

## Microcosm Study

Abbott (1966) described microcosms as miniaturized ecosystems. Among the oldest and most specialized examples of the microcosm technique were bioassay systems, such as that found in the standard BOD determination. Abbott also noted that, due to the unpredictability and complexity of natural systems, *in situ* experiment results were often vague and inconclusive, and many researchers had successfully used microcosm systems to simplify experimental conditions in their investigations of natural systems. In addition, he noted that, although microcosms do not reproduce natural systems precisely, they provide the advantage of allowing researchers to investigate under controlled conditions.

Mortimer (1941, 1942) was a pioneer in the use of microcosm systems in limnological investigations. He designed artificial batch reactor systems in order to observe mud-water interactions in Esthwaite Water. The microcosms enabled him to control degree of aeration and the areas of water surface exposed to the air. The results were similar to those in his *in situ* observations in Esthwaite Water. By using the controllable systems, he was able to outline a list of approximate redox potential ranges within which certain redox reactions proceeded actively.

Song and Muller (1999) studied sediment diagenesis processes by bringing cores into their laboratory and adding water and biological debris on top of them. Over time, they measured nutrients, dissolved organic carbon (DOC), and trace metal concentrations in the water column. They concluded that the method provided simple, inexpensive and direct measurements of degradation processes affected by changes of the physicochemical conditions.

Schroeder *et al.* (1992) studied the impact of deposited sediments of the Elbe estuary in Germany on the total nitrogen budget of the estuary. The authors constructed a batch reactor microcosm consisting of 6 sediment cores (a total sediment area of 1700 square centimeter (sq. cm.)) and 25 L of water. They found that the microcosm study yielded similar results to the *in situ* bell-jar experiments with a non-systematic deviation of less than 30% while allowing better control of important system variables, such as temperature, light and degree of agitation.

Beyers (1963) stated that microcosm studies had been assumed to be reproducible as well as controllable. Abbott (1966) recognized that the assumption of close duplication had been contradicted, at least partially, by other investigators. In order to resolve this contradiction, he set up a series of nutrient requirement studies, employing 18 carboy microcosms. The experiments were conducted under identical, partially controlled conditions. Several constituents were measured to analyze the degree of divergence over time. He concluded that, under proper conditions, groups of parallel microcosm systems could be established and studied under rigorously defined conditions, and the assumption of close duplication could be shown to hold through statistical analysis. Gunnison *et al.* (1978) studied the feasibility of using microcosms of soil slurries to investigate changes in chemical, biochemical, and microbial parameters occurring during development of anaerobic conditions in reservoirs. They found that the results resembled findings of investigators working with flooded soils and sediments. They concluded that microcosms represent a viable means of studying anaerobic processes in flooded soils and sediments, and with some care, may also be used to study such processes in reservoirs.

To (1974), McLaughlin (1981), and Sherman (1983) have previously used microcosm systems to study sediment-water interactions in the Occoquan reservoir. Their findings have shed light on the factors affecting sediment phosphorus release, the phosphorus release rates under aerobic and anaerobic conditions, and the effect of nitrate on oxidation-reduction potential and phosphorus release. These prior studies, however, were done with batch reactors and arbitrarily chosen sediment area:water volume ratios. Yung (1990) found that the exertion of sediment oxygen demand (SOD) could be shown to be a function of water volume to sediment surface area, which she defined as the “effective depth.” As shown in Figure 2-16, SOD exertion decreased as the sediment surface area to water volume ratio (the inverse of effective depth) increases and *vice versa*. Yung postulated that the sediment oxygen demand would reach the minimum value when the effective depth is close to the thickness of the boundary layer on the sediment surface (the layer where the only transport mechanism is diffusion). The upper limit is most likely occurs when effective depth is so large that there is just a small amount of sediment, compared to the water volume. Yung explained that, because deposited sediments may be a main source of oxygen demand, further increases in effective depth will leave nothing further to be oxidized and there will be no additional change in

