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# Dissipation Rates of Oxygen Nanobubbles in Recirculating Systems

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**Introduction:**

Dissolved oxygen (DO) in water is essential for the metabolism of aerobic organisms in hydroponics, aquaponics, waste water treatment, and aquaculture. DO levels at or near saturation are required to prevent the development of hypoxic conditions (Wei et al., 2019). Water with saturated amounts of DO is achieved by bubbling air through a tube or air stone via an air pump. Using pure oxygen for aeration can increase the concentration of DO from 21% to 100% compared to air. Nanobubbles have diameters on the nanometer scale ($10^{-9}$ m) and have extended lifetimes in suspension compared to macrobubbles (Atkinson et al., 2019). The combination of pure oxygen and nanobubbles can elevate DO levels for increased aerobic growth. In this study, we tested the dissipation rates of pure oxygen nanobubbles under circulated and uncirculated conditions with tap water and a calcined clay substrate.

**Methods:**

We used the Yellow Springs, Inc (YSI) Model 550A DO meter, which measures DO between -5 and 45 C and up to 50 mg DO $L^{-1}$. The meter electrode was sanded to remove oxidation and a new membrane and fresh electrolyte were installed. An oxygen tank was connected to a 25Boost Nanobubbler (Moleaer, Carson, CA) as shown in Fig. 1 to generate oxygen nanobubbles in a 100 L plastic water-filled reservoir. Theoretical DO concentration was calculated using the current atmospheric pressure and partial pressure of oxygen and compared with values measured by the YSI meter.

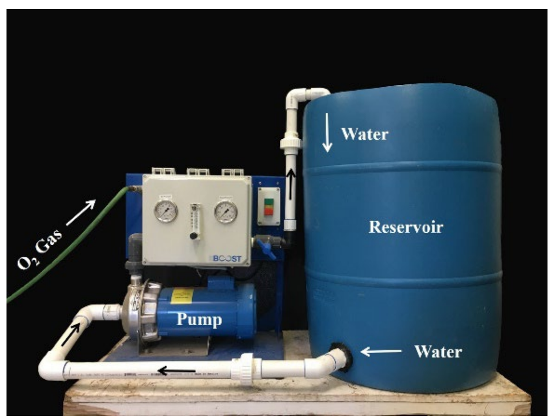

Fig. 1. 25Boost Nanobubbler system.

Oxygen dissipation from super-saturated, non-circulating water was measured with and without a 5-cm thick polystyrene cover and the DO concentration was monitored for ten minutes. To test for potential interference with the nanobubbles, multiple trials were conducted with the probe head facing both up and down and while using traditional aeration with 100% oxygen gas.

Oxygen dissipation from recirculating water was tested by placing a 500 mL aliquot of super-saturated water in a 500 mL plastic reservoir (Fig. 2). The reservoir was connected to the top of a 30-cm long, 5-cm wide PVC pipe by a 1-cm wide plastic tube. A peristaltic pump was used to move the water from the reservoir to the top of the column at a rate of 92 mL $min^{-1}$. The solution was allowed to drop to the bottom of the column before flowing back into the reservoir and completing the loop. DO concentration in solution was measured over ten minutes. The experiment was repeated at a higher flow rate of 222 mL $min^{-1}$. Coarse calcined clay (particle diameter 0.6 to 3.4 mm) was then added to the PVC column. The previous steps were repeated at a low and high flow rate.

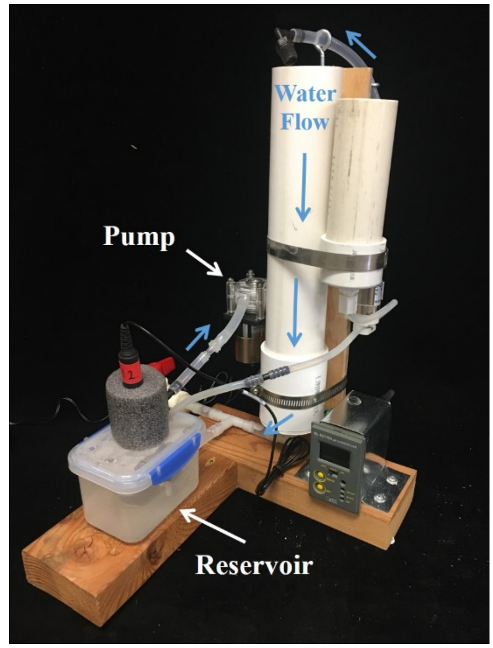

Fig. 2. Recirculating column system.

