AFFF Update . . .

Fire Fighting Foam Coalition

2111 Wilson Boulevard
8th Floor
Arlington, VA 22201
(703) 524-6636
Fax (703) 243-2874
cortina@alcalde-fay.com
www.fffc.org

October 2006 Special Edition

Aquatic Toxicity of Fire Fighting Foams

Introduction[1]

Firefighting foams are highly effective in preventing, suppressing and extinguishing fuel pool fires. When used in well-designed systems with the proper equipment, they can be the most effective method for doing so, and can be used in an environmentally responsible way. Since all firefighting foams (actually all firefighting systems) have some degree of environmental impacts and liabilities, an essential step in the design and planning for the use of firefighting foams must take into account the protection of the environment.

Marketing claims have been made about certain firefighting foams, stating that they are more environmentally friendly than others. The claim is usually that environmental laws do not regulate the solvent or the surfactant used in the 'environmentally friendly' foam. However, all firefighting foams are regulated at one point or another during their life, especially when they are used in training or for a fire event, regardless of the particular solvent or surfactant used in the foam. These firefighting foams are regulated because they have ingredients directly listed in environmental laws, or have properties; including foaming itself, that can cause an environmental impact or liability during storage, use, and discharge into the environment. Substituting one foam for another may make small improvements in environmental protection; however, the best method of ensuring protection of the environment is to design the system properly, with the correct amount of foam and water, conduct required system maintenance, prevent accidentally discharges, and provide a method of capture and control for any foam discharges.

Firefighting Foams and Systems[1]

There are several types of firefighting foams available, including: Aqueous Film Forming Foam (AFFF); Alcohol-resistant AFFF; Protein Foams, Alcohol Resistant Protein Foams, Fluoroprotein Foams, Class A Foams, Medium and High Expansion Foams, Wetting Agents, Training Foams, and others. Each of these firefighting foams is used for different purposes or because of standards and specification that require their use in specific systems. Firefighting foams usually come in a concentrate that is diluted with water and agitated to form a foam solution.

Firefighting foams are normally used for fixed-facility systems or on crash fire-rescue trucks in locations where fuel-pool fires are expected. When used in fixed-facility systems, the design should incorporate a diversion and/or containment structure that will collect or treat the foam prior to removal or release. This will prevent the foam from entering the environment, and the subsequent environmental impact or liability. When used on crash fire-rescue trucks, standard procedures should be set in place that capture and contain the foam flow.

These procedures and systems are important when foam is used in training, during accidental discharges, system checks, and during actual fire events. Although safety and fire suppression/ extinguishments is paramount during a fire event, the properly designed system and standard procedures will protect the environment as well.

Aquatic Toxicity[1]

Toxicity analysis focuses on the plants or animals most likely affected, and the route of entry that will cause the worst effects. In the case of foams, plant and animals in water are the ones that are most likely to be affected by exposure, and the exposure will generally be through ingestion or respiration. This type of toxicity is known as aquatic toxicity. Aquatic toxicity is an indicator of the relative toxicity of a chemical or compound in water. It is determined by using a series of tests to determine the acute (short term) or chronic (long term) toxicity, expressed as EC50 (Effective Concentration 50), LC50 (Lethal Concentration 50), or several other parameters.

The toxicity is compared to a standard toxicity reference to determine their potential impact, and evaluated based on use-specific conditions. Several scales are available; one example, the United States Fish and Wildlife Service (FWS) scale is provided in the following chart (this scale is highly situation-specific and should not be used as a planning tool or guidance for relative toxicity without consulting a qualified toxicologist).

FWS Acute Toxicity Rating Scale

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	1-10
Slightly Toxic	10-100
Practically Nontoxic	100-1000
Relatively Harmless	>1000

Toxicity parameters are counterintuitive – the higher the number, the less toxic the material. In concentrate form, many foams range from Practically Nontoxic to Slightly Toxic. When diluted to the fire extinguishing solution, almost all are typically categorized as Relatively Harmless.

Acute Toxicity Testing

In order to directly compare the toxicity of different fire fighting foam agents, six foam concentrates were tested for acute toxicity in two different aquatic species.

