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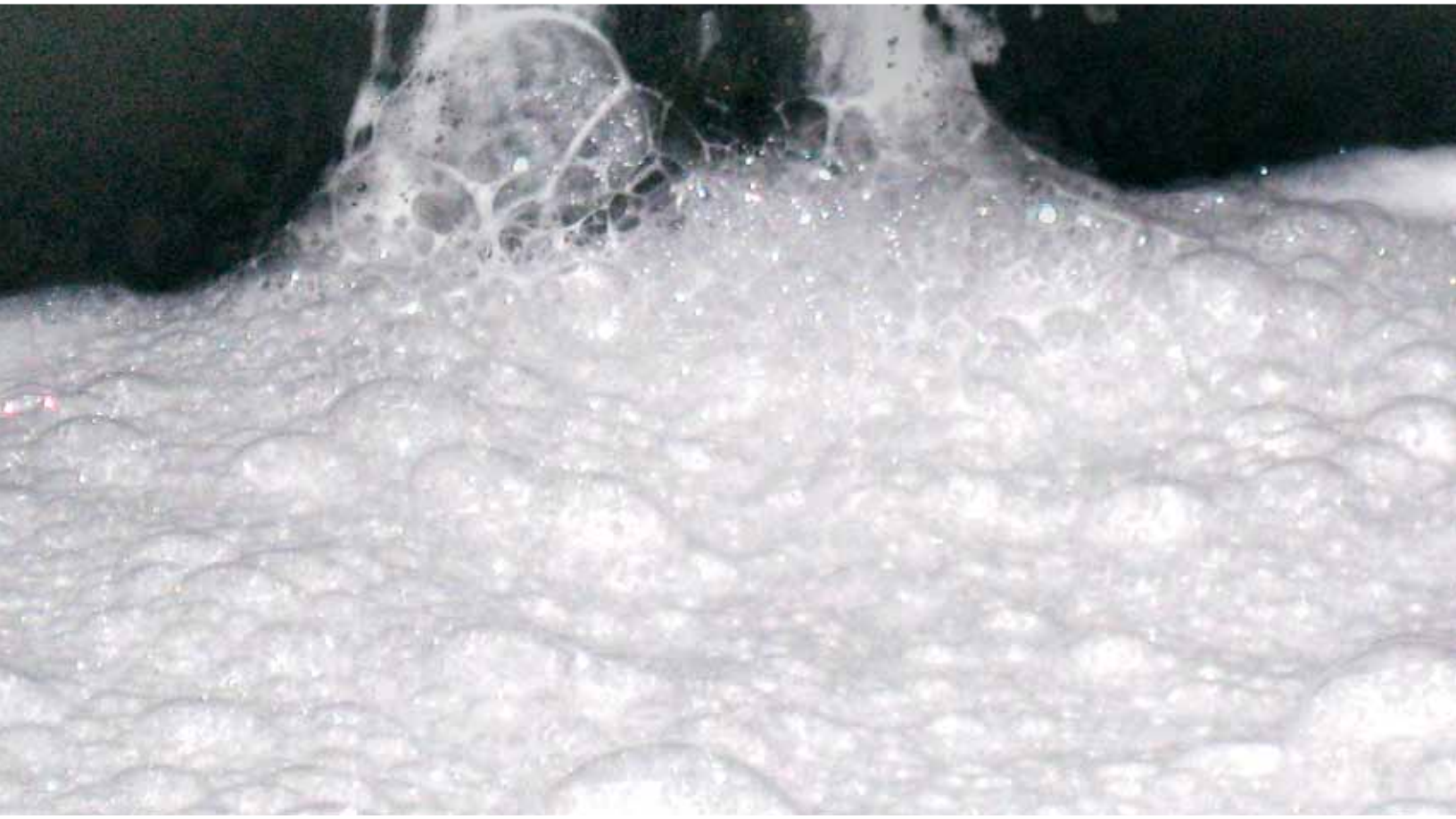
WHITEPAPER

