Measurement of O_2 transformation rates at nanomolar concentrations

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Ten years ago ultra sensitive oxygen sensors were for the first time used to quantify in situ oxygen concentrations in the oceanic oxygen minimum zones. It was immediately clear that these sensors also made it possible to quantify oxygen transformation rates in low O_2 waters at extreme resolutions of ~ 1 nM O_2 h^{-1} (e.g., E. Garcia-Robledo et al. 2017, PNAS 114:8319-24) when initial O_2 concentrations were < 100 nM. Several factors have, however, to be taken into account when such low rates are to be measured. Planktonic microorganisms have widely different O_2 half saturation concentrations for respiration, but "community K_m values" were estimated to be about 200-400 nM (E. Garcia-Robledo et al. 2016, Front Mar. Sci.). Oxygen concentrations should thus be above 500-1000 nM when transformation rates are to be determined in waters that are artificially lowered in O_2 concentration. It was also found that the duration of incubations should be short, preferably less than 12 h for 15°C water and 3 h for 25°C water. Longer incubation times led to highly elevated rates of microbial respiration. The handling of the water also had an effect on respiration rates, and gentle transfer and deoxygenation procedures have thus been developed. The containers used for incubations should be of glass only, as polymers such as butyl rubber can accumulate significant amounts of oxygen. The initial work on determination of low O_2 transformation rates was performed using electrochemical STOX sensors. Subsequently high resolution optodes have been developed that have several advantages over the electrochemical sensors including increased reproducibility and possibility for contact-free read-out through a glass window.

The methods developed for high-resolution determination O_2 transformation rates have made it possible to measure profiles of respiration rates in oceanic water columns, photosynthetic O_2 evolution in deep near-anoxic secondary chlorophyll maxima illustrating cryptic oxygen cycling, and oxidation rates of heavy metal sulfides at O_2 concentrations relevant for the early earth (Aleisha Johnson et al., in prep). For the first time it has been possible to compare rates of oxygen respiration with rates of for example anammox and denitrification at the oxic-anoxic interface of oceanic water columns.