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THE ENVIRONMENTAL IMPACT OF FIREFIGHTING FOAM

BY ROBERT C. ANDREWS, JR., P.E.

Editor's note: This article is a condensed version of the applied research project submitted to the National Fire Academy by the author as part of his participation in the Executive Fire Officer program. A complete copy of the research paper may be obtained through request to the Learning Resource Center, National Emergency Training Center, 16825 South Seton Avenue, Emmitsburg, MD 21727, or by calling 1-800-638-1821.

In early 1990 the Refinery Terminal Fire Company (RTFC) inititated a relocation study for its training academy that encompassed extensive research into firefighting foam concentrates and compliance with current environmental practices and regulations, specifically that of wastewater treatment and the prevention of water and ground

pollution. This research yielded significant findings relevant to chief fire executives involved in flammable liquid fire operations and flammable liquid fire training.

The project's objectives were threefold:

- To identify all existing information regarding wastewater treatment at flammable liquid fire training academies, with emphasis on the treatment of firefighting foam concentrates. Foam, because of its inherent foaming qualities and its tendency to form an emulsion with hydrocarbon fuels, presents the greatest challenge for wastewater design.
- To identify information regarding the environmental impact and toxicity of firefighting foam concentrates as they relate to fixed fire protection systems and manual fire suppression efforts.
- To identify current management considerations for chief fire executives as they relate to firefighting foam and the environment.

50,000 GALLONS OF FOAM

The RTFC was formed in 1948 (a year after the infamous Texas City, Texas, ship explosion) to provide quality industrial emergency response and training services to member owners of petrochemical refineries, industrial/manufacturing plants, terminal petrochemical tank storage, and oil docks in the Corpus Christi Bay area. Its membership today consists of 60 facilities owned by 23 corporations and the Port of Corpus Christi Authority. The Fire Company regularly inventories in excess of 50,000 gallons of firefighting foam concentrate of several types and manufacture as required for emergency response. Environmental protection features reflect those considered prudent at the time of the facility's construction in 1975.

Propane and unleaded gasoline are the primary fuels used at the training academy through fire extinguisher, pump seal, pit (large spill), overhead loading rack, and process unit firefighting projects. Firefighting foams and dry chemical extinguishing agents are used extensively throughout all training activities.

The RTFC had been leasing its training facility site from Koch Refining Company, which needed the property to expand its refinery. Hence, our need for information by which to develop a wastewater system design for the new RFTC fire training academy was immediate. The proposed cost of the academy could not be determined without a design for the wastewater system, and funding hinged on a properly defined cost estimate.

RESEARCH RESULTS

The approach to our research, in general, was to conduct a search for publications covering the area of fire training academy design and foam toxicity, visit relevant fire training academies to evaluate their wastewater treatment schemes and identify any allied research being conducted, and validate findings through discussion with technical experts in the field of foam concentrates and wastewater/environmental management. We agreed that if answers were not found within the United States, we would extend the research internationally.

(Note: Our search indicated that the environmental effects of dry-chemical extinguishing agents were considered to be of secondary importance, as their environmental impact appeared to be limited mostly to pH and to solids removal and disposal.)

U.S. fire training academies and operational experience. The RTFC uses firefighting foam concentrates regularly. In most cases, operations are very successful and there are no complications or there is no negative impact secondary to the firefighting operation. In some cases, however—such as in an April 1991 internal floating roof tank fire—firefighting foam significantly disrupted a refinery's wastewater treatment plant. Our attempts to find out why the entrance of firefighting foam concentrates into refinery wastewater plants sometimes caused facility upsets have been unsuccessful. The only practical way of learning if other facilities had a similar problem was through individual inquiry based on the "informal professional network," a method of research fraught with shortcomings, not the least of which is the lack of hard facts that can be validated to reach conclusions.

There was no readily identifiable, effective wastewater design strategy for a U.S. fire training academy that teaches flammable liquid firefighting. The team discovered that the schools currently teaching flammable liquid firefighting in the United States were designed when environmental requirements were less stringent and subsequently did not comply with current mandates. The team learned that these schools also were under pressure to improve their existing mode of operation.