Test concentrates included three AFFF agents, a wetting agent, and two "fluorine-free" foams. AFFF agents were chosen that are alcohol resistant (AR-AFFF), meet Underwriters Laboratories (UL) specifications, and meet US military specifications (milspec, Mil-F-24385). The wetting agent and "fluorine-free" foams were chosen because they are often marketed as "environmentally friendly" alternatives to AFFF. All of the foam concentrates tested were from stocks of commercially available products and all except the wetting agent were 3% concentrates. Test agents were manufactured by 3M Australia, Ansul, Buckeye, HCT, Kidde, and Solberg.

The two tests performed were the 96-hour LC50 Test in Fingerling Rainbow Trout[2] and the 96-hour LC50 Flow-Through Test in Fathead Minnows.[3] Both tests involve exposing fish to water containing different concentrations of the test substance for four days and determining the concentration that is lethal to half of the fish. In the fathead minnow flow-through test, water containing the test substances flows in and out of the test chamber at a rate of six changes every 24 hours. In the rainbow trout test, the water is aerated but not changed over the four-day test period.

These two tests have been used by industry and the United States Department of Agriculture Forest Service for many years to evaluate the environmental impact of fire fighting foams.[4] Fathead minnows are often used to measure the aquatic toxicity of AFFF-type agents and rainbow trout are often used to measure the aquatic toxicity of class A foams and wetting agents.

Results

Results from acute toxicity testing in rainbow trout and fathead minnows are presented in Tables 1 and 2 and Figures 1 and 2. The wetting agent had the highest acute toxicity of the foam concentrates tested with an LC50 of about 1 mg/L for both aquatic species. It would be classified as moderately to highly toxic according tom the FWS scale. The two "fluorine-free" foams were an order of magnitude lower in toxicity than the wetting agent, ranging from 65 – 171 mg/L. These concentrates would be considered slightly toxic to practically non-toxic according to the FWS scale. The AFFF agents were the least toxic of the foam concentrates tested, ranging from 884 to 5657 mg/L, which is an order of magnitude lower in toxicity than the "fluorine free" foams. AFFF concentrates would be considered practically non-toxic to relatively harmless according to the FWS scale.

The results from this testing program are consistent with other published data and with information on aquatic toxicity presented on the material safety data sheets (MSDS) for these agents. Gaikowski et al tested two commercially available Class A foams that are likely to be somewhat similar in make-up to fluorine-free foams A and B and obtained LC50 values ranging from 13-32 mg/L in fathead minnows and 11-78 mg/L in rainbow trout.[5,6]

Discussion

It is not surprising, despite marketing claims to the contrary, that wetting agents and "fluorine-free" foams would have higher acute aquatic toxicity than AFFF agents. AFFF agents contain fluorinated surfactants that provide a positive spreading coefficient and enable film formation on top of lighter fuels. It is this film-forming characteristic that makes AFFF agents highly effective. Foam agents that do not contain fluorinated surfactants usually contain higher concentrations of hydrocarbon surfactants and solvents in order to compensate for the lack of film formation. Hydrocarbon surfactants and solvents are generally more toxic in aquatic systems than fluorinated surfactants, so this likely explains the higher aquatic toxicity of the non-fluorinated foams as compared to AFFF.

It is also not surprising that milspec AFFF has a slightly higher toxicity than AR-AFFF and that AR-AFFF has a slightly higher toxicity than UL AFFF. Milspec AFFF contains a higher content of surfactants and solvents than AR-AFFF, which contains a higher content of surfactants and solvents than UL AFFF.

Conclusion

Fluorinated surfactants are persistent chemicals that have come under increased scrutiny in recent years as a result of the PFOS issue. This scrutiny has encouraged some manufacturers to supplement their range of foams to provide “fluorine-free” products under the descriptive title of “environmentally friendly” alternatives to AFFF, while relying on only minimum data and performance characteristics across a limited range of risks and flammable liquids. But it is important to acknowledge that just because a foam agent does not contain fluorine, it is not necessarily safer for the environment, as illustrated by the higher aquatic toxicity of non-fluorinated foams as compared to AFFF.

