Oxygen Demand and Biodegradation

There are two primary indicators of the oxygen demand of foams in the environment. Biochemical oxygen demand (BOD) measures the amount of dissolved oxygen used by biological organisms to breakdown a chemical, in this case foam, in a specific amount of time. The chemical oxygen demand (COD) measures the amount of oxygen necessary to oxidize compounds completely. BOD and COD are used to determine the 'strength' of a wastewater and to design a treatment plant for proper treatment capacity. The 20-day BOD is also known as the ultimate BOD, since most wastewater will have exerted its entire BOD by 20 days. However, in the case of firefighting foams, the ultimate BOD may go beyond 20 days [i]. This means that wastewater treatment facilities are not typically equipped to manage high volumes of untreated foams due to the extreme oxygen demand. Both the COD and BOD of firefighting foam solutions are considered extremely high when compared to common wastewater.

When the high oxygen demand in a foam solution is exerted directly on surface water, it can remove all of the oxygen from the water, and cause fish and plant kills, known as a 'red-tide' effect. This effect is in addition to the effects of aquatic toxicity. Figures 12, 13, and 14 provide available COD and BOD data for DoD firefighting foams and their common ingredients. BOD and COD data for twelve foams, six AFFF and six Hi-Ex, were provided on their MSDSs. A search of ingredient MSDS data provided the BOD5 for dipropylene glycol. All other BOD5 data are sourced from the 2006 Hughes Associates, Inc. whitepaper for Figure 14[**Error! Bookmark not defined.**].

Biodegradation is the capability of a chemical to be decomposed by biological means. There are several methods for measuring the biodegradation. Some are focused on industrial chemicals that degrade in water. Other methods are used to determine the biodegradability of plastics and other materials. The United Nations Organization for Economic Cooperation and Development (OECD) established one method for measuring biodegradability of industrial chemicals in water as the the ratio of BOD 20 to COD [ii]. This method is a quick screen to give an initial measure of biodegradability. The closer the ratio is to one, the greater the biodegradability of the material. Although this ratio describes how much a chemical biodegrades, it does not describe how rapidly biodegradation occurs, or how high the oxygen demand is for the chemical. In some cases, as in most foams, the oxygen demand is very high and some of the ingredients degrade rapidly. Even though materials with fast biodegradation are generally desirable, fast degradation in combination with high oxygen demand can have a greater short-term impact on the environment than a slow degradation. This rapid oxygen demand can starve the environment faster than oxygen can be replenished, leading to acute toxicity. Figure 15 provides data for biodegradation ratios of firefighting foams for 11 firefighting foams. There were data in the MSDSs for either the biodegrability factor or the BOD20 and COD used to calculate biodegrability for four Type 3 AFFF, three Type 6 AFFF, and three Hi-Ex foams. Additional data are needed to compare all AFFF and Hi-Ex foams. Based on available data, Type 3 AFFF is the most biodegradable of the foams used by DoD.

