Pic courtesy of Reuters/Hiroshi Adachi/Yomiuri (Japan)

Aircraft rescue and firefighting requires the best foam available: AFFF

I was looking over the abstracts for an upcoming foam seminar at which I will be speaking and noticed a presentation by the Chief Fire Officer at a small international airport. According to the abstract the airport fire department has switched to using a less effective "fluorine-free" foam in order to appease the local environment agency. All I could think of after reading the abstract was that I am glad I don't have to fly into that airport!

By Tom Cortina

Fire Fighting Foams Coalition

All joking aside, it is surprising and disappointing to see an environmental authority convince a fire department to use a less effective foam for a critical life safety application such as crash rescue firefighting over concern for the potential for a small amount of persistent but low-toxicity chemicals to be released to the environment. Although runway crashes of aircraft do happen at airports around the world each year, they are an infrequent occurrence at any particular airport, and so the risk of extensive groundwater contamination at any individual site from foam discharge will be very small. At the same time the risk from fire to passengers and ground personnel when such a crash does occur is very real, and in that situation you would hope that the airport is using the most effective product available to extinguish the fire.

Fluorosurfactants are a key ingredient

Fluorosurfactant-containing foams, in particular aqueous film-forming foams (AFFF), are the most effective agents currently available to fight Class B flammable liquid fires at airports and in military, industrial, and municipal settings. This fact has been consistently proven in fire tests done over the last 30 years and in tests that are being performed today. This exceptional fire-fighting effectiveness of AFFF is due to the formation and spreading of an aqueous film formed on top of lighter hydrocarbon fuels. Only fluorosurfactants can provide AFFF with the required low surface tension and positive spreading coefficient that enable film formation. It is this film formation capability that gives AFFF its name and its effectiveness against flammable liquid fires. AFFF agents provide rapid extinguishment, burnback resistance, and protection against vapor release.

3M used a process called electrochemical fluorination to manufacture the fluorinated components of the fluorosurfactants contained in its AFFF formulations. Fluorosurfactants produced by this process both contain and degrade into chemicals known as PFOS (perfluorooctyl sulfonate) and PFOA (perfluorooctanoic acid). Other competitive manufacturers use a process called telomerization to produce the chemical components of the fluorosurfactants contained in AFFF agents. Chemicals produced by this process are generally referred to as telomers or fluorotelomers. With the withdrawal of the PFOS-based products due to their persistence, bioaccumulative and toxic properties (beginning in May 2000) and their subsequent regulation by various national governments, there has been a substantial shift from PFOS-based AFFF agents to equally effective AFFF agents containing telomer-based fluorosurfactants.

Fluorine-free foams

As a result of the concerns raised by the PFOS issue, foam manufacturers continue to evaluate many types of potential products that do not contain fluorosurfactants. Efforts to date have not yielded working products with fire performance across all fuels and in all operational circumstances equal to film-forming foams. Some fluorine-free foam can provide an alternative to AFFF in some applications, but they are not currently able to provide the same level of fire suppression capability, flexibility, and scope of usage. A recent paper from the University of Newcastle that shows that even the best available fluorine-free foams would need to be replenished three times as often as AFFF to provide the same level of fire protection.[1]

Fluorine-free foams are often championed as "environmentally-friendly" alternatives to AFFF. Although such foams may not contain fluorine, their environmental profile related to biodegradation, acute toxicity, chemical oxygen demand (COD), and biochemical oxygen demand (BOD) is typically no better than fluorine-containing products and in many cases is not as environmentally responsible in use as AFFF. A recent study of commercially available fire fighting foam agents indicates that fluorine-free foams are at least an order of magnitude higher in aquatic toxicity than AFFF agents.[2]

An important consideration in assessing the risk of any foam will be its effectiveness in extinguishing the fire and preventing re-ignition. A fluorine-free foam may appear to present less risk to the environment because it does not contain persistent chemicals. But if it takes significantly longer and requires more foam to extinguish the fire, then it may actually present a greater risk, including the potential for loss of life and/or high value property.

Firefighter safety

All of the currently available fluorine-free foams rely upon having a good enough foam blanket in terms of expansion ratio and drainage rate to overcome the inherent problem of fuel contamination of the foam blanket. This requires the use of air aspirating branch pipes or nozzles in order to achieve the necessary level of foam quality, which is a step backwards for firefighter safety.

