research management
findings
Number 28 • February 1991

Evaluation of *Insitu* Chambers to Measure Sediment Oxygen Demand

by Richard Wulk

The Wisconsin Department of Natural Resources (DNR) puts forth much effort to determine and justify effluent limits for pollution dischargers. Most limits are based on water quality modeling with the goal of avoiding unnecessary wastewater treatment costs while ensuring the protection of the receiving water's aquatic community. Steady state models for aquatic systems require quantitative data pertaining to the sources and sinks of dissolved oxygen (DO). Experimental techniques for obtaining model input parameters have been developed for re-aeration rates, carbonaceous and nitrogenous biochemical oxygen demand (CNBOD), system respiration components, and photosynthetic production.

Although the water column CNBOD sink receives much attention in DO modeling, in some aquatic systems the sediment oxygen demand (SOD) may be a greater oxygen sink than the water column demand. For example, for a given aquatic system, the sessile biomass can be a thousand times greater than the overlying planktonic biomass (Ladd et al. 1979). Thus, in some aquatic systems only a small fraction of the total organic reduction budget is accounted for by water column heterotroph and autotroph metabolism. In addition, findings demonstrate that, at constant velocity, the CNBOD removal rates increase with decreasing river depths. This implies that shallow lotic river systems can have a substantial oxygen sink due to metabolic processes of the benthic community. Despite the importance of SOD in the whole oxygen balance of the aquatic system, SOD rates are often assumed or guessed. To date, there is no standard protocol for determining SOD rates.

This article reports on a study that investigated the use of *insitu* chambers to empirically determine SOD rates. Specifically, 2 objectives were investigated: (1) determine if *insitu* SOD measurement is repeatable using a specific chamber design at the same location, and (2) determine if *insitu* SOD measurement can be duplicated at the same location using 2 different chamber designs.

Study Sites

The study was conducted at 2 locations in northern Wisconsin: the Hat Rapids Flowage on the Wisconsin River and southern Green Bay of Lake Michigan. Four study sites were located at Hat Rapids and 2 at southern Green Bay. The Hat Rapids sites had widths of 40-300 m, depths of 2-7 m, velocities of 0-0.03 m/sec, and benthic composition ranging from sand/gravel to soft/detrital sediments. The 2 Green Bay sites were located 0.5 mile west of Communiversity Park and 1.5 miles west of Bayshore Park. Both Green Bay study sites were similar in benthic composition, characterized as soft sediments at 3-8 m deep, with near zero overlying water velocity.

Chamber Design and Use

Two different chamber designs were used to measure SOD rates, the Trichamber and the DNR Chamber (Figs. 1, 2). The Trichamber is constructed of clear Plexiglas enabling photosynthetic measurement and visual observation. One of the 3 cylindrical chambers is sealed from the sediments to allow measurement of water column productivity and respiration. The 2 remaining chambers are used for replicate SOD measurements. Volumes of the 3 chambers are 4.38 L, 4.16 L, and (sealed) 4.07 L. All chambers have an exposed sediment surface area of 0.0259 m^2. Volume to surface area ratios are 170:1 and 161:1. The DNR Chamber is constructed of opaque fiberglass, to eliminate photosynthetic production. Chamber volume is 31.35 L, with an exposed sediment surface area of 0.156 m^2. Volume to surface area ratio is 201:1.

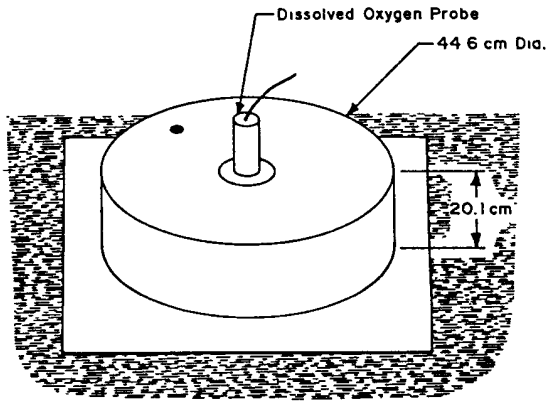

FIGURE 2. The DNR Chamber, constructed of opaque fiberglass.

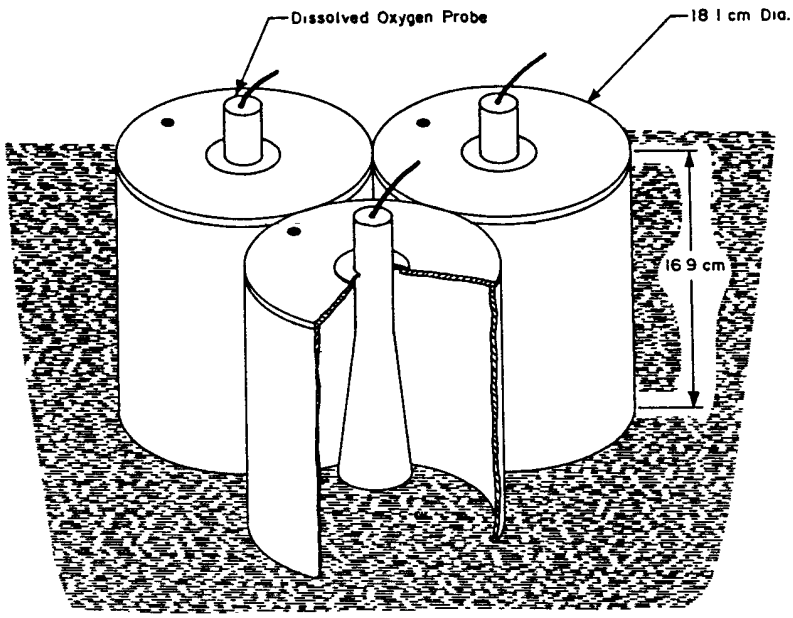

FIGURE 1. The Trichamber, constructed of clear Plexiglas.