Foam manufacturers. Foam manufacturers were polled in an effort to obtain environmental information concerning their products. Information regarding the specific treatment of firefighting foam concentrates in wastewater treatment facilities and recommendations for fire training facility design were unavailable from firefighting foam manufacturers.

In general, the most common source of information on foam toxicity is the material safety data sheet (MSDS), but the variations in form and content of these sheets as provided by different manufacturers make comparisons of foam products difficult. Some manufacturers, for example, do not list specific environmental data on their MSDSs, and most manufacturer reports available focus on performance instead of toxicity or the environmental effects.

Most foam concentrate MSDSs

contain toxic chemicals that fall under the scope of SARA Title III. A fire department theoretically could have enough foam concentrate in inventory to require it to report the ownership of one or more toxic chemicals as per this federal regulation. The question raised could be, Is the fire department responsible for reporting the release of the one or more of the toxic chemicals mentioned after using foam at an emergency? Departments should consult with their environmental and legal staffs to obtain and answer.

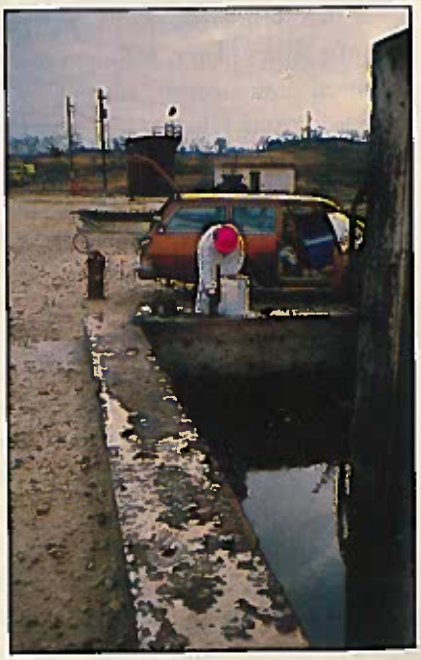
Some manufacturers of foam concentrate produce additional publications that provide product environmental data in greater specificity. This information is more useful in analyzing the environmental impact and toxicity of firefighting foam concentrates; however, the technical jargon is best interpreted by an environmental professional.

Environmental engineers/City of Corpus Christi. Environmental engineers—although they are experienced in almost every municipal and industrial wastewater application—have no standard design data for the kinds of contaminants found at a flammable liquids fire training academy, specifically firefighting foams and dry chemical extinguishing agents.

We obtained wastewater samples from each of the major training stations at the existing RFTC fire training academy (samples from one training area were collected before and after a test burn) and analyzed them for conventional pollutants and nutrients as well as hazardous constituents and toxic organic compounds. Environmental engineers on our design team began developing treatment and disposal options for the proposed fire training academy based on these test results.

We decided to adopt the pretreatment requirements set by the City of Corpus Christi Wastewater Services Division as the definitive standard for the wastewater quality of the proposed fire training academy wastewater stream unless a more suitable standard was found during the research phase. In the city's "Ordinance—Commercial & Industrial Waste Disposal & Pretreatment," specific pretreatment program discharge limits are given for total petroleum hydrocarbons (TPH); lead; benzene; benzene, toluene, ethyl benzene, and xylene (BTEX); pH; total suspended solids (TSS); total dissolved solids (TDS); color, biological oxygen demand (BOD); and oil and grease. (Our final decision was to use the city's plant for final treatment. Final wastewater treatment at the academy remains a future option.)

U. S. Military Specification. We were able to identify only one testing procedure that measured the toxicity of firefighting foam concentrates: U.S. Military Specification "Fire



The combination of foam concentrates and flammable liquid runoff have environmental repercussions that merit serious consideration from firefighting management. Above, firefighters at the former Refinery Terminal Fire Company training facility conduct a test burn to create a simulated wastewater condition for treatability testing. At top right, wastewater used in treatability research is contained within a pit, from which samples were drawn by environmental engineers, far right. (Photos by author.)

Extinguishing Agent, Aqueous Film-forming Foam (AFFF) Liquid Concentrate for Fresh and Seawater," MIL-F-243 85D, October 1989. If a foam concentrate is listed as meeting the "MIL-Spec," it is reasonably certain that the concentration meets the minimum toxicity requirements. However, this test applies only to foam concentrates of the AFFF type.