AQUATIC IMPACT OF FIREFIGHTING FOAMS



Firefighters have been confused by publications on the environmental impact of Class B firefighting foams over the past 20 years. Since 1999 the information is even more confusing. The most recent challenge is the persistence of the fluorosurfactants used in Fluoroprotein Foam, AFFF, FFFP and the related Alcohol Resistant foams (AR-AFFF) that dominate the industry. The Fluorochemicals used with firefighting foam technology have been estimated to have an environmental life that
could be measured in hundreds of years. In 2000, environmental concerns have initiated the development of new innovative products that contain no fluorochemicals. In 2006, information and testing was reported that fluorosurfactant containing AFFF firefighting foam concentrates had the lowest effect on fresh water fish species when compared to non-fluorosurfactant containing formulations. Testing was carried out as 96 hour tests on two fresh water fish species, rainbow trout (fingerlings) and fathead minnows (using a flow-through method) using a wetting agent, two fluorochemical free products, and three AFFF products. This was a study based on a simple acute toxicity test regime and did not reflect on any issues associated with the environmental persistence of fluorochemicals used in AFFF foams. [1]

The conclusion is that fluorine containing foams are more or less nontoxic and that the new fluorine free foams have a severe impact on the survival of fish species when we discharge these concentrates into the open water. [1]
The new Fluorine Free Class B foams are based solely on synthetic hydrocarbon surfactants, which do biodegrade completely. As the synthetic hydrocarbon surfactants biodegrade, they compete with fish for dissolved oxygen, since the biodegradation process is based on aerobic oxidation decomposition. As illustrated in Table 1, the fluorosurfactant containing AFFF firefighting foams have both synthetic hydrocarbon surfactants and fluorosurfactants. They also compete with fish for oxygen as the synthetic hydrocarbon surfactants biodegrade. However, the fluorosurfactant component of AFFF foam has no immediate effect on the respiration of the fish, as it is inert and does not consume oxygen. The use of fluorosurfactants delays the impact on fish, as they are highly stable and resist biodegradation. Fluorochemicals can remain in the environment for hundreds of years, while continued use of products containing them will result in a growing back ground concentration that will eventually become significant. [2] [3] [4]

Table 1: The Chemistry of Class B (Flammable Liquid) Firefighting Foam [5]

Aqueous Film Forming Foam	= Flourosurfactants + Organic Surfactants + Solvents* + Water
Fluorine Free (Synthetic)	= Organic Surfactant + Complex Sugar + Solvents* + Water

**NOTE: Solvent = Diethylene Glycol Monobutyl Ether*

The LC50 results were reported in the publication [1] and the US Fish and Wildlife Service (FWS) classification system was applied in the following discussion. The FWS classification system was summarized in a table which we have constructed at Table 2. [1] It shows relative toxicity versus toxic dosing responses as either aquatic EC50 or LC50 (mg/L). The table is presented below:

Table 2: FWS Acute Toxicity Rating Scale [1]

Relative Toxicity	Aquatic EC50 or LC50 (mg/L)
Super Toxic	<0.01
Extremely Toxic	0.01 - 0.1
Highly Toxic	0.1 - 1
Moderately Toxic	1 to 10
Slightly Toxic	10 to 100
Practically Nontoxic	100 to 1,000
Relatively Harmlesss	>1,000

As previously mentioned, the testing described was carried out on two fish species: rainbow trout (fingerlings) and fathead minnows (using a flow-through method). If the FWS rating system is applied to the test results and compared in Table 3 it becomes obvious that the two fish species in this test series react slightly differently.

Table 3: FWS Acute Toxicity Rating Scale Applied to the Reported Test Results [1]

Agent	Rainbow Trout	Fathead Minnow
Wetting Agent	Moderately Toxic	Highly Toxic
Fluorine-free Foam A	Slightly Toxic	Practically Nontoxic
Fluorine-free Foam B	Slightly Toxic	Practically Nontoxic
US Mil Spec AFFF	Relatively Harmless	Practically Nontoxic
AR-AFFF	Relatively Harmless	Relatively Harmless
UL AFFF	Relatively Harmless	Relatively Harmless

