C-sense™ in situ pCO_2 Sensor

Application Note
How the C-sense probe is used for measuring pCO_2 in water

Background

Carbon dioxide can enter the water through multiple pathways. Some primary land sources can include decay of organic matter, dissolution of carbonate rocks, wastewater discharge, and watershed draining. Other natural sources include biological respiration, sediment diagenesis, or volcanic activity. A major source/sink of CO_2 is atmospheric exchange at the air/water interface. Simply, carbon dioxide gas dissolves in water:

$$\mathbf{CO_2(g) \leftrightarrow CO_2(aq)}$$

And according to Henry's law of solubility, which states the solubility of a gas in a liquid is directly proportional to the partial pressure of the gas above the liquid, we can estimate the CO_2 concentration in water by measuring the partial pressure of carbon dioxide (pCO_2):

$$\mathbf{pCO2 = [CO2]aq / Solubility}$$

With current atmospheric CO_2 levels surpassing 400 ppm, compared with recorded values of ~300 ppm around 1960 (more than 30% increase), we expect seawater levels to have higher concentrations because carbon can be trapped within water layers. These isolated layers are limited from atmospheric equilibration/exchange leading to a buildup of CO_2 that can slowly diffuse across gradients or quickly mix through the water column.

An increase in pCO_2 concentrations in water causes a drop in pH. As many biological, chemical, and physical processes are pH dependant, sudden or rapid changes in pH may have adverse effects on the regulation of these processes. Along with pH effects, high levels of CO_2 have been shown to be detrimental to the development of certain organisms such as finfish, shellfish and other calcifying organisms, including phytoplankton.

Technology

Turner Designs offers the C-sense probe for measuring the partial pressure of CO_2 in water, providing users with a way to estimate dissolved CO_2 levels in water samples or systems. C-sense uses a sensitive membrane that allows CO_2 gas to pass into a chamber where it is then accurately measured. The resulting value is output as a voltage from 0 – 5 volts, proportional to and representing an estimate of the amount of CO_2 gas in the water sample analyzed. As a low power analog output instrument, C-sense can easily be integrated to any third party system, CTD or datalogger that accepts a 0 – 5 volt signal and provides 6 – 12 volt DC power. The C-sense probe can be manufactured to accommodate one of three different concentration ranges:

Range	MDL (3% of full range)	Part Number
0 – 1000 ppm	30 ppm	2400-001
0 – 2000 ppm	60 ppm	2400-002
0 – 4000 ppm	120 ppm	2400-004

Optional accessories include a water-pumped head & copper cutouts to minimize biofouling.

Applications

There are numerous research groups within government, industrial, and academic organizations that can benefit from the C-sense probe. Below are a few examples of how and why C-sense could be used:

Aquaculture

Aquaculture, the farming of aquatic organisms such as fish and mollusks involves cultivating marine or freshwater populations under controlled conditions to provide food for people and, on a smaller scale, supply fish for stocking lakes, and bait for fishing.

High CO_2 levels in finfish, a popular farmed fish, have been linked to poor growth, development, and ion regulation. Recent findings have shown that CO_2 levels below 2000 ppm should be maintained, specifically for finfish, but levels as low as 500 ppm should be kept for most fish farms to maximize farm efficiency and maturity of stock.

Shellfish are extremely sensitive to changes in CO_2 because they require calcification for the creation of a shell. High CO_2 levels inhibit precipitation of calcium carbonate affecting normal development of shellfish increasing mortality rate and ultimately leading to closure of these types of farms.

http://www.thelivingocean.net/2012/10/all-about-aquaculture.html

http://www.waikatoregion.govt.nz/Environment/Natural-resources/coast/Coastal-pressures/Marine-farming/

The low cost C-sense probe can easily be used to monitor aquaculture farms, both open water and tanks, ensuring water quality characteristics, namely CO_2, are within desired levels or warning aquaculture scientists of changing CO_2 levels within a farm.

Wastewater Monitoring

Keeping our waterways and coastal environments free of wastewater contamination is a growing problem. There is a detectable increase in wastewater dumping corresponding to the increase in human populations and densification of coastal, lake and riverine areas. An important step in mitigating or predicting harmful situations is to monitor and decrease the amount of wastewater dumped into aquatic habitats.