The United States Air Force issued a technical letter in June, 1986, that discusses AFFF waste discharge retention and disposal for fixed fire protection systems.[1] The letter

- indicates that "direct discharges of foam solution into watercourses can violate stream water quality standards";
- indicates that "AFFF solution discharges can adversely impact biological wastewater treatment processes and can cause foaming in aeration basins and similar plant components if the AFFF concentrations" exceed certain limits;
- defines those limits as "100 parts per million (ppm) by weight for a six percent mixture or 50 ppm for a three percent mixture (a three percent solution is more restrictive at the plant due to the strength of its concentrate); and
- addresses the method to be used for AFFF disposal. It does not, however, provide specific wastewater treatment technology.

Periodicals. Thirty-nine articles from periodicals were reviewed in an attempt to ascertain what existing fire training academies in the United States have done to address the treatment of wastewater containing firefighting foam concentrates. Only one article was applicable to the research project.[2] However, while the article described the basic wastewater treatment scheme utilized at seven fire training academies, there was not sufficient design data to assist us in the design of our proposed training academy.

Federal agencies. The Federal Aviation Administration Advisory Circular 150/5220-17, "Design Standards for an Aircraft Rescue and Firefighting Training Facility," provides a wastewater treatment scheme but does not provide specific data regarding the effectiveness of the recommended design.[3]

EPA requirements/standards were not specifically researched, since these standards typically are applied at the local or state level.

Europe: Forum, Paper 1. Our search for a method to extract foam concentrates from the Academy's wastewater stream was expanded to Europe, including the United Kingdom and France. Two papers presented at the Second International Oil and Petrochemical Forum, held in Reims, France, in May 1991, were relevant to our search.

The presentation by Rodney Camp of Camp & Associates in South Africa[4] reviewed how pollution by hydrocarbons occurs and discussed various general methods for preventing it and for cleaning up hydrocarbons, including bioremediation. Camp submits that protein-based foams are environmentally superior to synthetic foams in that use of protein-based foams accelerates the bioremediation process. However, he cautions that pure protein-based concentrates entering a "still holding of water" can create an "organic overload" that upsets the process.

South Africa fire training academies, according to Camp, use water recirculated through a "wetland," an approach we did not encounter during our research of U.S. training academies. Wetlands consist of filter ponds that contain plants which take oxygen from the atmosphere to below the surface of the water, thereby maintaining aerobic biodegradation. RTFC environmental engineers have learned that the technology of artificial wetlands is just beginning to be evaluated by the U.S. Environmental Protection Agency (EPA). Its drawback appears to be the quantity and cost of the real estate needed to have a wetland of sufficient size to accommodate the typically large firewater flows required of a fire training academy.

Paper 2. Jonathan Brittain of Angus Fire, in his presentation at the Reims conference, cites what the RTFC research team identified as the only scientific study that compares the environmental impact of several different foam types.[5] In that study, entitled "Analysis of the Toxic Effect and the Biological Breakdown Capabilities of Foam Extinguishing Substances in Waste Water" but more commonly referred to as the BWB report, protein-based foams were found to be both substantially less toxic and more biodegradable than those foams based on synthetic detergent. Brittain submits, "A major independent study undertaken by German government scientists in 1989 subjected 16 commercially available foam concentrate products to a host of rigorous toxicity and biodegradability studies....Protein-based foams were found on average to be less toxic to every organism....In one test a FFFP gave an LC10 of 7,500 ppm compared with a value of only 0.6 ppm for a synthetic detergent based AR-AFFF, making it a remarkable 12,500 times less toxic."

Unfortunately, since the BWB report was published in 1989, several of the most recent foams on the market have not been tested. Furthermore, classes of foams were listed by type, not as individual concentrates. Still, the BWB report remains the sole research effort (identified by this applied research project) that evaluates several foam concentrates on purely environmental terms.