References

[1] From a paper entitled *Environmental Impacts of Fire Fighting Foams* by William H. Rupert, Daniel P. Verdonik, and Christopher Hanauska of Hughes Associates, Inc. (2005)

[2] Tests performed by Harris Industrial Testing Service Ltd., Nova Scotia, Canada

[3] Tests performed by Aqua Survey Inc., Flemington, New Jersey, USA

[4] United States Department of Agriculture Forest Service, Evaluation of Wildland Fire Chemicals, Standard Test Procedures, STP 1.5 – Fish Toxicity

[5] Gaikowski, Mark P., Steven J. Hamilton, Kevin J. Buhl, Susan F. McDonald, and Cliff Summers. 1996. Acute toxicity of firefighting chemical formulations to four life stages of fathead minnow. Environmental Toxicology and Chemistry. 15(8) :1365-1374

[6] Gaikowski, Mark P., Steven J. Hamilton, Kevin J. Buhl, Susan F. McDonald, and Cliff Summers. Acute toxicity of three fire-retardant and two fire-suppressant foam formulations to the early life stages of rainbow trout, Northern Prairie Wildlife Research Center Online

Aquatic Toxicity Testing Results

Table 1 – 96-hour LC50 Test in Fingerling Rainbow Trout

Agent	LC50 (mg/L)
Wetting Agent	1.06
Fluorine-free Foam A	65
Fluorine-free Foam B	71
Milspec AFFF	2176
AR-AFFF	3536
UL AFFF	5657

Table 2 – 96-hour LC50 Flow-Through Test in Fathead Minnows

Agent	LC50 (mg/L)
Wetting Agent	0.887
Fluorine-free Foam A	171
Fluorine-free Foam B	171
Milspec AFFF	884
AR-AFFF	1487
UL AFFF	1726

Figure 1 96-hour LC50 Test in Fingerling Rainbow Trout

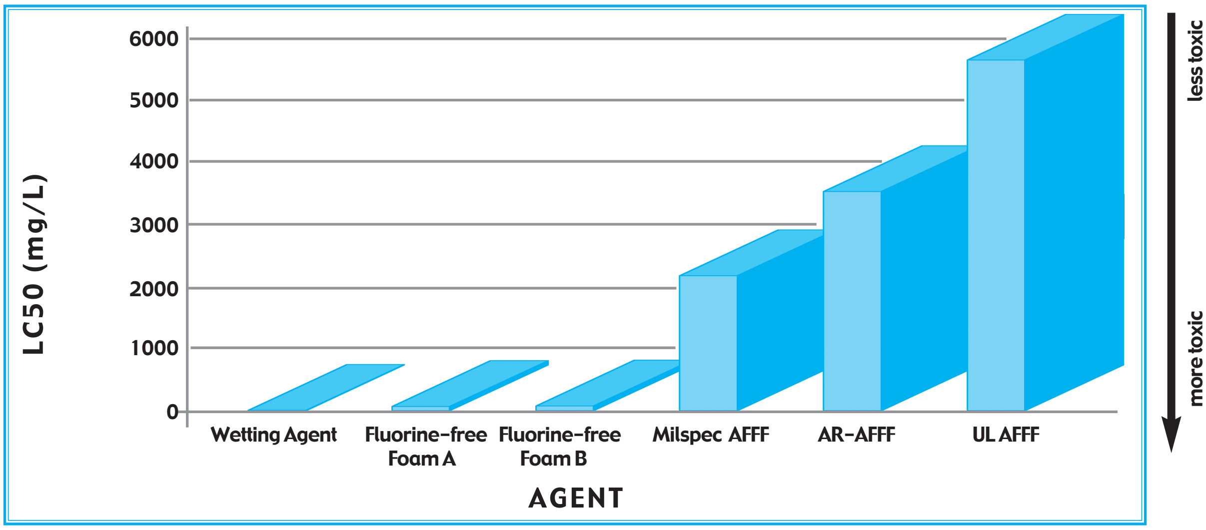

Figure 2 96-hour LC50 Flow-Through Test in Fathead Minnows