In our study, each chamber was equipped with a Yellow Springs Instrument (YSI) DO probe and stirrer. Measurements were recorded with the YSI model 56 recording DO/temperature meter. SCUBA was used for all chamber placement to allow visual observation and a gentle placement of the chambers with minimum disturbance to the sediment.

Test runs to measure SOD rates using *insitu* methods were made on July 20-24, 1987 and February 16-24, 1988. Five paired replicate measurements were made using both chamber designs on the Hat Rapids Flowage in 1987. For chamber design comparison, 3 duplicate measurements were made using both chamber designs at the 2 Green Bay sites in 1988 and at one Hat Rapids site in 1987. Standard deviations were calculated for (1) replicate measurements using the same chamber at the same site and (2) duplicate measurements for different chamber designs at the same site. A *t*-test was applied to test for significance.

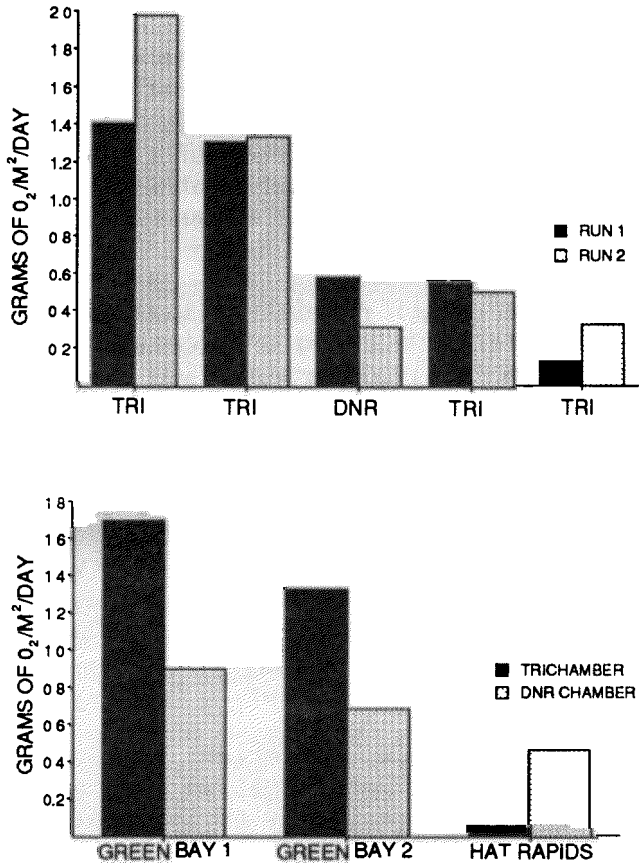

FIGURE 3. Measurements of SOD comparing (a) same site, same chamber replicates and (b) same site, different chamber duplicates.

Results and Conclusions

Results of the field experiments with these *insitu* SOD chambers are presented in Figure 3. At the 95% confidence level, replicate runs using the same chamber did produce repeatable oxygen demand rates (Fig. 3*a*). However, at the 95% confidence level parallel SOD measurements run at the same sites using 2 different chamber designs did not produce duplicate results (Fig. 3*b*). Thus, it appears that the experimental methods used can generate consistent SOD rates, but not independently of chamber design. This implies that the SOD rates determined for this experiment are not valid because they are not a function of the benthic substrate.

To measure a natural process, the procedure must be able to simulate the natural conditions of the environment. It has been determined that interface velocities and sediment resuspension can significantly drive SOD rates (Wittemore 1986). The chamber designs used in this experiment, with no velocity control, could not adequately simulate benthic turbulence and sediment interface velocities. SCUBA observations reinforced these concerns. It was observed that if the chamber was not placed gently with purge ports open, a substantial sediment resuspension occurred. Benthic composition (gravel, timber, soft sediment, etc.) can affect chamber performance. Use of these particular chambers requires that water flux in or out of the chamber not occur. This is accomplished by making sure that the chamber perimeter is seated properly in the benthic substrate. Thus, it is important to know what the benthic substrate is composed of and then adjust the chamber placement accordingly.

Recommendations

1. Protocol for *insitu* chamber design is needed. The design must be able to adequately represent natural benthic conditions. Specifically, the chamber must be a controlled volume system with velocity and turbulence control capabilities.

2. Water quality modelers should be skeptical when using or accepting experimentally determined SOD rates. To date, most laboratory and in-situ SOD measurement techniques lack turbulence and sediment interface velocity control.

3. SCUBA should be used for chamber deployment. This allows for observation (light permitting) and proper placement of the chamber in the benthic substrate.

References

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