German Army Study. As this research project neared completion, applicable technical information was provided by 3M Industrial Chemical Products Division. This paper, issued in August 1991, cites a "German Army Study: Independent Classi-

fication of Fire Extinguishing Agents." It advised that "The German Army has conducted a study in which the environmental properties of 16 fire extinguishing foam agents were evaluated." The source of the German Army study is cited by 3M as an article authored by Matthias Gahlen entitled "Schaumeinstaz und Umweltschutz" and published in the March 1991 issue of *Brandschutz/Deutsch Feuerwehr Zeitung*.

It is unclear if the study referred to in the 3M paper is an article about the BWB report or if it is a totally independent research effort. However, according to the paper, 3M's newest foam concentrate was not tested in the German Army study to which they refer.

Academies: England and Scotland. I toured six fire training academies in England and Scotland that conducted live flammable liquid firefighting. The wastewater treatment facility at the Offshore Fire Training Center in Montrose, Scotland, was the only facility directly relevant to the design demands of the proposed RTFC training facility and subsequently was toured by the entire RTFC design team.

The Centre's wastewater treatment facility has a design capacity of 500,000 gallons per day and can accommodate peak flows of from 4,000 to 6,000 gallons per minute. The wastewater system was operational and effective and provided the real-life working example the design committee was seeking.

The Centre's wastewater system routinely recovers 25 percent of the kerosene fuel used for firefighting projects and meets the requirements for wastewater discharge quality as dictated by the local Rivers Authority. Kerosene is the Centre's primary liquid fuel and was chosen for its increased safety, due to its higher flashpoint; its easier separation in environmental treatment systems; its economy; and its lack of benzene, toluene, and xylene constituents.

The design/construction engineers who built the Centre agreed to make all designs available for our review and future use. The Centre also offered to introduce the RTFC design team to the environmental engineers who originally developed the wastewater design scheme. The Montrose model served as a catalyst for our research and helped validate our theoretical research.

PERSONAL REFLECTION

For every written and verbal claim regarding firefighting foam toxicity encountered in the research for this paper, there was an equal and opposite claim. While many sources say that protein-based foams are environmentally more friendly than their synthetic-based counterparts, their opponents expostulate that fluoroprotein foams are manufactured with synthetic fluorochemicals, similar to those found in the manufacture of synthetic-based foam concentrates. There appears to be no published study by an independent source that compares the environmental impact or the toxicity of the three predominant foam concentrates in the North American market.

It became clear in the final analysis that the RTFC would have to conduct its own research, through its consulting environmental engineers, to obtain a definitive wastewater treatment strategy for the new fire training academy. Subsequently, I recommended that the design team begin its research by studying in great detail the design and operation of the Offshore Fire Training Centre in Montrose, Scotland.

CONSIDERATIONS FOR CHIEF FIRE EXECUTIVES

The use of firefighting foam concentrates to achieve fire control reduces the negative effect of the flammable liquid and the related fire on the environment. The adverse effects to the atmosphere are usually the most obvious result of the fire, and the smoke and soot produced by the fire contain particulate matter, volatile organic compounds, and possibly certain hazardous air pollutants known as "air toxics." Not so readily obvious are the effects on soil, groundwater, and streams and rivers. If partially burned liquid runs off into a waterway, the effects on wildlife can be devastating. Again, by controlling these fires faster through the use of firefighting foams, the impact to the environment is reduced.

However, firefighting foam concentrates in and of themselves have an impact on the environment. They have the capacity to disrupt or overwhelm public and industrial wastewater treatment facilities. Fire professionals in the future will have to respond to environmental legislation and post-incident investigation of foam use with greater regularity. They will be asked whether the environmental impact of the fire was increased or decreased by their decision to apply firefighting foam.

This applied research project has revealed the following findings that may be of use to chief fire executives:

- In the future, virtually all fire training academies using flammable liquid and firefighting foam concentrates will be under increasing pressure to improve their operations environmentally.
- The use of firefighting foam concentrates may upset municipal and industrial wastewater treatment facilities.
- Fixed fire protection systems typically require a lower application rate of foam than manual firefighting efforts. Subsequently, less firefighting foam concentrate is discharged through a fixed system, thereby reducing the wastewater disposal requirement.
- Fire codes should reflect that where environmental damage could occur, increased effort is needed to contain and manage the runoff produced by both the incident and the

mitigations efforts.

