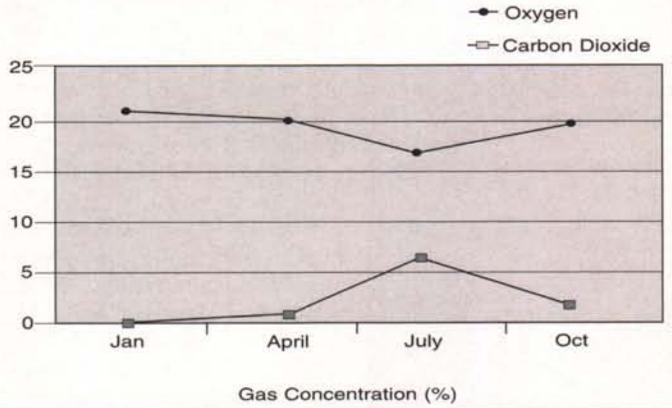
Forward Motion

Do seasonal changes affect soil gas concentrations?

When soil gas data is compiled over the long term, certain trends become evident. These trends are indicative of how weather patterns, biological activity, and plant growth interrelate.

In New England, temperature extremes are common. Average winter temperatures fall into the single digits, and summer temperatures routinely climb above 90°F. Figure 2 illustrates the respective concentrations of carbon dioxide and oxygen in the root zone at Dodd Stadium in Norwich, CT, throughout 1996.

Figure 2. Dodd Stadium's 1996 Seasonal soil gas concentrations



Dodd measured root depth in conjunction with soil gas analysis. As Figure 2 shows, rooting is deepest in the spring and fall, and most shallow in the summer. Also, oxygen concentrations decrease with warmer weather and the concentration of carbon dioxide increases.

During midwinter, the concentrations of these two gasses within the root zone are similar to the concentrations found in air. This coincides with the cessation or reduction of biological activity.

During the summer months, as biological activity increases with temperature, carbon dioxide concentrations of 7.0% and oxygen concentrations as low as 11.0% have been measured in the root zone. While 7.0% carbon dioxide may not sound like much, it is 233 times the level found in air. At 11.0%, the concentration of oxygen in the soil is only about half the level found in air.

In the summer of 1997, the crew at Dodd Stadium made a concerted effort to maintain 20.95% oxygen and 0.03% carbon dioxide in the root zone. A SubAir blower attached to the drainage system stabilized gas levels. Rooting depth remained consistent in the root zone and underlying gravel throughout the growing season, even during the hottest part of the summer. In addition, aerating the soil prevented the accumulation of excess organic matter.

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What techniques are available to monitor soil gas conditions?

It is indisputable that turfgrass roots flourish in core holes through the presence of air. Recently developed infrared technology allows turfgrass managers to perform root zone gas sampling and analysis.

This equipment enables managers to better determine when to aerate. It quickly and accurately determines soil gas concentrations of oxygen, carbon dioxide, methane, and hydrogen sulfide. If the carbon dioxide concentration in the soil is 0.03% and the oxygen concentration is 20.95%, there is no need for aeration. When the concentrations of these gasses deviate from these values, it is time to aerate.

Dodd Stadium made a concerted effort to maintain 20.95% oxygen and 0.03% carbon dioxide in its turf's root zone.
Courtesy: SubAir

There are still many questions that remain unanswered. More research into the myriad of variables involved in root zone management is certainly warranted. However, the bottom line remains the same: where air, moisture, and nutrients are present in desired quantities, root growth and plant vigor will be strong. ❑

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