**Results:**

DO concentration was stable for about five minutes when the solution was not subjected to flow (Fig. 3). After five minutes, the covered reservoir retained a constant DO concentration longer than the uncovered reservoir. Increasing flow rate increased the rate of oxygen depletion. At both flow rates, DO concentration of water flowing through calcined clay dissipated faster than water flowing without obstruction.

When exposed to super-saturated conditions with nanobubbles, the YSI meter overestimated DO levels by 11% (compared to theoretical values). This error may be an artifact of nanobubble presence as the meter was within tolerance when pure oxygen was added to the solution using standard bubbles (YSI Incorporated, 2009).

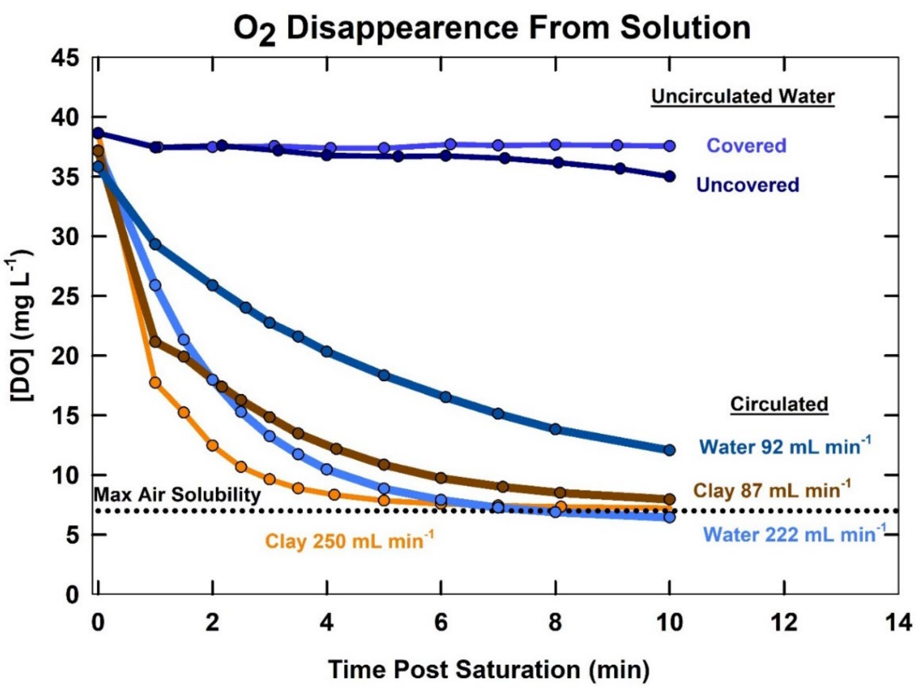

Fig. 3. DO dissipation rates over time, corrected to 25 C, for water super saturated with pure oxygen using the 25Boost Nanobubbler at three flow rates through columns.

Without continual nanobubble generation, DO dissipated within minutes from solutions under flow as the solution came into equilibrium with the atmosphere. Dissipation rate is a factor of flow rate. With no flow, DO stayed in solution with little change in concentration, particularly when the solution was covered to prevent escape of bubbles to the atmosphere.

The increased surface area of the calcined clay increased the rate of dissolution. The calcined clay was baked at 80 C for three days prior to addition into the column, so microbial populations were not likely present.

Nanobubble generation quickly increases the level of DO in solution, but continuous generation is required to maintain high concentrations.

**Literature Cited:**


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