• The chief fire executive should ensure that water supplies used by firefighters, both at their training academy and through their usual fire protection water systems, are healthy for the firefighter from an industrial hygiene perspective.

• State and local water authorities should be consulted to obtain specific and accurate guidance for water quality concerns.

• The manufacturers of fire control agents should be able to provide specific toxicity and environmental data for their products. Fire professionals should not accept anything short of complete cooperation.

• Chief fire executives should solicit the assistance of an environmental professional who can provide accurate, practical interpretation of technical environmental data.

• Dilution of a waste stream is not considered the prudent environmental solution (i.e., the solution to pollution is not dilution).

• Fire agencies may have enough foam concentrate in inventory to require them to report the ownership of one or more toxic chemicals under SARA Title III.

• The use of artificial wetlands for the treatment of wastewater containing hydrocarbons and firefighting foam, such as those utilized in other countries, eventually may be a technology used in the U.S. and may be an option to explore.

• Foams applied at emergency fire incidents may be discharged at rates comparable to small rivers. In such cases, the "slug" of foam that initially enters the body of water may have a concentration in excess of 10,000 ppm, as was the case in Switzerland in 1987 when a foam "raft" was accidentally discharged into a river and resulted in a fish-kill.

• Command officers must be trained in the benefits and risks associated with the use of firefighting foam concentrates, be aware of the mitigation choices available to them, and fully understand the environmental impact of implementing their mitigation strategy.

• Collection of firewater/foam runoff in a containment basin allows the incident commander to release the wastewater into treatment facilities at a controlled rate and prevents the wastewater from contacting the environment.

• The environmental properties of firefighting foam concentrates vary. Concerned chief fire executives should solicit assistance from environmental professionals or a testing laboratory when selecting foam concentrates.

• Chief fire executives, if unable to obtain research results within the United States, should not hesitate to obtain help from their international counterparts.

• Fire professionals as a group should lobby for an independent firefighting foam toxicity test (through a national standards organization such as UL or the NFPA) that could be applied to all foam concentrates so that their environmental impact and toxicity levels are consistently evaluated.

• Fire professionals should demand that firefighting foam manufacturers develop foams based on environmental impact as well as performance.

• Fire professionals are advised to work with local, state, and federal water and wastewater authorities before major incidents occur to preplan specific sites and release scenarios.

• Organizations operating flammable liquids training schools should evaluate diesel, raffinate, Jet A, Jet B, and kerosene with respect to their wastewater characteristics, constituents, cost, treatability, student and employee contact, and regulatory constraints for wastewater disposition. The RTFC finally decided on kerosene for the liquid fuel supply at our new training academy to minimize the presence of BTEX and reduce the possibility of the training academy wastewater stream being classified as a hazardous waste.

ENDNOTES

1. Mitchell, Col. Jarell S. *Engineering Technical Letter (ETL) 86-8; Aqueous Film Forming Foam (AFFF) Waste Discharge Retention and Disposal* (Department of the Air Force, Headquarters United States Air Force, Washington D.C. June 4, 1986), pp. 1-2.

2. Garcia, Carolyn S. "Water Supply and Fire Service Training" (*Firehouse*, October 1990), pp. 46-50.

3. U.S. Department of Transportation. *Design Standards for an Aircraft Rescue and Firefighting Training Facility—Advisory Circular 150/5220-17* (Federal Aviation Administration, Washington, D.C., April 1988).

4. Camp, Rodney. *Fire Control and the Environment*, a presentation (Angus Fire, Second International Oil and Petrochemical Forum, Reims, France, 13-15 May 1991).

5. Brittain, Jonathan. *Foams: The Environmental Challenge*, a presentation (Angus Fire, Second International Oil and Petrochemical Forum, Reims, France, 13-15 May 1992), p.1.

The Refinery Terminal Fire Company conducts research on firefighting foam concentrates on a continuous basis. Fire professionals desiring to exchange information should contact the author directly at the Refinery Terminal Fire Company, P.O. Box 4262, Corpus Christi, Texas 78469, or call (512) 882-6253. ●

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