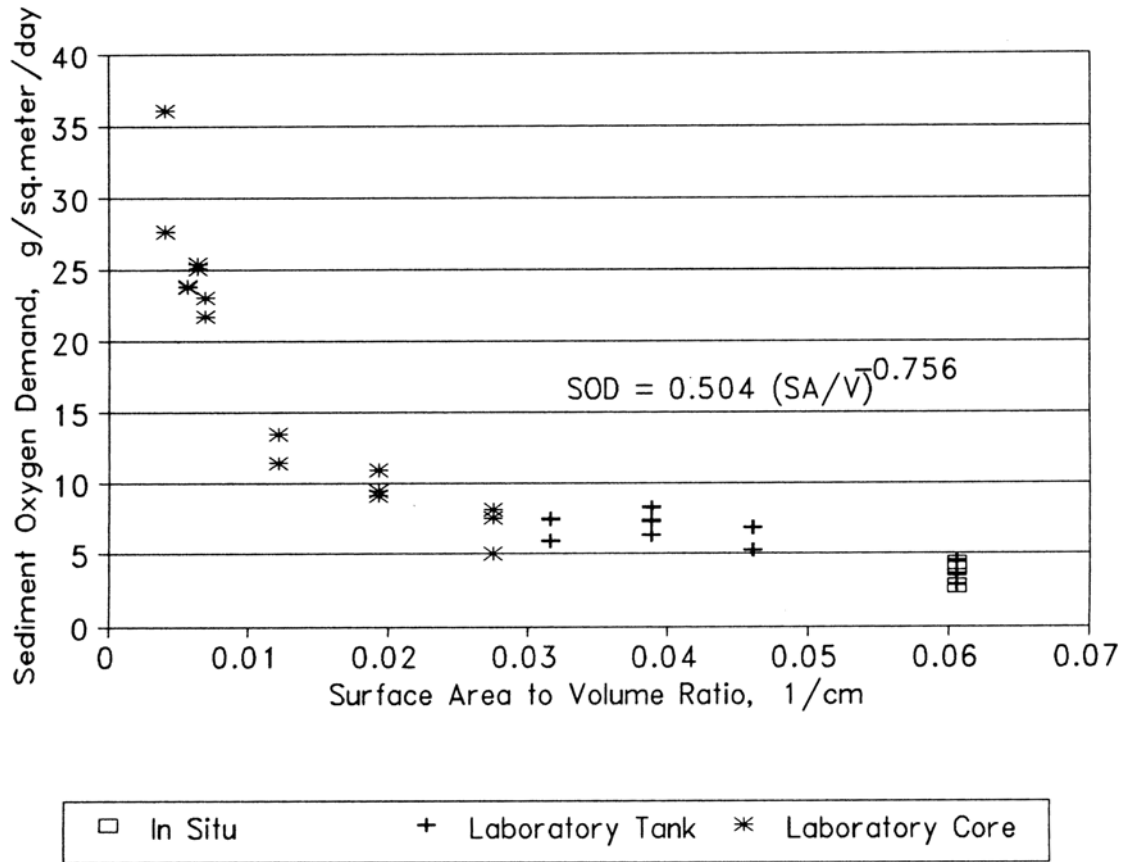


Figure 2-16. SOD as a function of the surface area to water volume ratio: results from *in situ*, laboratory tank, and laboratory core experiments. (Taken from Yung, 1990)

oxygen demand. This finding was in line with Cole (1994), who stated that sediment-water interactions do not have as much effects on lakes and reservoirs with large hypolimnetic volumes (large effective depth) as on shallow water bodies. He gave, as an example, the summer oxygen supply in the hypolimnion of a deep-water body, which was always plentiful while the oxygen often disappeared in small lakes as a result of organic matter decomposition.

Because it has been shown that the sediment-water interactions observed in a microcosm system may be altered by the effective depth, it follows that microcosms constructed to represent a given water body ought to have effective depths comparable to those of the actual aquatic system. In addition, while many successful microcosm studies have been performed with batch systems, reservoir water quality has also been simulated with flow-through, completely-mixed, contiguous segments (Ahlert and Hsueh, 1980; Martin *et al.*, 1985; and Tufford and McKellar, 1999). Therefore, it also appears that better representation of the

natural system might also result from a continuous stirred tank reactor (CSTR) or CSTRs in series. The latter could be used to effectively alter the physical system representation as a function of distance downstream. Several investigators have successfully used this type of microcosms in studies, including Cooke and White (1987) and Montuelle *et al.* (1997).

Cooke and White (1987) studied the effect of nitrate concentrations in the River Dorn in Oxford, England on sediment nitrification and denitrification. The authors simulated the sediment-water interface of the river, and its agriculture land drainage with a flow-through microcosm. The microcosm was a 7.8-centimeter (cm)-diameter, Perspex chamber containing 6 cm of sediment and 1 cm of stream water, which was continuously stirred with a magnetic stirrer. A peristaltic pump pumped new stream water from a 10-L container to the top of the microcosm where a like amount was pumped out to waste. The stock of stream water was changed daily. The authors kept the entire system in the dark at 25 °C. Cooke and White stated that one-pass systems such as the one described provided a better simulation of streams draining agriculture lands in England better than batch reactors of flooded soils or sediments. They explained that the nitrate concentrations in these streams were quite stable, while the nitrate concentrations in the overlying waters of batch reactor systems decreased over time, which prompted some question of whether the systems were adequately simulating the natural streams. The authors suggested that one might best maintain stable nitrate concentrations by passing a solution containing nitrate over a sediment surface once only before wasting.

Montuelle *et al.* (1997) assessed the effect of wastewater treatment plant (WTP) effluent on the River Saone in France using a 6-step microcosm. Each reactor was a 5.7-L, dual-walled glass container holding 2 L of sediment (5 cm deep) and 3.7 L of water. Fresh water collected from the river above the wastewater treatment plant discharge was pumped to the first reactor at 835 milliliter per hour (mL/h), and the effluent was pumped to the second reactor at 417 mL/h, resulting in hydraulic retention time (HRT) of 3 days for Reactors 2-6. The authors designed the first reactor as a point of reference for comparisons to the reactors receiving the effluent. The entire microcosm was kept in the dark at 20 °C, in order to avoid algal development, and saturated with dissolved oxygen by bubbling with air. They found that the effluent did not drastically alter the physicochemistry of the river, including the following water and sediment characteristics:

- pH,  $E_h$ , DO, total organic carbon, dissolve organic carbon, total nitrogen, nitrate, nitrite, ammonia, and phosphate in water; and
- pH,  $E_h$ , water content, phosphorus content, nitrogen content, mineral carbon content, organic carbon content, and interstitial ammonia in sediment.

The authors observed nitrate concentrations to increase due to nitrification passing down the series of reactors. They observed no significant changes in sediment physiochemical composition except for the phosphorus content, which was found to increase 50 to 100 percent in Reactors 2-6. They observed that the number of *Tubificidae* (pollution resistant strains of invertebrates) increased while *Limnodrilus udekemianus* and *Quistadrilus multicoetus* (pollution intolerant strains of invertebrates) decreased moving down the series. The authors concluded that, although the microcosm system might not mimic exactly the complex conditions of natural systems, it behaved like a continuum, and realistic changes in physicochemical and biological parameters were observed, and were found to be comparable to observations in the River Saone. They concluded that such microcosms might well suite studies of WTP discharge impacts, and could be used to simulate the effect of distance downstream from a discharge point by altering the HRT in each reactor. However, they noted that coupling microcosm data with field data is important to validate the results of such experiments.