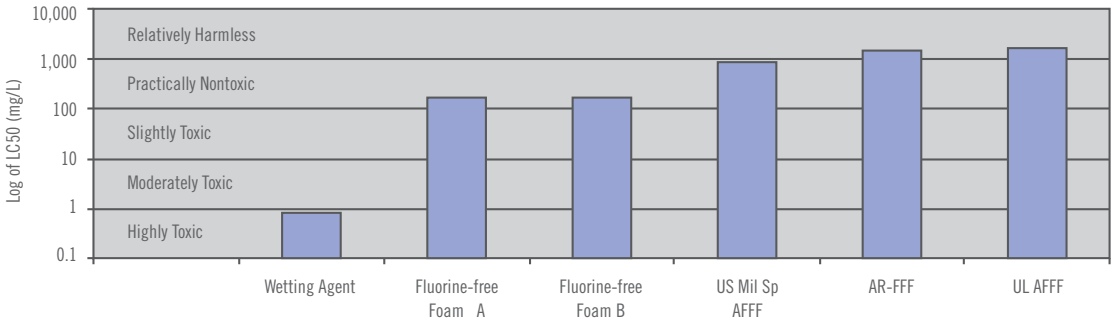
It is interesting to note that the fathead minnow is the more sensitive to the Wetting Agent and that the Fluorine-free Foams have the same toxicity as the US Mil Spec AFFF of “practically non-toxic”. In fact the fathead minnow appeared to be the more sensitive to the fluorosurfactant based foam concentrates. Table 4 compares the LC50 of the test results. There is marked increase in the sensitivity to the fluorosurfactant based foams with the LC50 dropping to at least half of its value when compared to the rainbow trout testing. As an observation, it appears that for the Wetting Agent and the three fluorosurfactant based foams, the LC50 appears to approximately drop by 50%, making them significantly more toxic to the Fathead Minnow. Both Fluorine-free Foams experience an increase in the LC50 of >100%, showing them to be less toxic under these conditions. Figure 1 illustrates the relationship between the FWS rating system and the test results.

Table 4: LC50 Test Results for Both Rainbow Trout and Fathead Minnow Test Regimes [1]

Agent	Rainbow Trout	Fathead Minnow
Wetting Agent	1.06	0.887
Fluorine-free Foam A	65	171
Fluorine-free Foam B	71	171
US Mil Spec AFFF	2176	884
AR-AFFF	3536	1487
UL AFFF	5657	1726

Environmental Regulators will examine the data over a variety of species of, including fish, and will apply rating scales, such as the Acute Toxicity Rating Scale to averaged results. Rating scales are typically logarithmic and create relative categories based on other experience used to develop this scale. With reference to Table 3, all of the firefighting foams fall within the categories of Slightly Toxic to Relatively Harmless, while the Wetting Agent was found to be Moderately to Highly Toxic. With the fish species Rainbow Trout, AFFF products have a lower toxicity rating of Relatively Harmless, while the two Fluorine Free formulations A and B have a rating of Slightly Toxic. The Fathead Minnow testing represent the acute toxicity effect to range between Practically Non-Toxic to Relatively Harmless. The two Fluorine-free products and the Mil Spec AFFF all were rated as Practically Non-Toxic. The above data show that more than one species may need to be studied. While Figure 1 illustrates the Fathead Minnow results graphically.

Figure 1: 96-Hour LC50 Flow-Through Test of Fathead Minnows [1]



While the data was presented as a comparison of aquatic impact, it would appear that the conclusions are not as clearly defined as described in the original 2006 publication [1]. In fact there appears to be less separation between the products than first thought. Tests such as these are guidelines, but only serve as one or two inputs to a risk assessment that needs to be done by the Authority Having Jurisdiction, and this is a job best done by the Environmental Agencies. Due to the different tolerance of species, fish toxicity should be determined as an average of multiple species.

In conclusion, all firefighting foams are a mixture of chemicals. Great care must be taken to prevent accidental release of any firefighting foam concentrate into the environment. It is obvious that firefighting foams that are based on only hydrocarbon surfactants, like the Fluoro-free type, there is an immediate impact (Acute) on fish. However, the stream or river will recover over a short period of time. When fluorochemical containing foams like AFFF, FFFP or FPF, then the effect is long lasting (Chronic) due to the long environmental persistence of the fluorochemicals that will continue to build in concentration over the years effecting other inhabitants of river systems, lakes and oceans which are known to bio accumulate Fluorochemicals. We need to remind ourselves that the use of firefighting foams is very dispersive and care must be taken to minimize the release of firefighting foams, and therefore the environmental impact. [6]

References

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About the Author

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Ted has received many industry awards and honors, and has written numerous conference papers and publications on firefighting foams that have helped raise the standards in firefighting foam technology.

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