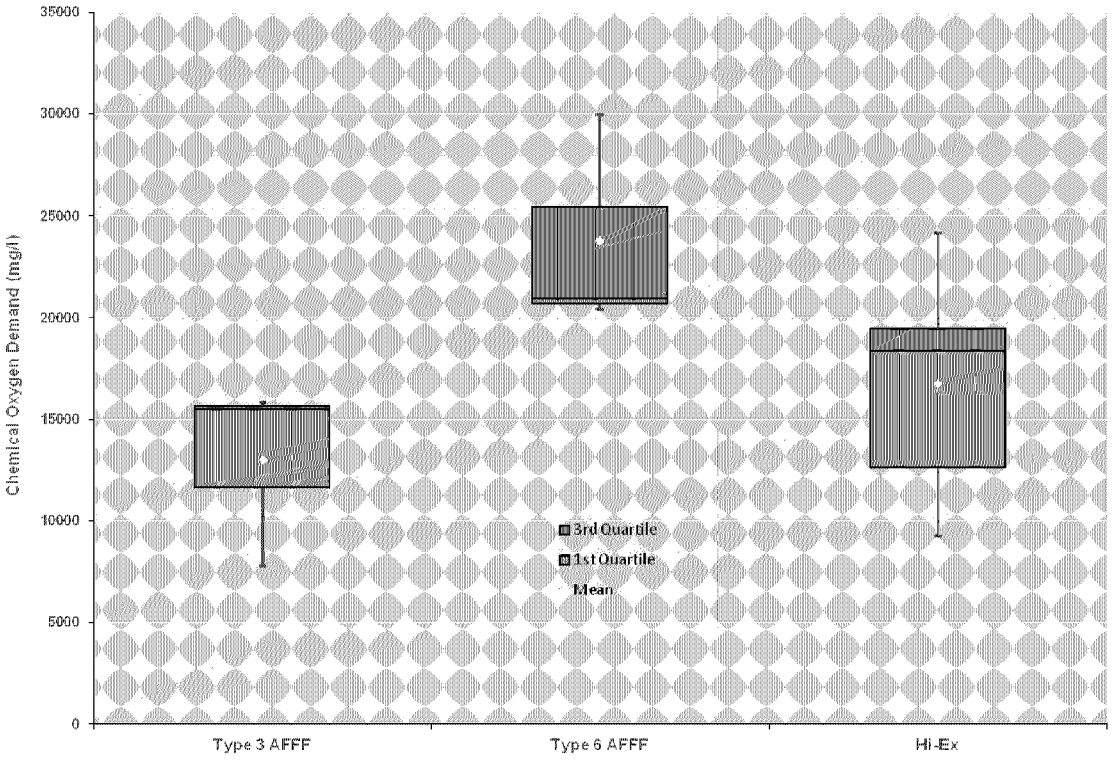

Figure 12 – COD DoD Firefighting Foam Solutions

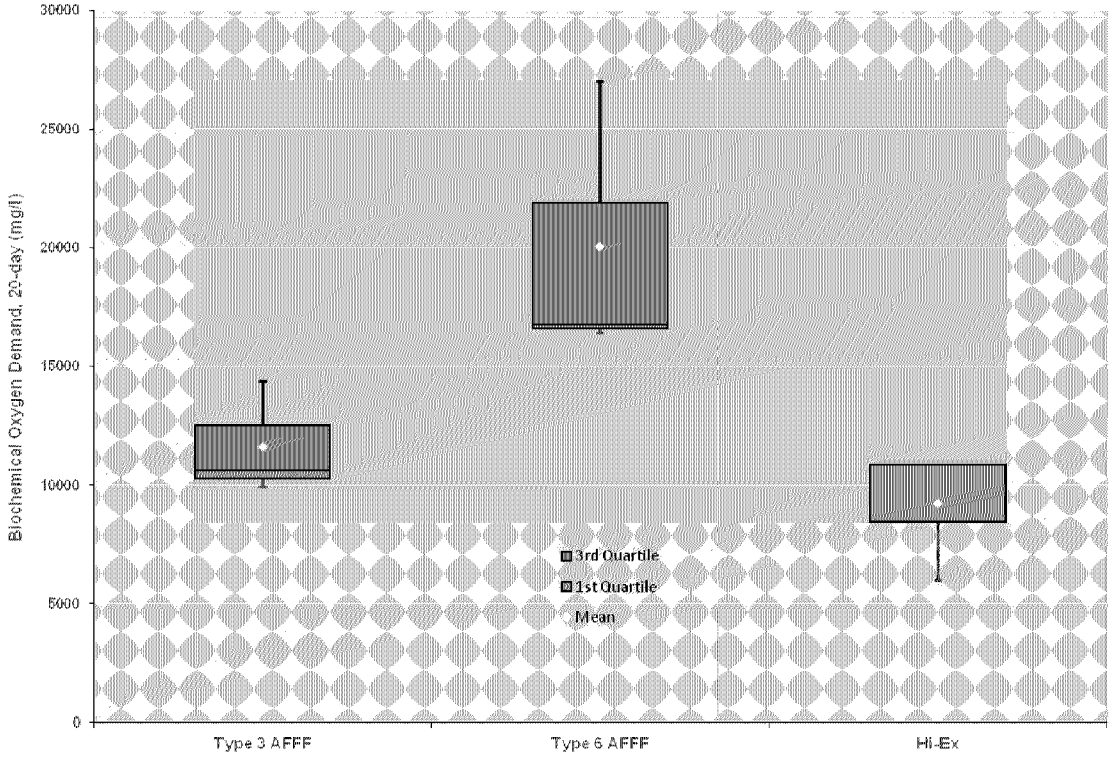

Figure 13 – 20 Day BOD of DoD Firefighting Foam Solutions

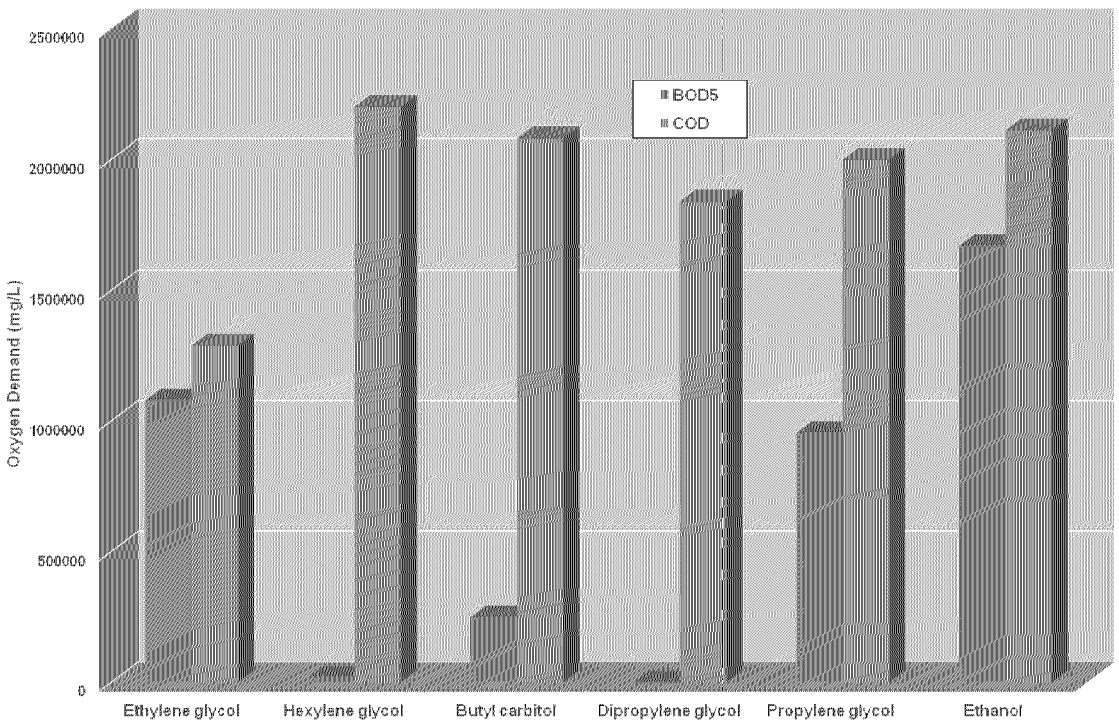

Figure 14 – BOD5 and COD of DoD Firefighting Foam Ingredients

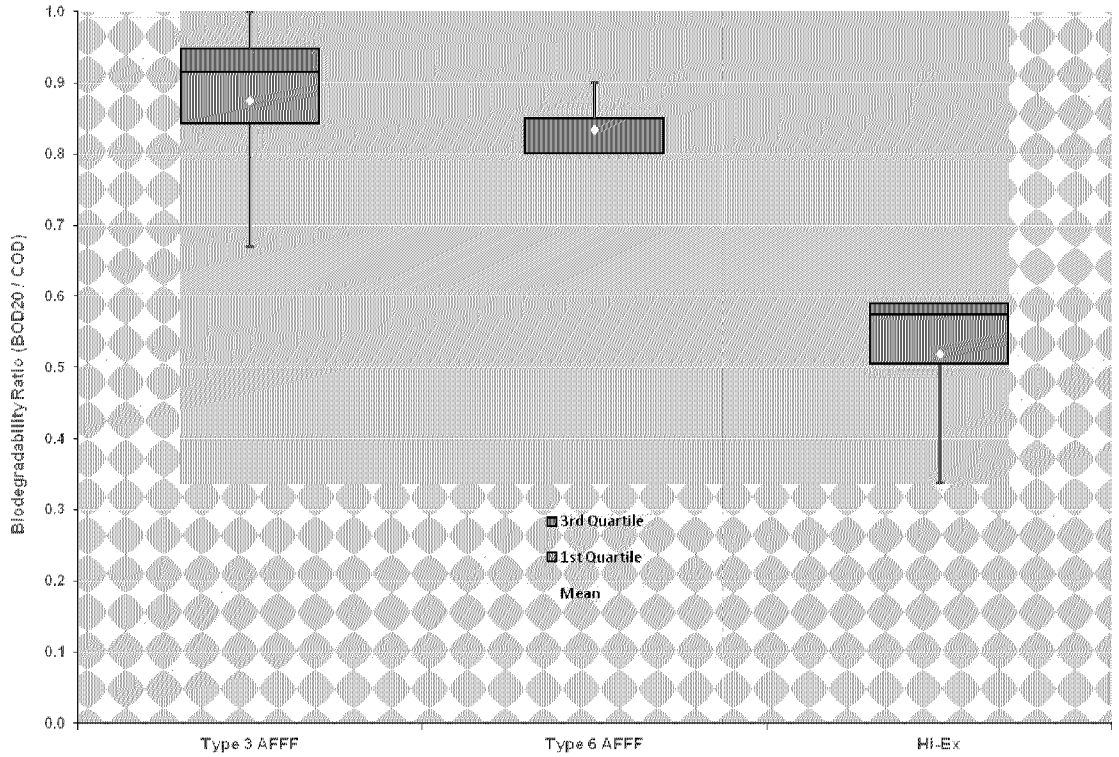

Figure 15 - Biodegradability Ratios of DoD Firefighting Foam Concentrates

i Chan, D.B., "Disposal of Wastewater Containing Aqueous Film Forming Foam (AFFF)," TM M-54-78-06, Naval Facilities Engineering Command, April 1978.

ii 3M Product Environmental Data, "3M Light Water Brand Aqueous Film Forming Foam (AFFF) Disposal Recommendations and Hazard Evaluation," 3M, 19 February 1993.