# Mineralization of MTBE in Bench-Scale High Biomass Reactor Systems

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We have been running four specialized bioreactors to evaluate the treatability of MTBE under different substrate/co-substrate conditions. All four bioreactors are operated under the same COD loading rate. In the first bioreactor, MTBE is fed at an influent concentration of 150 mg/L, where it is serving as the only organic carbon source. In the remaining three reactors, MTBE is fed at an influent concentration of 75 mg/L with the balance of the COD fed as either ethanol, diethyl ether, or diisopropyl ether. The reactors were initially seeded with biomass from a diethylether degrading biofilter, biomass from an MTBE degrading culture provided by Shell Development Corp., and sediment from the Port Hueneme aquifer. Each bioreactor consists of a sealed 12 L chemostat with a sealed headspace. A 10 L porous pot has been placed inside each reactor. The porous pot facilitates exit of the treated effluent while the biomass is retained within the reactor. Early in the project, biomass wastage for sludge age control was performed daily by manually withdrawing a fraction (3.3%) of the mixed liquor from each bioreactor. Effluent from each bioreactor was monitored by measuring the concentration of MTBE and its intermediate breakdown products in the liquid effluent and in the off gas.

The four reactors were operated at a sludge age of 30 days. At this sludge age the MTBE removal efficiency was initially stable and exceeded 95%. However, biomass yield was observed to be very low, and reactor performance deteriorated after two turnovers of sludge age. After observing these results, sludge wastage was stopped, and the sludge age was increased. The performance of all bioreactors improved steadily, and at present the concentration of MTBE in the effluent from all four reactors is below the 5 ppb detection limit (which represents greater than 99.99% biodegradation of MTBE). Furthermore, no intermediate or end-products from the biodegradation of MTBE have been found in the effluent. These findings illustrate that MTBE can be effectively treated biologically to extremely low levels if a high enough sludge age and biomass concentration are maintained.

To show that MTBE was being mineralized beyond simple t-butylalcohol (TBA), the bioreactor being fed MTBE as the sole carbon source was spiked with TBA at a reactor concentration of 20 mg/L and the effluent monitored. The MTBE concentration increased slightly after the perturbation but then declined to below detection limits shortly thereafter. The TBA also declined to below detection limits. After this perturbation experiment was completed, the reactor returned to pre-perturbation conditions with both MTBE and TBA present at below detection limits in the effluent, and no other intermediates were found to be present.

For a high sludge age system treating low concentrations of MTBE at high flow rates to be cost-effective, very low hydraulic retention times must be maintained. The membrane bioreactor (MBR) system offers an ideal solution to this problem. The MBR consists of an aeration tank connected to a membrane system that facilitates liquid/solid separation. The thickened biomass is returned to the aeration tank. Since this is essentially an activated sludge system, the hydraulic retention time is unimportant in determining system efficiency, and performance is totally dependent on sludge age and mass transfer limitations. The MBR is noted for its ability to provide higher sludge ages than any other biotreatment system. If provides total sludge age control since no biomass leaves the reactor unless it is physically removed from the mixed liquor. Furthermore, because it is a high shear system, floc sizes are extremely small and mass transfer limitations are negligible. With the MBR, it is not unrealistic to treat a low strength water at a hydraulic retention time of less than 20 minutes while at the same time effecting essentially complete MTBE mineralization.

One further feature of the MBR bioreactor system is its ability to retain all microorganisms inside the reactor. Particles as small as bacteriophage have been found to be retained within the reactor contents and not escape to the liquid effluent discharge. This is a very important feature for drinking water treatment at the well head.

A fluidized bed bioreactor is unlikely to be as efficient in removing MTBE to extremely low levels for the following reasons. First, since we are dealing with a high flow rate system, biomass attrition due to the high shear condition within the system will be appreciable. Under such conditions a high sludge age in the system will not be attainable. Furthermore, mass transfer limitations may not allow the attainment of effluent concentrations in the 5 ppb range. Typically, fluidized-bed systems are ideal for the treatment of waters when microbial yield is not as low as it is in the case of the biodegradation of MTBE. Our results are consistent with literature citations where MTBE has been shown to be a growth uncoupler, thereby causing very low biomass yields even under the most optimum operating conditions. Since high biomass with long sludge age is key to successful biotreatment, the only way to achieve such high removals in a liquid stream is through the use of an MBR bioreactor system.