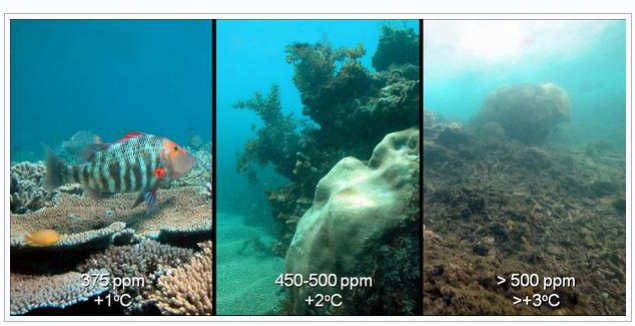
Wastewater isn't a specific material; rather, it is composed of multiple materials sometimes making it difficult to distinguish from other water types. However, wastewater does have certain characteristics such as high organic loading, which can result in rapid decay and production of pCO_2 upwards around 10,000 ppm, for certain holding ponds. Those CO_2 levels are 20x the typical CO_2 levels found in natural water. If leaked into natural waterways such as estuaries, rivers, or lakes, these systems and the organisms contained within can be greatly impacted changing the dynamics or the productivity of that aquatic habitat.

http://knowledge.allianz.com/environment/climate_change/?2270/Record-CO2-highs-back-to-the-climate-future

C-sense can be used to warn of the potential for these types of harmful situations and help indicate to researchers the need for employing mitigating processes in an effort to reduce CO_2 levels if they become too high; some countries require monitoring of wastewater to earn credits towards carbon tax.

Reef Monitoring

Reefs provide protection and food for many aquatic organisms and help with diversification of near shore environments. They're also great tourist attractions generating income for surrounding residential and business owners. Ocean acidification attributed to increasing atmospheric CO_2 levels can greatly impact organisms such as corals that highly depend on calcification for building these reefs. Also, because of their proximity to land, anthropogenic eutrophication, which results in high degree of CO_2 loading, may significantly speed up the acidification process in a body of water, affecting and even degrading coral reefs.



Monitoring reefs or rivers and other water flows that spill into near shore environments using C-sense can give a good indication of expected change in a reef system. This can inform regulators to redirect, slow, or better control anthropogenic input to maintain the integrity of these habitats.

CCS Monitoring

Carbon Capture Storage (CCS) is the action of pumping carbon dioxide into deep saline aquifers for the purpose of removing carbon from surface waters or the atmosphere. These deep waters are isolated from carbon exchange deeming them one of the major sinks for CO_2. The aquifers can reach up to 10% CO_2 (100,000 ppm), more than 200x atmospheric levels. To ensure the CO_2 remains at depth, monitoring of aquifers, ground and surface waters is critical. C-sense's accuracy, low cost, and robustness can greatly aid this monitoring effort as a detection tool for ensuring CO_2 remains sequestered.

Bio-Fuels

The bio-fuels industry utilizes atmospheric CO_2 to grow algae on a large scale for production of fuels. To appropriately set up an algal farm, *in situ* pCO_2 measurements need to be made during pilot-scale testing to determine optimal levels for growing algae maximizing the farm's efficiency or algal productivity. Once a farm is up and running, CO_2 loss also needs to be regulated to comply with carbon emission laws set for this type of an industry. The large scale nature of these farms leads to large scale changes for *in situ* pCO_2 which can be easily and accurately detected using Turner Designs' C-sense.

C-sense's robust design, low power consumption, versatility, and easy integration make it a great tool for accurately measuring or monitoring pCO_2 levels in water, oil, or water & oil systems.

Sales Contact

In business for over 40 years, Turner Designs is well known for supporting and working with customers to get them instruments required for their research needs. Call or email any of our Environmental Science Group team members listed below for a free consultation regarding how Turner Designs can help you with your study or research and what we can provide in the way of service, instruments, or recommendations.

Tom Brumett	408-212-4046	tbrumett@turnerdesigns.com
Kathleen Henderson	408-212-4067	khenderson@turnerdesigns.com
Lawrence Younan	408-212-4063	lyounan@turnerdesigns.com