An oxygen sensor for continuous long-term measurement of soil respiration

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Continuous Soil Carbon Dioxide and Oxygen Measurements and Estimation of Gradient-Based Gaseous Flux

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CH₂O + O₂ → CO₂ + H₂O

Advantage of measuring CO₂

\[ \frac{O₂}{CO₂} = \frac{20.95\%}{0.04\%} = 520 \times \]

Advantage of measuring O₂

CO₂ is 30 times more soluble in water than O₂
CO$_2$ is 30 times more soluble in water than O$_2$.
Respiratory quotient: \( \frac{\text{CO}_2}{\text{O}_2} \)

- Carbohydrate = 1.0
- Protein = 0.8
- Fat = 0.6
- Lignin = 0.2

Nitrification:

\[
\text{NH}_4^+ + 2\text{O}_2 \rightarrow \text{NO}_3^- + 2\text{H}^+ + \text{H}_2\text{O}
\]

RQ = 0.0
Factors affecting gas concentration in soil

- Temperature
  - gas / liquid partitioning
  - effect on molar density and sensor electronics
Factors affecting gas concentration in soil

- Humidity

H₂O
Effect of Temperature and Humidity on $O_2$ Concentration in Air

Relative $O_2$ Concentration [%]

Temperature [°C]

100% Relative Humidity Correction Coefficients

$C_0 = 1.506 \times 10^{-1}$
$C_1 = 1.044 \times 10^{-2}$
$C_2 = 4.224 \times 10^{-4}$
$C_3 = 2.858 \times 10^{-6}$
$C_4 = 1.527 \times 10^{-7}$
Factors affecting gas concentration in soil

- Atmospheric pressure
Effect of Barometric Pressure on Reading From O₂ Sensor at 1455 m Elevation

Ideal Gas Law Effect (PV=nRT)

Typical Annual Range

20.95 % O₂

Barometric Pressure [kPa]

Apparent O₂ Concentration [%]
These graphs illustrate the oxygen concentration in dry and wet sand over a period of days, recorded by a soil sensor and a fast-response sensor. The top graphs show the uncorrected oxygen concentration, while the bottom graphs display the corrected oxygen concentration. The data indicates variations in oxygen levels, which may be influenced by environmental factors such as temperature and moisture content.
Figure 3: $\text{O}_2$ Sensor Long-Term Stability

- **Soil Sensor**
  - Response Time: 60 seconds
  - Signal Decrease: 0.08 mV per year
    ($< 0.2\%$ per year)

- **Fast-Response Sensor (Flow-Through Applications)**
  - Response Time: 12 seconds
  - Signal Decrease: 0.4 mV per year
    ($4\%$ per year up to 5 years)