The use of non-aspirating discharge devices, such as variable pattern water fog nozzles, provides two very important safety factors for firefighters. First, since none of the available energy of the system needs to be utilized by an air aspirating venturi at the discharge devise, the range from that devise will be maximized. Distance from the fire is always a key to firefighter safety. Second, when using a variable pattern water fog nozzle, the firefighter has the ability to change his stream pattern to a full fog for personnel protection against a thermal event ("left for life – right for fight").

The use of non-aspirated film-forming foam provides an added benefit in terms of speed of knock down and control of the fire as well as the ability to quickly cover the areas where the foam blanket has been disrupted. Again, these two factors improve firefighter safety and when used in operations such as crash fire rescue, are absolutely essential in terms of overall safety and success. These are some of the factors that led the Federal Aviation Administration in 2006 to require US airports to be equipped with AFFF that meets the US military specification (Mil-F-24385F), one of the most respected foam standards in the world.

The use of non-aspirated film-forming foam provides an added benefit in terms of speed of knock down and control of the fire as well as the ability to quickly cover the areas where the foam blanket has been disrupted.

Environmental update

In my last article that was co-authored by Dr. Stephen Korzeniowski of DuPont (June 2008 issue) we reviewed all of the latest science related to the environmental effects of fluorosurfactants. Since that article there has been a new study published by SFT related to fluorochemicals found at fire training facilities in Norway. Although the study does not contain any new conclusions, it has drawn interest within the foam industry.

The SFT study confirms the findings of previous studies that the likely ultimate biodegradation products of the fluorosurfactants used in currently manufactured AFFF agents are persistent, but are not considered to be significant environmental toxins. The low bioaccumulation values developed in this study reinforce previous assertions of the general safety of these products. Because these studies were done at fire training areas where foams were released uncontrolled numerous times over many years, the findings should not be used to assess the impact of a one-time use of a fire-fighting foam to extinguish a fire, which would result in significantly smaller contaminant concentrations. Current accepted practice is to use fluorine-free training foams whenever possible as well as to collect and treat foam discharges when fluorine-containing foams are used for training or testing.

The three main fluorochemicals found in the SFT study – PFOS, PFOA, and 6:2 FTS (6-2 fluorotelomer sulfonate) – have been found previously in groundwater studies from fire training facilities in the United States.[3] PFOS and PFOA were likely contaminants and/or biodegradation products of the ECF-based fluorosurfactants contained in AFFF agents primarily manufactured by 3M prior to 2002. 6:2 FTS is a likely biodegradation product of the telomer-based surfactants contained in currently manufactured AFFF agents (manufactured since the 1970s). Neither of these compounds (PFOS or 6:2 FTS) was used directly 'as is' in the AFFF agents, as was cited incorrectly in the SFT study. As noted above they are contaminants and/or biodegradation products of the more complex fluorosurfactants that are the key functional ingredients in AFFF.

The SFT study does confirm previously reported data that 6:2 FTS is neither bioaccumulative nor biopersistent. The bioaccumulation factor (BAF) values for 6:2 FTS in earthworms from the SFT report and in rainbow trout from previous studies[4] are 100-1000 times lower than EU regulatory criteria for bioaccumulation.

The BAF values were slightly higher for 6:2 FTS than for PFOS and PFOA in the SFT study. For this reason we would expect advocates of alternative foams to argue that 6:2 FTS has similar environmental properties to PFOS and therefore the use of telomer-based foams should be limited. We would argue that the SFT study results do not change the basic conclusion from a broad range of existing data that 6:2 FTS is not similar to PFOS in either its physical or ecotoxicological properties.[5,6,7,8] Recent studies on AFFF telomer-based fluorosurfactants likely to break down to 6:2 FTS show it to be generally low in acute, sub-chronic, and aquatic toxicity, and neither a genetic nor developmental toxicant. Both the AFFF surfactant and 6:2 FTS were significantly lower than PFOS when tested in biopersistence screening studies that provide a relative measure of biouptake and clearance.[9]

The SFT study confirms the findings of previous studies that the likely ultimate biodegradation products of the fluorosurfactants used in currently manufactured AFFF agents are persistent, but are not considered to be significant environmental toxins.

