Applications and Uses of Oxygen Sensors

About Apogee Oxygen Sensors

Apogee Oxygen Sensors are galvanic cell sensors that have a lead anode, a gold cathode, an acid electrolyte and a Teflon membrane. The current flow between the electrodes is proportional to the oxygen concentration being measured. An internal bridge resistor is used to provide a mV output. Being a galvanic cell type Oxygen Sensor, a small amount of oxygen is consumed in the reaction in order to produce the current flow and subsequent mV output. The oxygen consumption was measured to be 2.2 ?mol O_2 per day when the O_2 concentration was 20.95 percent (3240 mmol) at 23°C.

The mV output responds to the partial pressure of oxygen in air. The standard units for partial pressure are kPa. However, gas sensors that respond to partial pressure are typically calibrated to read out in mole fraction of the gas in air, which has units of moles of oxygen per mole of air. These units can be directly converted to percent O_2 in air or ppm O_2 in air.

Gas sensors read out in percent because this value does not change with temperature or pressure. The concentration of oxygen in our atmosphere is 20.95%, and this value, to 4 significant digits, has not changed for decades. This means that we are surrounded by calibration gas for this sensor (provided you are not breathing on the oxygen sensor when it is being calibrated. Our exhaled breath is about 17 percent oxygen).

Soil Respiration

Apogee oxygen sensors can be used in conjunction with carbon dioxide sensors to help improve the characterisation of soil respiration. Typically, soil oxygen sensors use a galvanic cell to produce a current flow that is proportional to the oxygen concentration being measured. These oxygen sensors are buried at various depths to monitor oxygen depletion over time, which is then used to predict soil respiration rates. Apogee oxygen sensors are equipped with a built-in heater to prevent condensation from forming on the permeable membrane, as relative humidity can reach 100 percent in soil.

Cited Works and Case Studies Using Apogee Oxygen Sensors

Case Studies

Dr. Wendy Yang's Global Change Ecology Lab, at the University of Illinois at Urbana-Champaign, is currently using the Apogee SO-110 oxygen sensor, with the optional diffusion head, for quasi-continuous measurements of bulk soil oxygen concentration in managed and natural ecosystems. Their quasi-continuous field measurements of soil oxygen has allowed them to correlate soil oxygen concentrations with process rates and determine how soil oxygen concentrations relate to precipitation and soil temperature, which can drive high biological oxygen demand to induce anoxia. The Apogee SO-110 allows Dr. Wendy Yang's Global Change Ecology Lab to collect long-term data sets in the field without fear of compromising the sensors under harsh conditions, due to the sensors ability to withstand cold winter temperatures and wet conditions.

Oxygen is a major control for reduction-oxidation reactions in soil and can lead to the production or consumption of methane and nitrous oxide, both potent greenhouse gases. Processes such as methanogens and nitrous oxide reduction to dinitrogen were once thought to be restricted to flooded or saturated soils such as those found in wetlands, however, Dr. Wendy Yang's lab has documented the importance of these processes in unsaturated soils from upland ecosystems. Their measurements have allowed them to correlate soil oxygen concentration with process rates and determine how soil oxygen concentrations relate to precipitation and soil temperate, even under saturated soil conditions. They are currently investigating these relationships in agricultural fields in the Midwest to better understand how current land management and historical soil drainage patterns mediate soil greenhouse gas emissions.

Works Cited

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- The best understood method of lignin breakdown if by dioxygenases in fungi, which generally require oxic conditions provided by soil respiration. In the quest for a robust, effective and inexpensive method of breaking down lignin for use in biofuels, this article investigates the role of anaerobic microorganisms in the tropical rain forests of Puerto Rico. Apogee sensors were used to measure the soils oxygen concentration around bio-traps used to study the organisms responsible for this breakdown, and the data collected "suggests that in low fluctuating redox soils, bacteria could play a role in anaerobic lignin degradation."
  [Link] DeAngelis, K.M., Allgaier, M., Chavarria, Y., Fortney, J.L., Hugenholtz, P., Simmons, B., Sublette, K., Silver, W.L.,

and Hazen, T.C. (2011). Characterization of Trapped Lignin-Degrading Microbes in Tropical Forest Soil. PLoS ONE 6, e19306.

- This article explores the biogeochemical potential of Earth's driest exosystem, the Atacama Desert, arid and semi-arid soils with extremely low levels of organic carbon and moisture. Apogee sensors were used to determine if the soils were anoxic or oxic during their experiments. The study data show that more CO_2 was produced under oxic conditions than in sub-oxic conditions in soil sites with existing vegetation and therefore higher C concentrations, which suggests the presence of aerobic microbial decomposers. This is in contrast with the most arid and lowest carbon sites where CO_2 production is predominantly abiotic.
  [Link] Hall, S.J., Silver, W.L., and Amundson, R. (2012). Greenhouse gas fluxes from Atacama Desert soils: a test of biogeochemical potential at the Earth's arid extreme. Biogeochemistry 111, 303–315.

- This study compares two types of oxygen sensors, galvanic and chemi-luminescent, for use in monitoring soil air oxygen in flood-irrigated Pecan orchards. Apogee's galvanic oxygen sensors with the diffusion head accessory were deployed at multiple depths and continuous data was collected. The spectrometer–coupled chemical sensor was used to field analyze gas samples from diffusion chambers. "The responsiveness of the galvanic sensor and its capability to continuously gather hourly data makes it superior to methods dependent on manual sample collection. Galvanic sensors were adequately suited for long-term in situ use in agricultural soil when housed in appropriate diffusion chambers."
  [Link] Kallestad, J.C., Sammis, T.W., and Mexal, J.G. (2008). Comparison of Galvanic and Chemi-Luminescent Sensors for Detecting Soil Air Oxygen in Flood-Irrigated Pecans. Soil Science Society of America Journal 72, 758.

- Temporal and spatial patterns in soil redox are not well understood and this study investigates these variations in tropical forests. Soil air oxygen levels, measured with Apogee sensors, were found to be significantly lower in upper elevation cloud forest than in lower elevation wet tropical forest, where interestingly the concentration of oxygen changed as much as 10 % in one day.
  [Link] Liptzin, D., Silver, W.L., and Detto, M. (2011). Temporal Dynamics in Soil Oxygen and Greenhouse Gases in Two Humid Tropical Forests. Ecosystems 14, 171–182.

- [Link] Phillip, E. (2009). A Pilot-Scale Compost Reactor for the Study of Gaseous Emissions from Compost (Rena, Nevada). ASABE Meeting.

- [Link] Raciti, S.M., Burgin, A.J., Groffman, P.M., Lewis, D.N., and Fahey, T.J. (2011). Denitrification in Suburban Lawn Soils. Journal of Environment Quality 40, 1932.

- [Link] Rubol, S., Silver, W.L., and Bellin, A. (2012). Hydrologic control on redox and nitrogen dynamics in a peatland soil. Science of The Total Environment 432, 37–46.

- [Link] U, K.T.P., Xu, L., Ideris, A.J., Kochendorfer, J., Wharton, S., Rolston, D.E., and Hsiao, T.C. (2006). Simultaneous Carbon Dioxide and Oxygen Measurements to Improve Soil Efflux Estimates.