PFOA is not likely to have come from fluorotelomer-based AFFF in any significant amounts. The fluorotelomer-based surfactants used in AFFF agents are not made with PFOA and PFOA is not used in the manufacturing process. Current unintended trace quantities of PFOA in fluorotelomer-based AFFF will be virtually eliminated under the US Environmental Protection Agency (EPA) PFOA global stewardship program. Under the program telomer producers have committed to 95% reductions of PFOA, PFOA precursors, and related higher homologue chemicals by year-end 2010 and are working toward the elimination of these chemicals from both plant emissions and finished products by year-end 2015.

Members of the Fire Fighting Foam Coalition that make telomer-based fluorosurfactants and AFFF agents are in position to meet the goals of the global stewardship program before the 2015 target date with a family of all C6-based fluorosurfactants that provide the same fire protection characteristics with reduced environmental impacts. Incorporating these new fluorosurfactants will require some reformulation and likely some type of re-approval of most current AFFF, FFFP, and fluoroprotein foam products between 2010 and 2015.

PFOS is not completely gone

Although the manufacture and import of PFOS-based foams is banned in the United States, Canada, and the European Union, it is our understanding that these foams are still being manufactured in China. One of the reasons for this continued production may be a misconception that PFOS-based AFFF agents are more effective than telomer-based AFFF agents. This is simply not true. AFFF agents are equally effective whether they contain PFOS-based fluorosurfactants or telomer-based fluorosurfactants. The PFOS-based AFFF agents previously sold by 3M, and the telomer-based AFFF agents currently sold by companies such as Kidde, Ansul, and Chemguard, all meet the same material specifications of the International Standards Organization (ISO Standard 7203), Underwriters Laboratories (UL Standard 162), and the US military (Mil-F-24385). PFOS-based and telomer-based foam concentrates are used interchangeably in the same equipment and at the same concentration levels by military and industrial users around the world. Considering the significant differences in toxicity and environmental effects between PFOS and telomer-based foam agents, it seems logical for China to make the switch as most of the rest of the world has done. APF

References

1. Sealability Properties of Fluorine-Free Fire Fighting Foams by Ted Schaefer, Bogdan Dlugogorski, and Eric Kennedy, University of Newcastle (2007).
2. 96-hour LC50 Value in Fathead Minnows (flow-through test), Report of tests on six fire fighting foam agents performed by Aqua Survey Inc., Flemington, New Jersey, USA and 96-hour LC50 Test in Fingerling Rainbow Trout, Report of tests on six fire fighting foams agents performed by Harris Industrial Testing Service Ltd., Nova Scotia, Canada.
3. Moody, C.A., Hebert, G.N., Strauss, S.H., Field, J.A., 2003. Occurrence and persistence of perfluorooctanesulfonate and other perfluorinated surfactants in groundwater at a fire-training area at Wurtsmith Air Force Base, Michigan, USA. Journal of Environmental Monitoring 5, 341-345.
4. Dupont 2009. H-27901: Bioconcentration and Bioaccumulation in Rainbow Trout, *Oncorhynchus mykiss*. Unpublished draft report, DuPont-22737 Draft.
5. DuPont 2007a. H-27901: Static, Acute 96-Hour Toxicity Test with Rainbow Trout, *Oncorhynchus mykiss*. Unpublished report, DuPont-21909.
6. DuPont 2007b. H-27901: Static, Acute 48-Hour Toxicity Test with *Daphnia magna*. Unpublished report, DuPont-21910.
7. DuPont 2007c. H-27901: Static, 72-Hour Growth Inhibition Toxicity Test with the Green Alga, *Pseudokirchneriella subcapitata*. Unpublished report, DuPont-22048.
8. DuPont 2007d. H-27901: Early Life-Stage Toxicity to the Rainbow Trout, *Oncorhynchus mykiss*. Unpublished report, DuPont 22219.
9. Serex, T. et al, 2008. Evaluation of Biopersistence Potential Among Classes of Polyfluorinated Chemicals using a Mammalian Screening Method. SOT 2008 Poster #958.